A study of the reasons for an increase in poaching of the one-horned Indian rhinoceros in Royal Chitwan National Park, Nepal

by

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ABSTRACT

Despite a relatively successful conservation programme for the one-horned rhinoceros in national parks of the Terai region, poaching has been one of the major threats to the survival of the rhinoceros, an endangered species in Nepal. This study uses a model to explain the level of poaching in Royal Chitwan National Park (RCNP) over a 30-year period, based on the factors that are thought to influence poaching in the Terai. The results indicate that anti-poaching units (APUs), in their original organisational and operational form were highly successful in controlling the level of poaching in RCNP. Further, the availability of economic opportunities locally seemed to reduce the level of poaching significantly. However, the penalties imposed on the convicted poachers were found to have little or no effect on the level of rhino poached in RCNP. The results also indicate a sharp rise in the number of rhinos poached since the start of a Maoist insurgency in 1996. These results will be helpful in formulating effective policies to tackle the growing problem of rhino poaching in Nepal, especially in and around RCNP, since this national park holds the largest population of the one-horned rhinoceros in the country.

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APU(s)	Anti-poaching Unit(s)
CITES	Convention on International Trade in Endangered Species
DNPWC	Department of National Park and Wildlife Conservation
HMGN	His Majesty's Government of Nepal
NPWCA	National Parks and Wildlife Conservation Act
RBNP	Royal Bardia National Park
RCNP	Royal Chitwan National Park
RNA	Royal Nepalese Army

CHAPTER 1 INTRODUCTION

1.1 Introduction

Wildlife conservation has been one of the most heavily budgeted natural resource management programmes in Nepal since the late 1970s. This is especially true for the one-horned Indian rhinoceros (*Rhinoceros unicornis*), which is protected within the national parks in the low-lying Terai region of the south. Established in 1973, the Royal Chitwan National Park (RCNP) in the Chitwan Valley provides a habitat for most of the rhinoceros in Nepal, and the preservation of rhinos in this park is considered one of the greatest conservation success stories (Martin and Vigne 1996). The park held less that 200 rhinos in 1973, and according to the 2000 census, rhino population in RCNP had reached 544. Furthermore, during a period of 13 years between 1986 and 1999, 42 rhinoceros were translocated from RCNP to Royal Bardia National Park (RBNP) to create a second viable population (Dhakal 2002). According to the rhino census of 2000, RBNP held 67 rhinos (DNPWC 2001).[1] Despite the success in preserving rhinos, a considerable number have been poached both within and outside these parks since their establishment. The year 1992 is considered one of the worst in this respect: 18 rhinos were killed in and around RCNP from a population of less than 500 (Maskey 1998). Moreover, recent years have seen an even more alarming rise in the number of rhinos poached; recent figures indicate 37 rhinoceros were poached in and around RCNP in the year 2002 alone (**Figure 1-1**).

Over the last decades, there have been a number of policy changes to combat the loss of endangered species like rhino. For example, stronger enforcement techniques have been put in place, such as the use of Royal Nepalese Army (RNA) to protect the rhinos and other endangered

[1] From 2000 to 2003, further 41 rhinos have been translocated from RCNP to RBNP (DNPWC 2000, 2001, 2002, 2003).

species within the national parks. The main conservation policy and wildlife management option in Nepal has been the legal protection of wildlife within (and outside) the parks, and the use of enforcement and penalties for those who infringe those laws. Although rhino poaching levels are influenced by the price of rhino horn on the international black market, there has not been an attempt to study the reasons behind poaching using models that have been developed and applied elsewhere (mostly in Africa). This study is an attempt to develop and empirically test such a model for rhino poaching in the Nepal.

1.2 Background of the Problem

Due to its large variation in elevation, Nepal has a very diverse ecological landscape. An important part of this diversity is the one-horned Indian rhinoceros that inhabits the low-lying Terai region along the border with India. Abundant in the past, the one-horned rhino has come under pressure due to significant poaching. Efforts to protect the species, while at times successful, continue to face challenges associated with wildlife protection in a very poor country. Considering the importance of maintaining biodiversity and the fact that the one-horned rhino is an endangered species, it is important that the reasons behind the recent increase be understood. This study looks into poaching of the one-horned Indian rhinoceros in RCNP to determine the role of economic factors and incentives in explaining losses from poaching. Such information could be vitally important to aid planners in devising effective policies to reduce these losses.

The Terai is a region of sub-tropical lowlands straddling the Indian border and making up about 20 percent of Nepal (Brown 1996). Much of it comprises tall grasslands that are important habitat for a variety of species, including the one-horned rhinoceros. Of the five protected areas in the Terai, RCNP and RBNP are the most important for the rhinoceros, having a combined population of over 600 animals (2000 est.) (Gurung and Guragain 2000). In addition to the protection afforded by location within a national park, the one-horned rhinoceros is protected under Appendix I of CITES, the Convention on International Trade in Endangered Species of fauna and flora. Nepal has been a member of CITES since 1975, but outlawed hunting/poaching of rhino anywhere in the country under the 1973 National Parks and Wildlife Conservation Act (NPWCA) (NCSIP/NPC-HMG/IUCN 1991).

After the establishment of RCNP in 1973, poaching reached a peak in 1992 with 18 animals killed from a population of less than 500 (Maskey 1998). In response to this increase, a system of enforcement using anti-poaching units (APUs) was established in 1992 (Gurung and Guragain 2000). Furthermore, the penalties for poaching were significantly increased by the 1993 amendment of the NPWCA, with 5 to 15 years in prison and up to a 100,000 rupees (about US $1,430 in 2004) fine for the convicted poachers (Maskey 1998). As had been the case in the 1970's with the establishment of RCNP, the change in anti-poaching enforcement was initially successful, as poaching was negligible in the Terai region through 1997 (Maskey 1998). However, as had occurred in the 1970s, poaching resumed in dramatic fashion in 1998, with 43 rhinos killed in a period of 16 months (Gurung and Guragain 2000). In recent years, the situation has worsened due to Maoist insurgency in the country, which has especially affected the level of anti-poaching enforcement by the RNA within the park. This has led to an alarming level of poaching every year, with more that 70 rhinos poached in a three-year period between 2001-2003 (DNPWC 2001, 2002, 2003). Poaching remains high today.

There are three categories of poachers that are involved in the killing and illegal trading of rhino from the Terai: (a) local hunters, (b) middlemen, and (c) international traders. The local hunters know the area, the behaviour of the wildlife and the enforcement techniques. They kill the animals using firearms, electrocution or large pit traps and they sell the horns to middlemen. Most poachers are local villagers from the Tharu and Tamang ethnic groups (Maskey 1998). Gurung and Guragain (2000) cite poverty, political turmoil, a hunting culture, high prices on the international market and protection of livestock/crops as the principal reasons for poaching in this category. Middlemen purchase the horns from the local hunters and sell to the third category of poachers, who market the contraband internationally (Gurung and Guragain 2000). The poaching of rhinoceros can be quite lucrative, as dealers receive an average of US $20,000 per kilogram of rhino horn, with the price rising as high as US $30,000 per kilogram (Maskey 1998). The international traders have strong networks that may include close connections to powerful individuals who can provide them with protection.

After the formation of APUs in RCNP in response to the high level of poaching in 1992, anti-poaching efforts in and around RCNP centred on these APUs. Unlike the RNA, which could only operate within the park boundary, the APUs could patrol both inside and outside the park (Gurung and Guragain 2000). These APUs had specific organisational and operational structures. An APU was headed by an assistant park warden and was composed of senior game scouts, game scouts, assistant game scouts and local informers; and with the help of these informers they formed intelligence networks in the local communities, and gathered information about poachers and their poaching activities (Gurung and Guragain 2000; Maskey 1998; Adhikari 2002). This information was used for anti-poaching patrols and raids to capture poachers, often with the help of the RNA. It has been widely acknowledged that anti-poaching programs with these APUs were very effective (Martin and Vigne 1996; Martin 1998; Adhikari 2002). However, the original APUs' organisational and operational structures were changed in 2001. The new APU structure does not include local informers, and has been blamed for weakening the anti-poaching programs (Adhikari 2002). This has coincided with extremely high levels of poaching, with more than 55 rhinos poached during 2002-2003 (Dhakal 2002; DNPWC 2002, 2003).

1.3 Research Objectives

The purpose of this research is to examine the recent increase in poaching of the one-horned rhinos in the Terai within the context of theories on motivations for poaching at the individual and community levels. Determining the reasons for this increase will be extremely important because one-horned rhinos are an endangered species that has significant biodiversity value, and continuing high levels of poaching will put significant pressure on the ability of this species to survive in the Terai region. Knowledge regarding the motivations for poaching at these levels will also be extremely important for devising anti-poaching measures that are more effective in deterring the poachers.

The specific objectives of this research are to

- Examine the trend in the number of rhinos poached over the years along with the trends in the factors that are hypothesized to affect the level of poaching
- Construct a suitable theoretical framework for analysing the poaching behaviour in Nepal regardless of data constraints that could prevent a full empirical investigation
- Derive and estimate a reduced-form harvest function for the rhinos poached in RCNP
- Test hypotheses regarding the factors (variables) that are considered to affect the level of poaching, make inferences, and draw conclusions that will serve as recommendations for planners and policy makers.

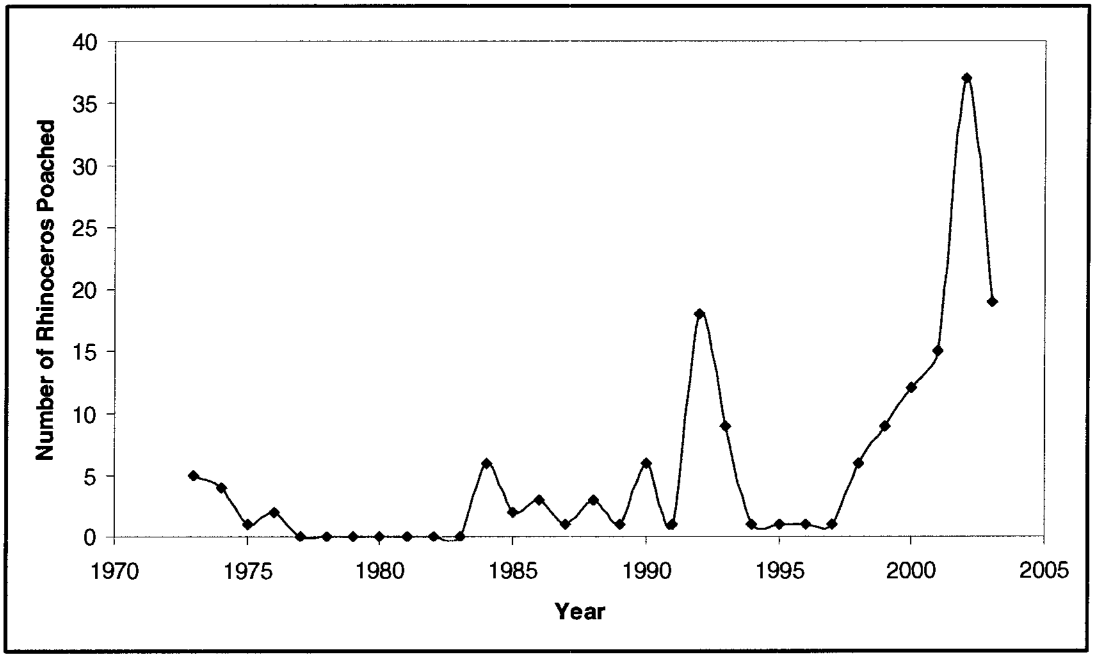

Figure 1-1 Number of one-horned Indian rhinoceros poached in the Chitwan Valley from 1973–2003

CHAPTER 2 LITERATURE REVIEW

2.1 Analysis of Poaching: An Overview

There have been a number of studies on the illegal exploitation of African rhinos and elephants, most notable are those concerned with the Luangwa Valley in Zambia (for example, Leader-Williams *et al.* 1990; Milner-Gulland and Leader-Williams 1992a; Leader-Williams and Milner-Gulland 1993). Although these studies are focussed on the relationship between illegal exploitation and anti-poaching law enforcement, they have attempted to look at socioeconomic factors affecting the level of poaching (such as alternative economic opportunities). The study by Leader-Williams *et al.* (1990) concluded that the declines in rhino numbers occur due to problems originating outside the protected areas, such as the increasing price of rhino horn on the international market and a decline in other economic opportunities for local people living in and around the protected areas. Leader-Williams *et al.* (1990) report that "law enforcement units were effective in capturing poachers, but were too small to provide protection to large populations of rhino and elephant". They estimated an optimal rate of one officer per 20 km^2 for effective law enforcement in the protected area.[2]

Milner-Gulland and Leader-Williams (1992a) modelled the poaching in the Luangwa Valley by local poacher and dealer with respect to the financial gains, detection and penalties. They report that a penalty that varies with the output of a poacher is more effective than a fixed penalty. More importantly, the detection rate was found to be more of a deterrent for poachers than the penalty. Furthermore, they report that different incentive structures attract local poachers and dealers to poaching, and hence any policy to curb poaching by a local poacher might not stop

[2] According to Martin (1996), the Royal Chitwan National Park has approximately one man per square kilometre for anti-poaching enforcement.

poaching by organised gangs employed by the dealer. It is worth noting that Milner-Gulland and Leader-Williams (1992a) depict the dealers as the resource controllers in their model, implying that they focus on long term profit maximisation from wildlife exploitation. This assumption, however, seems unlikely in the case of national parks such as RCNP in Nepal, where the resource controller is obviously the park authority (or the state) who is in charge of managing the parks. There are important distinctions between the dealer and the park authority as resource controllers. Firstly, the dealers' action is illegal and thus liable to a penalty, which must be considered in modelling their net returns from poaching. Unlike dealers, park authorities bear an extra cost of law enforcement. More importantly, in the context of RCNP, the resource controller (park authority) does not maximize net benefits by harvesting rhino, as the national park's economic benefit comes mainly from tourism.

Skonhoft and Solstad (1996, 1998) develop a more general model of wildlife exploitation. Their model is similar to that developed by Milner-Gulland and Leader-Williams (1992a) in that it explicitly models the exploitation of wildlife by local poachers. However, there is a fundamental difference – rather than setting the dealers as the resource controllers, they model an agency managing the park in this role, which is more realistic (see above). Their model is a two agent (local poachers and park authority) model where each agent maximizes its net benefits given constraints and the other agent's actions. The variables, such as wildlife numbers and the degree of law enforcement effort, enter the benefits function of both the agents, with differing impact. Similar to Milner-Gulland and Leader-Williams (1992a), Skonhoft and Solstad (1996, 1998) model the resource controller (the park authority in this case) as a long term profit maximiser. However, there is still a fundamental difference between these two resource controllers – the park authority holds the property rights to the park, whereas the dealers do not. This distinction applies to local poachers as well. In this respect, Skonhoft and Solstad (1996, 1998) analyse the outcome of the agents' actions under different property rights structures.

In a similar but more empirical study, Bulte and van Kooten (1999a) constructed a model to analyse the effects of the ivory trade ban on poaching and elephant stocks in Africa. They used data from Zambia to parameterize their model, and showed that banning trade may increase or decrease equilibrium elephant stocks depending upon the assumptions regarding the discount rate and the probability of detection. Nevertheless, they conclude – "the ivory trade ban is more effective in conserving the African elephant than in permitting open trade." While the models of Skonhoft and Solstad (1996, 1998) are based on utility maximization at the household level (agricultural household model), Bulte and van Kooten (1999a) use a simpler open access formulation that is more amenable to empirical application. A more recent study on poaching of tigers and their prey in India by Damania *et al.* (2003) combines utility maximization at the household level with the tiger population dynamics. They do this through a household model that explains poaching behaviour of farmers and poachers using tiger population growth to determine time paths of tiger stocks under alternative scenarios. They suggest that the increasing opportunity costs of poaching might be a potentially effective way to reduce poaching.

2.2 Factors Influencing Poaching: A Conceptual Framework

The conceptual model builds on the factors that are hypothesised to influence the decision to poach (and subsequent levels of poaching) by the local poachers. Studies of the incentives (or disincentives) to get involved in illegal activities have suggested that (i) a rise in the probability of punishment or stricter punishment, (ii) a fall in profits from an illegal activity, or (iii) a higher opportunity cost of an illegal activity due to economic opportunities elsewhere, reduce the level of illegal activities (Cook 1977, cited in Milner-Gulland and Leader-Williams 1992a). Rhino poaching, being an illegal activity can be studied under a similar incentives (or disincentives) structure. The conceptual model (**Figure 2-1**) is built based on this structure, which looks into (i) effectiveness of anti-poaching measures that determine "the probability of being caught and convicted", (ii) penalties (fines and prison sentences) when caught poaching, (iii) available economic alternatives (i.e., the opportunity cost of poaching), (iv) the cost of poaching (direct costs of poaching that determines the level of profits), and (v) the price of rhino horn on the international (black) market (which is often the biggest motivator for poaching). I discuss each of these factors in detail.

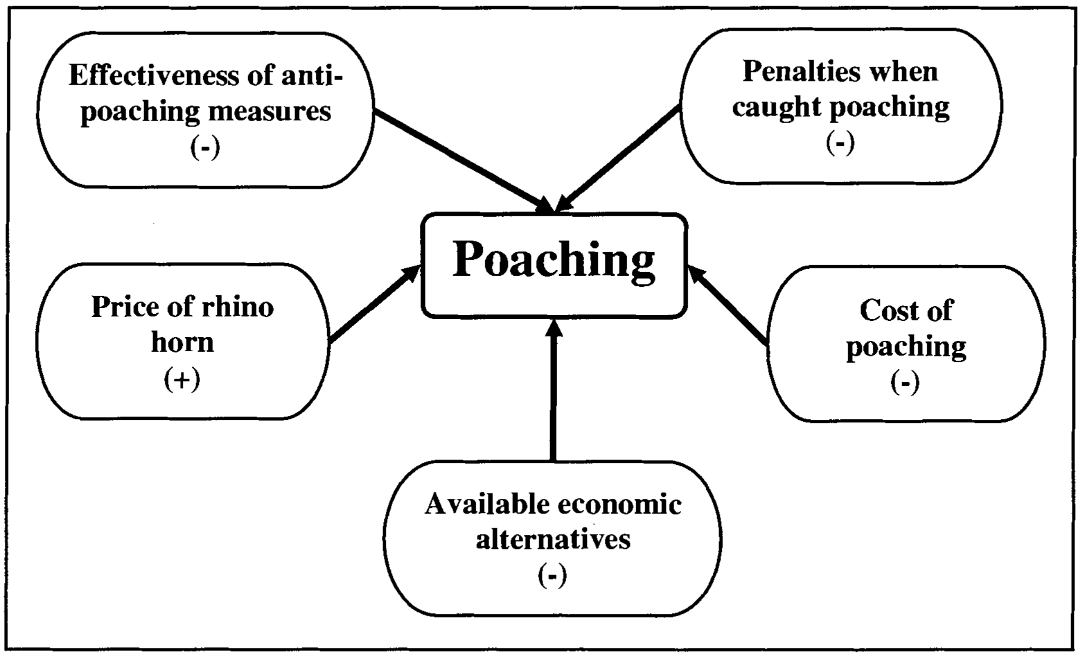

Figure 2-1 Factors that affect poaching by local poachers in Terai

2.2.1 Effectiveness of anti-poaching measures

It is intuitive that poachers adjust their behaviour and decisions to account for the likelihood of their detection and capture. This likelihood, in large part, depends upon the level and effectiveness of the anti-poaching measures in place. A number of studies have looked into the effect of the level of law enforcement and its effectiveness on the poaching of wildlife, most notably in African contexts (for example, Leader-Williams *et al.* 1990; Leader-Williams and

Milner-Gulland 1993; Milner-Gulland and Leader-Williams 1992a; Jachmann and Billiouw 1997; Yi-Ming *et al.* 2000). Leader-Williams *et al.* (1990), in their study of poaching of black rhinoceros and elephants in the Luangwa Valley (Zambia) found that an increased patrol effort reduced illegal activity within the protected area, which in turn reduced the decline in rhino and elephant populations. Milner-Gulland and Leader-Williams (1992a, 1993) confirm this proposition in their subsequent studies at the same site. They have suggested that the probability of detection – a direct result of the enforcement effort and its effectiveness – could be a better deterrent than the penalty imposed on poachers when caught (the issue of penalties is discussed in **2.2.2**). A more recent study on elephant poaching, also in the Luangwa Valley, looked at resources allocated to enforcement in terms of manpower, budget, rewards etc. The study concludes that success in elephant conservation is due to increased levels of enforcement (i.e., manpower and budget), and also due to effectiveness in enforcement (through the introduction of specific investigation operations, and the bonus system) (Jachmann and Billiouw 1997). A similar study by Yi-Ming *et al.* (2000) on illegal wildlife trade in the Himalayan region of China found that the poaching and smuggling of wildlife in this region did not show a significant reduction after the introduction of a stricter wildlife protection law, mainly due to lack of effective enforcement.

The studies on rhino conservation in Nepal have also reported that stricter wildlife protection laws are insufficient in reducing the level of poaching without effective enforcement (for example, Martin and Vigne 1996; Martin 1998, 2001, 1996; Dhakal 2002; Adhikari 2002; Yonzon 2002). It is reported that increases in level of enforcement (through introduction of APUs) and increases in effectiveness of enforcement (through increased patrols and use of intelligence networks) have reduced poaching significantly over the years. Moreover, a lack of these measures has resulted in higher levels of poaching in certain 'in-between' years and more so in the years after 1998 (*ibid*). Yonzon (2002) further points out that the ongoing Maoist insurgency has affected the level and effectiveness of the enforcement, thereby increasing the level of poaching.

The effect of enforcement on the level of poaching seems to be well established, however, most of these studies have failed to look into how poachers react to these changes in enforcement, and whether they adapt to these changes by becoming more effective hunters themselves, or just opt out of poaching and find other sources of income. There is evidence that the effectiveness of anti-poaching enforcement in Nepal is affected by the knowledge that poachers possess of the enforcement techniques that are used (Gurung and Guragain 2000). The study further points out that poaching increased in the Terai region as poachers became familiar with the anti-poaching efforts and adapted to the techniques used by enforcement personnel (*ibid,* p. 5). By knowing what the enforcement officers would do, how they would do it and when they would be at a given location, poachers could increase their poaching success. Moreover, this knowledge is liable to increase over time for a given set of enforcement arrangements. For example, the initial success of new anti-poaching activities from 1977-1983, and before 1992, was followed by increases in poaching in 1984 and 1992. A further change in enforcement in 1993 subsequently halted poaching for a number of years before it picked up again in 1998 (Adhikari 2002). So, it is essential to look not only at the level of enforcement and its effectiveness for a given year, but also how this effectiveness changes over the years due to changes in poachers' hunting patterns, and also due to other external factors (such as the Maoist insurgency).

2.2.2 Penalties when caught poaching

Another factor affecting the level of poaching is the penalties that poachers face when captured and convicted. Penalties could either be fines, prison sentences or a combination of both;

confiscation of trophies is often considered additional to the penalties faced by the poachers.[3] For a given probability of detection, a penalty also increases the expected cost of poaching, and hence it should, theoretically, reduce a (rational) poacher's incentive to poach. However, the opinions, as well as results, seem to be mixed in this regard (see for example, Leader-Williams *et al.* 1990; Leader-Williams and Milner-Gulland 1993; Milner-Gulland and Leader-Williams 1992a; Clarke *et al.* 1993). This mixture of opinions and results could, to a large extent, be attributed to the complex nature of the penalty itself. Since the penalty not only constitutes monetary fines (and confiscation of trophies) but also the prison sentences, administering a penalty that comprises a fine or a prison sentence or a mixture of both has a very different effect on a poacher's behaviour (Leader-Williams and Milner-Gulland 1993; Milner-Gulland and Leader-Williams 1992a; Clarke *et al.* 1993).[4]

Clarke *et al.* (1993) looked into a penalty structure that constitutes only fines, in their study of illegal logging in developing country forests.[5] They point out that while higher fines might have a deterrent effect when poachers make decisions about whether to poach or not, the level of poaching itself depends on the marginal net benefits from poaching, and hence on the marginal fines. Thus, contrary to expectations, higher fines may induce poachers to poach at a higher level to offset the greater fines they face in the event of their capture and conviction (*ibid*, p. 284). Leader-Williams and Milner-Gulland (1993) state that due to poverty, fines are likely to deter local poachers from poaching elephants and rhinos; however, they also agree that too high a penalty could exacerbate poaching instead of reducing it. A penalty that only constitutes a prison

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[3] For example, Milner-Gulland and Leader-Williams (1992) include confiscation of trophies in the total fines imposed on poachers in their analysis of poaching incentives

[4] Scholars further argue that from a government's perspective, fines are more beneficial than prison sentences as they are much cheaper to administer, and they act as a "tax" on illegal activity. On the other hand, prison sentences incur large costs to the state as well as the prisoner (see for example, Leader-Williams and Milner-Gulland 1993; Clarke *et al.* 1993). However, our focus here lies solely on the effects of penalties on the poachers.

[5] The case of illegal logging or "poaching" of trees can be considered similar to rhino poaching in that both are driven by short term economic gains, and both are protected by strict conservation legislation in many instances. Yet poachers act as if there is a *de facto* open access to the resource.

sentence provides a different incentive (or disincentive) structure to the poachers. In the case of a prison sentence, the deterrence effect on the poachers depends upon their discount rate and time horizon i.e., how much they value the present over the future and how far into the future they look when making decisions (Leader-Williams and Milner-Gulland 1993). Assuming poachers have a sufficiently low discount rate and higher time horizon, they will be more hesitant to poach wildlife and risk capture and conviction when the penalties for doing so are higher (i.e., when they are likely to be in prison for a long time). Leader-Williams and Milner-Gulland (1993) point out that in Africa, the future is very uncertain so poachers are less likely to have a longer time horizon or a lower discount rate. This, in turn, suggests that the severity of prison sentences might not deter poachers from poaching. They further state that focussing on increasing detection rates could be a better strategy in these countries, rather than increasing the severity of prison sentences (p. 613). Similar strategies could be argued for many of the other developing countries (including Nepal) as they face similar political and economic problems.

However, in contrast to the two scenarios above, the real penalty structures governing wildlife conservation in most countries are a mixture of prison sentences and fines. Thus, characteristics of both these penalties come into play, which determines the behaviour of poachers. One of the major issues raised regarding this mixed penalty is that of the conversion rate between prison and fines (Milner-Gulland and Leader-Williams 1992a). Milner-Gulland and Leader-Williams (1992a) point out that standard methods of conversion (using loss of earnings when in prison) fail to take into account other factors associated with a prison sentence, for example, the difficulty in getting a job with a criminal record. Furthermore, standard conversion tends to imply that a prison sentence is more severe for the rich than for the poor, given higher loss from the foregone earnings of the rich. However, it has been argued that a prison sentence is usually more severe for the poor local poachers as it has serious effects on their families' welfare. This is because these poachers are, in most cases, the sole provider of family income (Leader-

Williams and Milner-Gulland 1993). As such, in their study of poaching incentives, Milner-Gulland and Leader-Williams (1992a) use the magistrates' perception of the conversion rate between prison and fines when sentencing poachers. They justify their choice by arguing that "a person's perception of the penalty must be better than a wage-based conversion, even if that person is a judge" (p. 390).

Another issue lies with the relative severity of each component in the prison-fine penalty structure and in devising an optimal combination.[6] Milner-Gulland and Leader-Williams (1992a) point out that if the prison sentence is less severe than the fine, then many poachers would simply choose prison instead, which increases expenses to the state. On the other hand, a less severe fine could encourage dealers and middlemen to buy acquittal of the hunters they hired for poaching, as dealers and middlemen are usually not convicted themselves (Leader-Williams and Milner-Gulland 1993; Gurung and Guragain 2000).

In reality, most countries have been increasing the severity of penalties over the years – both in terms of higher fines and longer prison sentences (Leader-Williams and Milner-Gulland 1993; Maskey 1998). However, owing to the difficulties in enforcing the penalties on poachers as discussed earlier, Leader-Williams and Milner-Gulland (1993) suggest that a more appropriate solution would be to sentence dealers themselves. Nevertheless, severe penalties mean that poachers must be paid more in order to persuade them to risk being captured; this means dealers and middlemen hiring these poachers are likely to be deterred. Furthermore, Milner-Gulland and Leader-Williams (1992a) have shown that a penalty that varies with poachers' output (e.g., number of horns) is a more effective deterrent than a fixed penalty. The level of penalties, however, depends on the magistrates or judges who administer the sentences to the convicted poachers, and on many occasions they were found to misinterpret their own country's wildlife laws (Leader-Williams *et al.* 1990).

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[6] Optimal combination here is that which has the most deterrent effect.

The case of Nepal seems even more serious. Gurung and Guragain (2000) point out a number of cases where sentences have been influenced, and poachers released without serving the entire sentence, due to pressure from the political elite (pp. 14-15). Nevertheless, the severe penalty structure in place in Nepal for wildlife offences since 1993 is reported to have significantly deterred the poachers (Martin 1998). Although the likely deterrent effect of a severe penalty is acknowledged, scholars seem to agree that a higher probability of detection is more of a deterrent than a higher penalty (Milner-Gulland and Leader-Williams 1992a; Leader-Williams and Milner-Gulland 1993; Clarke *et al.* 1993).

2.2.3 Available economic alternatives

Poaching at the local level is essentially an economic phenomenon, and hence the availability of alternative economic opportunities locally plays an important role in determining the incentives for poaching. If alternative pursuits offer a higher rate of return, then the opportunity cost of poaching increases and the incentive to poach declines. A number of studies have reported the success of local investment schemes, such as savings and credit programme and eco-tourism ventures, initiated by wildlife conservation authorities in partnership with local bodies. These programs reduce the level of illegal activities (such as poaching) by increasing the opportunity cost of such activities (for example, Leader-Williams and Milner-Gulland 1993; Milner-Gulland and Leader-Williams 1992a; Martin 1998; Martin and Vigne 1996). Theoretically, the programs that provide a greater role for the local communities in wildlife management by giving the local people the user or property rights to the wildlife, such as through community-based wildlife management, should help conserve the wildlife in the long term (Skonhoft and Solstad 1998). However, recent studies regarding the community-based wildlife management programs in Africa show that providing a greater role for the communities in wildlife management has not been particularly successful (Songorwa *et al.* 2000). Songorwa *et al.*

(2000) blame the failures of community-based wildlife management programs in Africa to the "problematic assumptions" that they are based upon.

Greater user rights to the wildlife do not necessarily accrue greater benefits for the communities, especially when such rights prohibit extraction of such resources and instead rely on benefits from conservation and non-extractive use, such as from tourism. Furthermore, lack of appropriate benefits from the conservation and non-extractive use of the resources often fails to create compatible incentives that could hinder the conservation rather than helping it. Nevertheless, some positive outcomes from the programs that have sought to create compatible incentives to reduce human-wildlife conflicts have also been reported. Archabald and Naughton-Treves (2001) report that the tourism revenue-sharing in national parks in western Uganda has had improved local attitudes towards parks and park management. However, the study also argues that providing community level incentives, such as schools or clinics, might not be an adequate incentive in itself for the revenue-sharing programme to effectively help in conservation; and point out that such programmes may be more effective if incentives are provided at both the community and individual [household] level. Furthermore, ineffectiveness of another community-based conservation program in Zimbabwe, CAMPFIRE, has also been reported to be due to incompatible incentives provided by the program, amongst a host of other socio-political and administrative issues (Logan and Moseley 2002; Virtanen 2003).

Martin and Vigne (1996) report that the growing tourism sector in and around RCNP has been providing an increasing number of jobs to the locals. Increases in the opportunities locally are likely to deter poachers/would-be poachers from taking up poaching. Martin (1998) provides examples of a number of community development schemes initiated by the government and non-government organisations in and around RCNP and the RBNP in Nepal, which have been helping improve skills of the locals, create employment opportunities locally, and raise overall economic opportunities. These programs have helped protect wildlife, such as rhinos, within those parks.

Furthermore, he points out that the new buffer zone management scheme, which provides up to half of the parks' revenue to the local community, could have a significant impact on creating projects that increase economic opportunities locally, especially around a park like RCNP, which generates substantial revenue from tourism. Moreover, potential for eco-tourism initiatives within the community forests of RCNP buffer zone (as demonstrated by the case of Baghmara Community Forest[7]) could create sufficient economic incentives to deter locals from poaching. However, it should be noted that the prospects for these kinds of eco-tourism initiatives seem limited thus far to areas, such as Baghmara, that are closer to the tourism centres like Sauraha in RCNP. In general, it is justifiable to assume that greater availability of alternative economic opportunities locally will deter local poachers and would-be poachers from being involved in poaching. Furthermore, a higher opportunity cost from the availability of alternative economic opportunities means that the dealers and middlemen who hire local poachers must pay more in order to make poachers take on a risky job. This makes poaching more costly. It should be noted, however, as Milner-Gulland and Leader-Williams (1992b) point out, that organised gangs, middlemen, and poachers who are not locals are not directly deterred by such local economic alternatives. As such, local alternatives would not affect their opportunity costs.

2.2.4 Cost of poaching

The (direct) financial costs of poaching are defined as the wages (labour) and equipment (capital) that are required for a poaching expedition, as well as the ease of finding and killing the animals. Generally, it is assumed that as the cost of poaching increases, the incentives to poach will decrease and vice-versa, all else being equal. A number of issues emerge when analysing the effect of the cost of poaching on poaching incentives as per this assumption. Firstly, a major issue relates to the types of poachers and differential costs they face when organising a poaching expedition. A general observation in the previous studies has been that the local poachers

[7]See Martin (1998) for more details.

generally face low costs for a poaching expedition compared to an organised gang member, mainly due to the sophistication of the equipment (e.g., weapons, communication equipment) used (see for example, Leader-Williams and Milner-Gulland 1993; Milner-Gulland and Leader-Williams 1992a). However, it is important to note that a local hunter in the Chitwan Valley in Nepal, whether acting himself or hired to poach a rhino, faces very low costs either way. If he is acting himself, his cost is low due to the primitive technology used, such as digging pits, poisoning and using home-made firearms; on the other hand, if he is hired by a dealer or an organised gang, the direct costs of poaching would be borne by the employers as all the equipments used will be provided by his employers.

A number of previous studies have shown that the most common method to kill a rhino in the Chitwan Valley is pit digging[8], followed by spearing, snaring, and poisoning (Martin and Vigne 1996; Chungyalpa 1998; Maskey 1998; Gurung and Guragain 2000). Nevertheless, more firearms are reported to have been used recently (Martin 2001). Gurung and Guragain (2000) point out that the community forests and farms within the park buffer zone are the areas where poaching occurs frequently. In recent years, due to a relatively higher rhino population in RCNP, more rhinos are found to wander out into the community forests or farms (Dhakal 2002), suggesting that it is relatively easy for a poacher to find a rhino. This lowers the search effort and hence the costs. On the other hand, poachers are also found to target the areas with high rhino concentration (Gurung and Guragain 2000), which of course leads to a lower cost in terms of search efforts. Thus, although high costs of poaching could be a definite deterrent for poachers, the fact remains, in the case of rhino poaching in the Chitwan Valley, that poaching costs for local poachers have remained low historically and continue to be so. This also suggests that, for the local poachers in the Chitwan Valley, opportunity costs could be more of a deterrent than the direct financial cost of poaching.

[8] Martin and Vigne (1996) report that more than 50 pits were dug in RCNP in 1992 alone, in which 14 rhinos were reported to have been caught.

2.2.5 Price of rhino horn

The price of rhino horn on the international black market directly affects the profitability of poaching. An obvious assumption would be that an increase in the price of rhino horn increases the incentives to poach. Studies on rhino poaching have shown that middlemen, dealers, and international traders are the groups that profit the most from a high price of rhino horn on international markets, with the actual hunters getting relatively low prices for their efforts in comparison (for example, Martin and Vigne 1996; Maskey 1998; Gurung and Guragain 2000; Martin 2001; Menon 1996). However, it is often the case that the low price obtained by poachers is well above their average earnings at local wage rates (Chungyalpa 1998). Indeed, previous studies have all suggested that one of the main reasons local hunters get into rhino poaching is their abject poverty. The price they receive for poaching a rhino (which is often more than their entire year's earning from other sources) becomes much more lucrative and hence, provides real incentives to poach (Maskey 1998; Gurung and Guragain 2000).

The price of Asian rhinoceros horn (e.g., from the one-horned Indian rhinoceros) has historically been very high on the international market, in comparison to that of African horn.[9] Leader-Williams (1992) reports increasing demand for rhino horns, and the growing (illegal) trade in rhino horn and products derived from it to be "largely responsible for reducing rhinos to their presently endangered status." This growing demand for horn on the international market (which in turn increases the price) is likely to increase the price received by the poachers at the local level. This subsequently increases the incentives to poach.

In fact, a simple analysis of the retail price of Asian rhino horn (reported in earlier studies) and the share of profits that go to local poachers highlights the incentives to poach. The local poachers are reported to receive about 1% of the final profit from the horn trade

[9] See, for example, price information compiled in Leader-Williams (1992), Nowell *et al.* (1992) among others. Nowell *et al.* (1992) report that the retail price of horn from Asian rhinos, called the "fire" horn is often ten times as high as the retail price of horn from African rhinos, called the "water" horn.

(Chungyalpa 1998), and the price of Asian rhino horn has been reported to be anywhere from US$ 20,000 – 30,000 (Maskey 1998) up to US$ 40,000 – 60,000 at the higher end (Nowell *et al.* 1992). This shows that even 1% of the profit could be highly attractive to a poor hunter in Nepal, where annual per capita income is less than US$ 250, and 42% of the population live in poverty.[10] The actual price received by a local hunter for poaching a rhinoceros is not reported in most of the earlier studies except in Gurung and Guragain (2000), who report that a local hunter in Nepal is paid approximately US$ 150 for poaching a rhino (p.18).[11] The authors confirm that the growing value of rhino horn on international markets is one of the important reasons behind rhino poaching (*ibid,* p. 18).

Although it is difficult to find studies that have formally analysed the effects of the price of rhino horn on the level of poaching, Milner-Gulland (1993) studied the demand of rhino horn in Japan – one of the biggest consumers of rhino horns and horn products – based on price of the horn and income (GNP per capita), among other variables, such as the exchange rate and the discount rate. The study reported that the demand for the rhino horns in Japan was mainly income-driven until 1980, and further stated that the demand was likely to have risen as the Japanese GNP continued to rise beyond 1980. Finally, the study concluded that the market for rhino horn was more likely to be supply driven [since the early 1990s] as the market for rhino horn changed significantly due to the CITES ban on the trade of rhino horns and its products worldwide, and due to the fact that the import of rhino horn in Japan was made illegal.

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[10] This figure of 42% comes from the Nepal Living Standard Survey's head-count index measure as reported in the Nepal Human Development Report 2001; the poverty figure is reported to be 37.7% under the definition of "one US dollar a day" (UNDP 2002, p. 31).

[11] It is important to note that most of the other studies do report the price received by a local gang involved in rhino poaching (for example, Vigne and Martin 1996; Maskey 1998; Martin 2001). However, the actual size of these gangs seem to vary according to the techniques used for poaching. For example, gangs using guns are reported to include three to seven individuals, whereas a gang involved in poaching using pit trapping is reported to include as many as 15 individuals (Martin 2001). This means the price received by an individual hunter will vary according to the size of the gangs he belongs to.

CHAPTER 3 AN OLIGOPOLY MODEL OF POACHING BEHAVIOUR

3.1 Overview

The review of the factors considered in the literature to influence the level of poaching forms the basis for the structural model. The objective here is to derive a reduced-form poaching function that captures the incentives structure outlined above (see Chapter 2, Section 2.2). A number of works reviewed in Chapter 2 have tried to model poaching under different assumptions. However, most of these works are focussed on the African context and differ significantly from the poaching structure in Nepal. Firstly, although the hunters are mainly locals in Nepal, poaching is largely controlled by a relatively few dealers based in major cities like Kathmandu and Pokhara (Gurung and Guragain 2000; Martin 2001). Furthermore, these local hunters are very poor and landless with few alternative opportunities (Maskey 1998; Gurung and Guragain 2000), which suggests that an optimisation framework involving labour allocation between farming and poaching at the household level is unsuitable in the Nepalese context. Nevertheless, poaching in RCNP can be modelled in a number of different ways – the difference in the models reflecting the assumptions made regarding the poaching structure in Nepal. In this chapter, the focus is on an oligopolistic formulation where only a few traders are considered to control the harvest of the resource.

It is widely accepted that the poaching for endangered species like rhinoceros could be modelled as *de facto* open access due to a lack of control on the access to rhino stocks by the poachers (for example, Milner-Gulland and Leader-Williams 1992a; Bulte and van Kooten 1999a; Bulte and van Kooten 1999b). Majority of the studies on the poaching of rhinoceros (and elephants) to date seem to follow this open access line of analysis (*ibid.*). However, it has been reported that the trade in rhino horns, especially with regard to the Greater one-horned rhinoceros is controlled by only a few individuals (Maskey 1998; Martin 1996, 2001; Gurung and Guragain 2000). Furthermore, there seems to be a clear distinction between the traders (including the middlemen) who supply the horns to the market, and the poachers who actually kill the rhinos, with regard to the poaching of the one-horned rhinoceros in Nepal (Gurung and Guragain 2000). This situation essentially creates an oligopoly in the supply market, whereby the market is controlled by a small number of traders. It requires a slightly different approach to modelling than with the traditional open access assumptions. The oligopoly in the market of rhino horns means that the traders either try to set the price of the horns directly or influence the price by controlling the supply. I assume that the latter proposition holds as far as the trade in Asian rhino horns is concerned. This would mean that the local poachers, who act as the suppliers to these traders would have a restricted opportunity to poach, the restriction coming from the demand for horns by the traders.[12] Nevertheless, the poaching at the local level could still resemble a *de facto* open access as the control in illegal access to the park by the poachers will not be perfect.

One of the major differences between the traditional open-access analysis of poaching and the oligopoly involving a few traders who pay local poachers to supply them with the horns is that the traders are less affected by the enforcement as they are not directly involved in poaching. On the other hand, local poachers, who actually kill the rhinos, get paid according to the number of horns they supply, and are affected by the level of enforcement. However, these local poachers are not directly influenced by the [international] price of the horn. The local poachers are paid a local price set by the traders for supplying a horn, and this price is too small compared to the

[12] One could also argue that these local poachers might not be affected by the supply opportunity and just stockpile the horns when the demands by the traders are lower. However, in case of poaching in Nepal, this is highly unlikely as the poachers involved at the local level are usually very poor (e.g., Maskey 1998; Chungyalpa 1998; Gurung and Guragain 2000) and will not be able to sustain their (and their family's) livelihood unless they have immediate sources of income. Thus, stockpiling the horns for future sale can be safely ignored in this analysis.

international price[13] to be affected by fluctuations in the international price of the horn. The local poachers will be willing to poach as long as they expect to make profits from poaching under the given level of enforcement. Thus, the *de facto* open access condition will still hold for the local poachers. In order to model the poaching of rhinos and the horn trade with these oligopoly market assumptions, a two stage modelling is required – (1) to find the harvest level set by the traders under oligopolistic conditions, and (2) to find the open access effort level by the local poachers. This open access effort level will help in deriving the reduced-form poaching function under oligopoly assumptions.

Although the market (and agent) characteristics regarding the trade of rhino horns from Nepal seem to be very well understood (Maskey 1998; Martin 1996, 2001; Gurung and Guragain 2000), there is not a single study that has tried to model rhino poaching in Nepal (and India) using an oligopolistic formulation (or even traditional open access formulation for that matter). In fact traditional open access modelling seems to dominate the analysis of poaching of rhinos and elephants to date (e.g., Milner-Gulland and Leader-Williams 1992a; Bulte and van Kooten 1999a; Bulte and van Kooten 1999b). An extensive search of literature revealed a discussion paper by Damania and Bulte (2001) that had tried to model wildlife poaching as an oligopoly involving wildlife poachers and captive breeders who supply wildlife parts legally. Although the case presented in that analysis and the poaching of rhinos in Nepal is quite different, it still serves as an example on how poaching could be modelled as an oligopoly. Damania and Bulte (2001) assess the effects of captive breeding programs on the level of poaching of the wildlife stock using an oligopolistic formulation. The analysis is quite complex in the sense that the costs faced by captive breeder and wildlife poacher are different, and that they face different prices under the assumption that the products from captive bred animals and those from wildlife stock are not perfectly substitutable. Damania and Bulte (2001) show that analyses under the assumption of

[13] Chungyalpa (1998) reports that the local price paid to the poachers is only around 1% of the final price of the horn.

non-perfect substitution and under relaxation of this assumption produce very different results – the important outcome being that supplying captive bred animal parts to crowd out illegal trading of wildlife parts might not always have the desired effects. The worse outcome being an increase in poaching under both the quantity competition (i.e., Cournot equilibrium) (p. 17), and the price competition (i.e., Bertrand equilibrium) (p. 18).

The oligopolistic analyses with regard to the poaching of the one-horned rhinoceros, however, would be much simpler. First, there are no captive breeders of rhinoceros so the structure of oligopoly is slightly different – with a few illegal traders of rhino horns being the agents in the oligopoly market structure. Furthermore, the oligopolists face the same market price for rhino horns they trade, which makes the analyses simpler. Below I develop an oligopolistic model for the poaching/trade of horns from the one-horned rhinos.

3.2 The Model

3.2.1 Traders

For the traders, the cost of poaching would include the cost of obtaining the rhino horns from the local poachers at a set price per unit of the horn. In addition, the cost would also include the cost of transporting the horns, and costs associated with marketing of the horns. The revenue would be generated through the sale of the horns on the [international] black market price. As stated earlier, I assume that these traders influence the price of the horn through the supply mechanism (i.e., setting the level of harvest/supply but not setting the price directly). Further, I also assume that these traders will not be affected in their decision to set the level of harvest by any anti-poaching enforcement efforts as they will pay the poachers as and when the horns are supplied and are not directly involved in poaching or arranging a poaching expedition.

I consider the simplest case of oligopoly at the rhino-horn-trader level, where there are only two traders each setting its level of harvest given the harvest level set by the other trader.

Further, I assume that among these two traders, one operates in India and another in Nepal – the two countries that have the stock of the one-horned rhinoceros. As per the assumptions, the trader operating in each country will clearly have a monopoly over the harvest in that country. Nevertheless, this assumption of two-traders/two-countries would allow bringing in the dynamics of different enforcement levels and different local prices in these two countries, should the analysis be extended from a one period scenario to a multi-period scenario. It is worth noting, however, that the model discussed here is a static model in that it takes the rhino stock as given (i.e., does not include population dynamics of rhino within the model), and only considers a simple one-period scenario.

Let h be the total harvest (and hence total supply to the market – assuming harvest and supply levels are the same), and h_1 and h_2 be the level of harvest for trader 1 and trader 2 respectively. Thus,

$$h = h_1 + h_2 \quad \text{.......} \quad (3.1)$$

Also assume that the traders face a simple linear inverse demand function of the form

$$p(h) = a - bh = a - b(h_1 + h_2) \quad \text{.......} \quad (3.2)$$

where a and b are constants, and $a, b > 0$, and p is the [international] market price per unit of rhino horn assuming all horns are homogenous.[14]

The cost function facing traders is assumed to be linear in the output (horns), i.e., $c(h_i) = (c_i + p_{iL})h_i$, where c_i is unit cost for marketing and transporting and p_{iL} is the price paid by the traders to local poachers per horn supplied.

[14] On average, a horn from an adult one-horned Indian rhino is reported to weigh about 700 gm (Martin 2001; Martin and Vigne 1996). Alternatively, price could be taken as price per kg of horn, which would mean that instead of measuring output in units of horns, it would have to be measured in kilograms.

Now, the profit expressions for trader 1 and trader 2 could be written as, respectively:

$$\pi_1 = p(h)h_1 - (c_1 + p_{1L})h_1 = [a - b(h_1 + h_2)]h_1 - (c_1 + p_{1L})h_1 \quad \text{.................... (3.3)}$$

$$\pi_2 = p(h)h_2 - (c_2 + p_{2L})h_2 = [a - b(h_1 + h_2)]h_2 - (c_2 + p_{2L})h_2 \quad \text{.................... (3.4)}$$

where π_i is the profit for traders. The profit expressions are concave in output (i.e., h_i's).

Each trader will choose an optimal harvest level taking harvest by the other trader as given so as to maximise its profits from the harvest. Assuming an interior optimum, trader 1's optimal harvest is given by solving the first order condition as

$$\frac{\partial \pi_1}{\partial h_1} = a - 2bh_1 - bh_2 - c_1 - p_{1L} = 0$$

$$h_1^* = \left(\frac{a - c_1 - p_{1L}}{2b}\right) - \frac{h_2}{2} \quad \text{... (3.5)}$$

And for trader 2, it would be

$$\frac{\partial \pi_2}{\partial h_2} = a - 2bh_2 - bh_1 - c_2 - p_{2L} = 0$$

$$h_2^* = \left(\frac{a - c_2 - p_{2L}}{2b}\right) - \frac{h_1}{2} \quad \text{... (3.6)}$$

Equations 3.5 and 3.6 are the *reaction curves* for trader 1 and trader 2 respectively that depict the *optimal level* of harvest by each trader given the other trader's harvest level. These reaction curves can be graphed as shown in **Figure 3-1** below. The intersection of the two reaction curves gives the equilibrium harvest levels by the two traders and is called a Cournot-Nash equilibrium (Varian 1992, pp. 285-88).

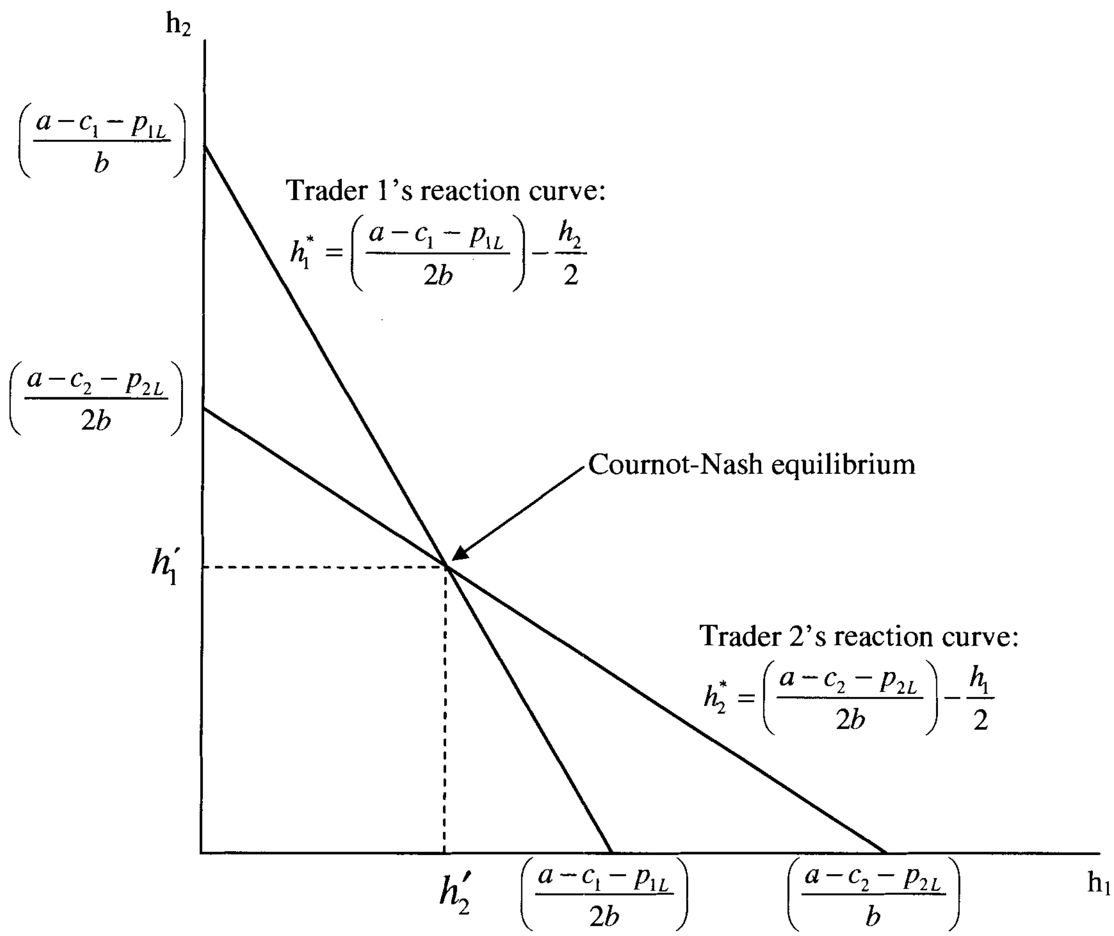

Figure 3-1 Reaction curves for Traders 1 and 2, and the Cournot-Nash Equilibrium

Now, let trader 1 be the one who harvests the horns from the rhino stock in Nepal. This would mean that the total harvest from the Nepali rhino stock could be as much as h_1^*. Also, under the assumption that only trader 1 harvests the horns in Nepal, it would have a natural monopoly over harvesting horns from the rhino stock in Nepal. This trader would rely on the local poachers to supply it with the required quantity of horns, in return, paying them a local price (p_{1L}) per horn supplied.

3.2.2 Local Poachers

For the local poachers, total costs of poaching include the costs related to the poaching efforts and expected costs if detected/captured/convicted (i.e., the costs due to anti-poaching enforcement). The revenue would be the local price (p_{iL}) paid by the traders per horn supplied. Thus, the local poachers would try to maximise the difference between the price they receive for the horns and the costs associated with poaching -- i.e., they would try to maximise their profits. Under the assumption that the traders purchase horns from local poachers but do not specifically hire them for poaching, local poachers would enter poaching as long as there exists some profit from poaching. This would, in the long run, result in profit being equal to zero and hence the analysis of poaching at the local level would be similar to that of the *de facto* open access analysis of poaching. The only difference being that instead of [international] price of rhino horn bringing in revenue directly (at local level), it would be the local price per unit of the rhino horn set by the traders.

For the local poachers in Nepal, expected profit from poaching could be expressed as

$$\pi_{1L} = p_{1L}h_{1L} - \theta_{1L}(F_{1L} + p_{1L}h_{1L}) - c_{1L}E_{1L} \quad \text{.. (3.7)}$$

where π_{1L} is expected profit, h_{1L} is the quantity of horns harvested by the local poachers, θ_{1L} is the probability of detection (and capture and conviction), $(F_{1L}+p_{1L}h_{1L})$ is the total fine (monetary, and prison sentence + value of horns confiscated) if convicted of poaching, c_{1L} is the local [opportunity] cost of poaching per unit effort, and E_{1L} is the total poaching effort.

Following Milner-Gulland and Leader-Williams (1992a), Bulte and van Kooten (1999a, 1999a) and others, I define the harvest function as

$$h_{1L} = qX_1E_{1L} \quad \text{.. (3.8)}$$

where q is species-dependent catchability coefficient, and X_1 the population (stock) of rhinoceros in Nepal. Although a non linear production (i.e., harvest) function has also been used in some analyses (Milner-Gulland and Leader-Williams 1992a), I use the linear production function (equation 3.8) for the purpose of this analysis.

The probability of detection (and capture and conviction), θ_{IL}, should depend on the anti-poaching enforcement effort, B_{IL}, as well as the poaching effort, E_{IL}. However, it has been modelled in a number of different ways, mainly due to the data constraints. Milner-Gulland and Leader-Williams (1992a) model the probability of capture as being proportional to the poaching effort only, and do not consider the influence of anti-poaching efforts on this probability. Bulte and van Kooten (1999a) follow the same line citing "data limitations". Bulte and van Kooten (1999b) present a slightly different approach, where they measure probability of detection per expedition and multiply it with the number of expeditions to obtain "total probability of detection". Finally, Bulte and van Kooten (2001) model the probability of capture in the same way as the harvest function – the probability of capture being a linear function of poaching effort and anti-poaching effort with a catchability coefficient in the formulation. They argue that the APUs "hunt" the poachers in the same way as poachers hunt wildlife. I follow this formulation for the probability of capture for the purpose of this analysis, and model it as

$$\theta_{1L} = \eta E_{1L} B_{1L} \quad \text{.......} \quad (3.9)$$

where η is the "catchability coefficient" for the poachers, E_{IL} the poaching effort, and B_{IL} the anti-poaching enforcement effort.

Inserting equations 3.8 and 3.9 in the profit expression (equation 3.7) gives

$$\pi_{1L} = p_{1L} q E_{1L} X_1 - \eta E_{1L} B_{1L} (F_{1L} + p_{1L} q E_{1L} X_1) - c_{1L} E_{1L} \quad \text{.......} \quad (3.10)$$

Now, under the open access condition in the long run, the profit from poaching dissipates as new poachers enter until the poaching accrues positive profit. Thus, entry will occur until $\pi_{IL} = 0$. Solving equation 3.10 under this condition gives the equilibrium poaching effort by the local poachers under open access as

$$E'_{1L} = \frac{p_{1L}qX_1 - \eta B_{1L}F_{1L} - c_{1L}}{\eta p_{1L}qB_{1L}X_1} \quad \text{.......... (3.11)}$$

Substituting the equilibrium poaching effort in the long run, E'_{1L} from equation 3.11 in the harvest function in equation 3.8 gives the equilibrium harvest of rhino horns (by the local poachers) in the long run as

$$h'_{1L} = \frac{p_{1L}qX_1 - \eta B_{1L}F_{1L} - c_{1L}}{\eta p_{1L}B_{1L}} \quad \text{.......... (3.12)}$$

Now, in order for the local poachers to meet the demand of the trader (i.e., the harvest level for the trader, h_1^*), the trader must set the price of rhino horn at the local level, p_{lL}, such that optimal harvest set by the trader equals the long run equilibrium harvest by the local poachers, i.e., $h_1^* = h'_{1L}$. Solving this equality condition gives the equilibrium price per horn paid to the local poachers as[15] (assuming $B_{lL} \neq 0$)

$$p'_{lL} = \frac{[(a-c_1-bh_2)\eta B_{lL} - 2bqX_1] + \sqrt{[2bqX_1 - (a-c_1-bh_2)\eta B_{lL}]^2 + 8\eta bB_{lL}(\eta B_{lL}F_{lL} + c_{lL})}}{2\eta B_{lL}} \quad \text{...... (3.13)}$$

Substituting the local equilibrium price from equation 3.13 to the equilibrium harvest function (equation 3.12) gives the equilibrium harvest in the long run by the local poachers. This harvest would supply trader 1 with h_1^* horns. The equilibrium harvest would be

$$h_1^* = h'_{lL} = \frac{qX_1}{\eta B_{lL}} \frac{2(\eta B_{lL}F_{lL} - c_{lL})}{[(a-c_1-bh_2)\eta B_{lL} - 2bqX_1] + \sqrt{[2bqX_1 - (a-c_1-bh_2)\eta B_{lL}]^2 + 8\eta bB_{lL}(\eta B_{lL}F_{lL} + c_{lL})}} \quad \text{... (3.14)}$$

[15] Solving $h_1^* = h'_{1L}$ yields equilibrium prices as $p'_{lL} = \frac{[(a-c_1-bh_2)\eta B_{lL} - 2bqX_1] \pm \sqrt{[2bqX_1 - (a-c_1-bh_2)\eta B_{lL}]^2 + 8\eta bB_{lL}(\eta B_{lL}F_{lL} + c_{lL})}}{2\eta B_{lL}}$. The equilibrium price that is non-negative is chosen.

Equation 3.14 shows that under oligopolistic market structure at the horn-trader level, and an open access at the local poacher level, the equilibrium harvest is a complex function of the rhino stock (X_1), anti-poaching enforcement level (B_{1L}), fines (F_{1L}), local cost of poaching (c_{1L}), trading costs (c_1), and the level of harvest (h_2) by trader 2 (i.e., the competitor in India). Thus, the harvest of the rhino horns in Nepal not only depends on the local conditions, such as the enforcement levels, costs, and the rhino stock, but also on such conditions in India. For example, the enforcement levels, costs of poaching, and the rhino stock in India will affect the level of harvest from the Indian stock (h_2), which eventually affects the harvest from the Nepali rhino stock (h_1).

CHAPTER 4 EMPIRICAL APPLICATION OF A RETROSPECTIVE RHINO POACHING MODEL TO RCNP

In this chapter I try to empirically estimate a reduced-form poaching function for rhinos in RCNP. Although an oligopolistic model formulation is much closer to reality in terms of poaching industry structure in Nepal, due to lack of data, it is not possible to estimate the harvest function derived from the oligopolistic formulation, such as the equation (3.14). Nevertheless, as discussed in the previous chapter, the poaching at the local level can be characterised as *de facto* open access, and using general functional relationships, a reduced-form poaching function for such scenario can be derived. This reduced-form model can then be estimated as an *ad hoc* model using available time-series data to explain the level of poaching of rhinos in RCNP over the years.

4.1 Reduced-form Poaching Model

Although the management of rhinos is under a state property rights regime, I assume that poachers act as if there is *de facto* open access governing their industry, since they operate outside legal property rights. A simple model for poaching industry profits under open access and the threat of capture and conviction might be:

$$\pi_t = p_t h(B_t, E_t, X_t) - \theta(B_t, E_t)[F_t + p_t h_t] - c(A_t)E_t \quad \text{.............................} (4.1)$$

where π is poaching profits; p is the gross price per poached animal product; $h(B, E, X)$ is the poaching harvest function; B is the anti-poaching efforts; E is poaching effort; X is the stock of the poached animal; $\theta(B, E)$ is the combined probability of detection, capture, and conviction, expressed as a function of poaching effort and anti-poaching enforcement effort; F is the fine upon conviction and/or proxy for the value of time, if incarcerated; and *c(A)* is the cost of poaching efforts, expressed as a function of alternative economic opportunities, *A*. Note that if captured the poacher must pay the fine plus forego the benefits of the animal products in his possession.

If open access profits are assumed to be zero in each time period (as a result of free entry and exit) then the equilibrium level of effort (E_t*) can be derived for each time period from equation (4.1). Given a set of parameters and observations on the variables in (4.1), we get:

$$E_t^* = f(B_t, X_t, A_t, F_t, p_t) \quad \text{.......} \quad (4.2)$$

Equation (4.2) defines poaching effort in terms of anti-poaching efforts, *B*; stock size, *X*; opportunity costs of poaching, *A*; fines imposed on poachers when captured and convicted, *F*; and price of the rhino horn, *p*. Substituting this equilibrium level of effort from equation (4.2) into the harvest function *h(B,E,X)*, a reduced-form poaching function can be obtained (Skonhoft and Solstad 1998). This reduced-form poaching function can be depicted as follows:

$$h_t^* = h^*(E_t^*, B_t, X_t) = h^*(f^*(B_t, X_t, A_t, F_t, p_t), B_t, X_t) = h^*(B_t, X_t, A_t, F_t, p_t) \quad \ldots (4.3)$$

Equation (4.3) shows that the reduced-form poaching can be depicted as a function of anti-poaching efforts, *B*; the rhino population, *X*; alternative economic opportunities, *A*; penalties when caught and convicted, *F*; and the price of rhino horn, *p*. It is possible to estimate (4.3) if sufficient data are available for all of the variables, as either an *ad hoc* model or by deriving a fully specified model from the general functions in (4.1). The above approach is just representative of many such approaches that could be taken to model the poaching problem. Nonetheless, the variables captured in the model cover the key economic determinants of poaching as hypothesised earlier, thereby allowing modelling of alternative policies for their impact on poaching. Given the data constraints, I estimate the reduced-form poaching function as shown in equation (4.3) as an *ad-hoc* model for the purpose of this study. The following section discusses data requirements for estimating this model, data availability and collection issues, and the model estimation.

4.2 Data Requirements and Availability

The primary data required for the analysis of the reduced form poaching function is the number of rhinoceros poached each for the period specified. The number of rhinos poached each year has been very well recorded since the establishment of RCNP, and was easily available from various previous studies (Martin and Vigne 1996; Maskey 1998; Dhakal 2002), and from DNPWC Annual Reports (DNPWC 2003, 2002, 2001, 2000, 1999). Other than the number of rhinoceros poached, an empirical estimation of the reduced-form poaching function specified above required data on (i) the stock size (i.e., rhino population), X, (ii) anti-poaching effort, B, (iii) opportunity costs of poaching, A, (iv) fines imposed on poachers when captured and convicted, F, and (v) the price of rhino horn, p. **Appendix 1** provides data used in the analyses with notes on the data sources.

4.2.1 Stock size, X

The data on Nepal's rhino population is highly discontinuous, for there have only been a couple of official censuses to determine the population, and demographic structure of the one-horned rhinoceros. Most of the earlier figures on population come from individual studies (for example, Laurie 1978) and tentative estimates. The first official census was carried out in 1994 and the second in 2000. Due to the unavailability of a complete set of time series data on the population of rhinoceros in RCNP, I use model estimates from Rothley et. al. (2004) covering the period of 1972-2003. This estimated population (**Appendix 1**) is used for modelling the reduced form poaching function. Since the population estimated by Rothley *et al.* (2004) provides end of the year estimates, I lagged this variable one period in the regression equation (which gives the start of the year estimate for the current year). This allowed me to capture the exploitable stock size for a given year. This variable is expected to have a positive effect on poaching, as a higher population allows the poachers to find and kill rhinos with less effort.

4.2.2 Anti-poaching effort, *B*

It is very difficult to actually measure anti-poaching efforts in RCNP and within the Chitwan Valley, due to various anti-poaching structures in place inside and outside the park. For example, the RNA only patrol inside the park, whereas APUs patrol both inside and outside the park, and forest guards patrol in the adjoining forests. Moreover, the recorded information on anti-poaching efforts is almost non-existent. The information on the number of RNA staff stationed within the park and their patrolling efforts was unavailable due to security reasons (given the highly unstable and sensitive political situation in the country in recent years). The only information on anti-poaching available through DNPWC Annual Reports and WWF reports was on the number of APUs active within the Chitwan Valley since they were established in 1993 (**Appendix 1**). The RNA has been stationed in the park since 1975, so using a dummy for that variable would not make sense; there would be only two previous years when it would be zero. Thus the number of APUs active during a year is used to capture anti-poaching effort within RCNP and in the Chitwan Valley in general. This variable is expected to have a negative effect on poaching, as it has a deterrent effect on poachers.

4.2.3 Opportunity costs of poaching, *A*

The opportunity costs of poaching for a region could be captured by using an economic indicator, such as per capita GDP, for that region. However, there was no long term data available for regional economic indicators of such kind. Another alternative would have been to use the local/regional wage for unskilled workers to capture the opportunity cost of poaching; however, any record of such local/regional wage for unskilled workers for the period of 30 years necessary for the analysis was also not available. Since the socio-economic structure of the Chitwan Valley very much mirrors the national socio-economic structure, I used the national per capita GDP (**Appendix 1**) to capture the opportunity costs of poaching. Furthermore, it has been reported that some of the poachers actually come from outside the Chitwan Valley, so national per capita GDP in general should be a good indicator of the opportunity costs of poaching. This variable is expected to have a negative effect on poaching, as the higher the opportunity costs of poaching, the more likely it is that the poachers will be attracted to alternative economic activities rather than to poaching.

4.2.4 Fines imposed on poachers when captured and convicted, *F*

Over the years, there have been only two levels of fines and jail terms for convicted poachers. The current law on the penalty for convicted poachers states that the maximum penalty for a convicted poacher is 15 years in jail or a Rs 100,000 fine, or both. However, a study on earlier convictions reveals that hardly any prisoners served more than 4-5 years in jail and that judges seem to impose fines rather than prison sentences. Furthermore, most of the poachers in prison are those who could not pay the fines and/or default on them. As discussed earlier (in Chapter 2, Section 2.2.2), translating prison sentences into equivalent fines is very complex. Given this complexity and the fact that fines were more frequently imposed than jail terms for convicted poachers in Nepal, I use just the fines portion of the penalties for the purpose of this analysis. Since the data on actual fines imposed on convicted poachers over the years was not available, I use the level of maximum fines set by the law in real terms for the analyses (**Appendix 1**). This variable is expected to have a negative effect on poaching due to the deterrence effect penalties have on poaching.

4.2.5 Price of horn, *p*

Data on the international price of rhino horn is very difficult to find, mainly because this trade has been banned since the early 1970s. There have been various attempts to compile price of horns on the black market, such as by Martin (1983, 1987, 1989) and Leader-Williams (1992), but the data are too few and far between. To get around this problem, I follow a similar approach to that by Milner-Gulland (1993), where she used GNP per capita to estimate the demand for rhino horn in Japan. She found that the demand for rhino horn in Japan was mainly income-driven, and that the demand for horn was likely to have increased as the per capita GNP in Japan continued to increase beyond 1980 (the final year in her analysis). East Asian countries, such as Korea, Japan, China, Taiwan, and Hong Kong are major consumers of rhino horns (and the products derived from the horns, such as traditional medicine) (Leader-Williams 1992; Mills 1993, 1997; Nowell *et al.* 1992). Thus, demand for the horns in this region is likely to affect the level of poaching by increasing the international market price. Almost all the horns from Indian rhinoceros poached in India and Nepal go to East Asia via Kathmandu, and the first entry point into this market is Hong Kong. Following Milner-Gulland (1993), I assume that the demand for rhino horn and products derived from the horns in this region is primarily income-driven. Hence, as people get richer in this region, their overall demand for rhino horn increases, and hence the price goes up. This would increase the incentives to poach the Indian rhinoceros, potentially increasing the level of poaching. Under this assumption, I use per capita GDP for East Asia (in constant 1990 prices), lagged by a year, as a proxy for the price of rhino horn (**Appendix 1**). This variable is expected to have a positive effect on the level of poaching in RCNP.

4.2.6 Political Instability

Some recent studies on the status of the one-horned rhinoceros and problems of poaching in Nepal have suggested that the ongoing Maoist insurgency in the country is having a negative impact on rhino conservation. A significant reduction in the number of RNA guard posts in RCNP (due to the Maoist problem) is considered a major factor behind the high poaching levels of recent years (Yonzon 2002; Martin 2004). To account for this factor, I introduce a dummy variable, MAOIST, in the data, which equals 0 up to the year 1996 (when the insurgency started) and 1 from the year 1997 onwards (**Appendix 1**). This variable is expected to have a positive effect on the level of poaching in RCNP.

The codes and descriptions of the variables used in the model are presented in **Table 4-1**, and the frequency distribution and descriptive statistics for the dependent variable are presented in **Table 4-2** and **Table 4-3** respectively. Full time series data used for the analyses is presented in **Appendix 1**.

Table 4-1 Variables used in the estimation of reduced form poaching function

Variable Code	*Definition*
Dependent Variable:	
POACH_NP	Number of rhinoceros poached during the year inside RCNP
Independent Variables:	
POPN	The population of rhinoceros inside RCNP at the end of the year
REAL_PEN	The penalty imposed for convicted poachers in real terms
APU	The number of anti-poaching units active during the year
GDPC_NEP	Per capita GDP of Nepal in constant 1990 prices
GDPC_EA	Per capita GDP for East Asia in constant 1990 prices
MAOIST	Dummy variable that equals to 0 up to year 1996 and 1 for the year 1997 onwards (to account for the effect of Maoist insurgency in poaching)

Table 4-2 Frequency Distribution for the number of rhinos poached inside RCNP from 1973-2003

Number of rhinoceros poached	*Frequency*	*Percent*	*Cumulative percent*
0	10	32.3	32.3
1	6	19.4	51.6
2	3	9.7	61.3
3	3	9.7	71.0
4	1	3.2	74.2
5	1	3.2	77.4
6	1	3.2	80.6
9	1	3.2	83.9
12	1	3.2	87.1
15	1	3.2	90.3
17	1	3.2	93.5
19	1	3.2	96.8
37	1	3.2	100.0
Total	**31**	**100.0**	

Table 4-3 Descriptive Statistics for the number of rhinos poached inside RCNP from 1973-2003

N	*Minimum*	*Maximum*	*Mean*	*Std. Deviation*	*Variance*
31	0	37	4.68	7.985	63.759

4.3 Estimation Procedure

The regression model for estimating the reduced form poaching function depends on the characteristics of the data at hand. The number of rhinos poached over the years (the dependent variable) is count data ranging from 0 to 37 (**Table 4-2**), which cannot be negative; this means OLS regression is not suitable for the estimation of the reduced form poaching function. Instead, I use the Poisson regression technique, which is commonly used for count data models.[16] The density function of a discrete random variable, Y, with a Poisson distribution is

$$\Pr[Y = y] = \frac{e^{-\mu}\mu^{y}}{y!}, \; y = 0, 1, 2, \ldots$$

The Poisson distribution has a single parameter, μ, where $E[Y] = V[Y] = \mu$. Given these characteristics of the distribution, a Poisson regression function is specified as:

$$\mu_i = \exp(\mathbf{x}_i'\beta), \text{ so that } \mu > 0.$$

Thus, a Poisson regression is a log-linear regression model where, by assumption, the conditional mean $E[y_i \mid \mathbf{x}_i]$ is equal to the conditional variance $V[y_i \mid \mathbf{x}_i]$. This assumption of mean being equal to variance rarely holds in practice, as can be seen from the descriptive statistics for the dependent variable POACH_NP in **Table 4-3**. The variance is more than thirteen times the mean of the variable. When the conditional variance is greater than the conditional mean, this is called "overdispersion". The overdispersion in a Poisson regression model has similar consequences as heteroskedasticity in the linear regression model (Cameron and Trivedi 1990). Thus, in a correctly specified regression function, although the parameter estimates would be consistent, the estimates of variances for the estimated parameters would be inconsistent, and hence the hypothesis tests will be invalid. The presence of overdispersion in a Poisson regression

[16] Cameron and Trivedi (1998) provide one of the most comprehensive accounts of models and methods to analyse/interpret count data.

model can be tested using a number of techniques.[17] The LIMDEP 7.0 econometric package (Econometric Software 2002), which was used to estimate the reduced-form poaching function for this analysis, automatically provides statistics for the regression-based overdispersion tests.[18] This package was used to test for overdispersion in the regression model and to consider alternative regression models. The alternative to the Poisson regression model that relaxes the assumption of equality in mean and variance is the Negative Binomial model. Both the Poisson and Negative Binomial models were estimated and the most suitable model was selected after (i) tests for overdispersion, and (ii) tests for the model itself against the alternative. The results are presented in the following chapter.

[17] Greene (2003 pp. 743-44) describes (i) regression-based test, (ii) conditional moment test, and (iii) Lagrange multiplier test as the three common tests for overdispersion.
[18] See Greene (1998, 2003) for details on regression-based overdispersion tests.

CHAPTER 5 RESULTS AND DISCUSSION

5.1 Results

The reduced-form model was estimated including all the explanatory variables that were thought to influence the number of rhinoceros poached in RCNP. The results are presented in **Table 5-1**, where column 3 provides the estimation results from the Poisson model, and column 4 provides the estimation results from the Negative Binomial model. Coefficients on all the explanatory variables in the Poisson model have expected signs. However, the coefficient on fines in real terms, REAL_PEN, is highly insignificant, along with the coefficient on real per capita GDP for East Asia lagged by a time period (GDPC_EA[-1]). Overdispersion test obtained from LIMDEP 7.0 for the Poisson model (i.e., $g = u(i)$: 2.077) indicates the presence of overdispersion in the dependent variable (POACH_NP). The Negative Binomial model (column 4) was estimated to take into account the presence of overdispersion. Since the estimation of the Negative Binomial model in LIMDEP 7.0 presented a convergence problem,[19] the overdispersion parameter, α, was fixed at 0.2 to estimate the model. The results from the Negative Binomial model estimation show an overall improvement in the estimated coefficients and their significance; however, the coefficient on REAL_PEN is still highly insignificant. The likelihood-ratio test for the Poisson model vs Negative Binomial model gives a Chi-squared value of 12.93,[20] which is higher than the critical value of 6.63 at 1% with 1 degree of freedom. Thus, the Negative Binomial model is preferred over the Poisson model (i.e., the restricted model).

[19] See Greene (1998) pp. 613 – 614 for details.
[20] $LR = -2*[\text{Log L}_{\text{Poisson}} - \text{Log L}_{\text{Negative Binomial}}] = -2*[-71.555 - (-65.0863)] = 12.93$

Table 5-1 Estimates from Poisson and Negative Binomial regressions

Explanatory Variables	*Mean (Std. Dev.)*	*Poisson Model*		*Negative Binomial Model*		*Expected Sign*
		Coefficient (Std. Error)	*P-value*	*Coefficient (Std. Error)*	*P-value*	
Constant		-1.4093 (3.6401)	0.6986	0.4501 (2.6990)	0.8676	
POPN[-1]	385.35 (91.758)	0.0209 (0.0092)	0.0232	0.0189 (0.0098)	0.0536	+
APU	1.8387 (3.1101)	-0.1986 (0.0343)	0.0000	-0.2130 (0.0578)	0.0002	-
REAL_PEN	934.2333 (397.1678)	-0.0001 (0.0006)	0.8033	-0.0002 (0.0006)	0.7038	-
GDPC_NEP	166.8709 (43.424)	-0.0413 (0.0171)	0.0157	-0.0526 (0.0173)	0.0025	-
GDPC_EA[-1]	2502.4516 (1509.5733)	0.0004 (0.0005)	0.4036	0.0007 (0.0004)	0.1018	+
MAOIST	0.2258 (0.425)	1.8768 (0.5659)	0.0009	2.3371 (0.5823)	0.0001	+
α				0.2	(Fixed Parameter)	
R^2_P		0.7966				
Log L		-71.555		-65.0863		
Overdispersion Test:		$g = \mu(i)$: 2.077				

The estimation results from the Negative Binomial model (**Table 5-1, Column 4**) show that the coefficients on APU, real per capita GDP for Nepal (GDPC_NEP), and the dummy for Maoist insurgency affected years (MAOIST) are all significant at 1%. Coefficient on the start-of-the-year rhino population (POPN[-1]) is significant at 10% (*p-value = 0.0536*). Although the coefficient on REAL_PEN stays highly insignificant (*p-value* = 0.7038) in the Negative Binomial model, there is a significant improvement in the significance of the coefficient on the real per capita GDP for East Asia (*p-value = 0.1018*). Furthermore, looking at the economic significance, the results show that a hundred dollars increase (about 4% increase with respect to the mean) in real per capita GDP for East Asia increases poaching by about seven percent, other variables staying the same.

The coefficient on the population of rhino at the beginning of the year (POPN[-1]) shows that an increase in population of rhino in RCNP by one animal is likely to increase poaching by about 2 percent, all else being equal. On the other hand, an increase in the APU by one unit provides an estimated reduction in the level of poaching by about 21 percent, all else being equal. Similarly, the estimated coefficient on real per capita GDP of Nepal (GDPC_NEP) reveals that a one unit increase in this variable is likely to reduce the level of poaching by about five percent, all else being equal. Finally, the coefficient on the dummy variable capturing the effects of the Maoist insurgency (MAOIST) shows that the poaching of rhino in RCNP after the insurgency (i.e., post-1996) is higher by about 9 animals on average per year, compared to the level of poaching before the insurgency (i.e., pre-1996).

Figure 5-1 shows the observed level of poaching and the predicted values from the Negative Binomial model. The predicted values follow the observed value very closely for most of the years, including the year 2002 and 2003, when 37 and 19 rhinos were poached respectively. The observed level of poaching, and the predicted values from the Negative Binomial model are presented in **Appendix 2**.

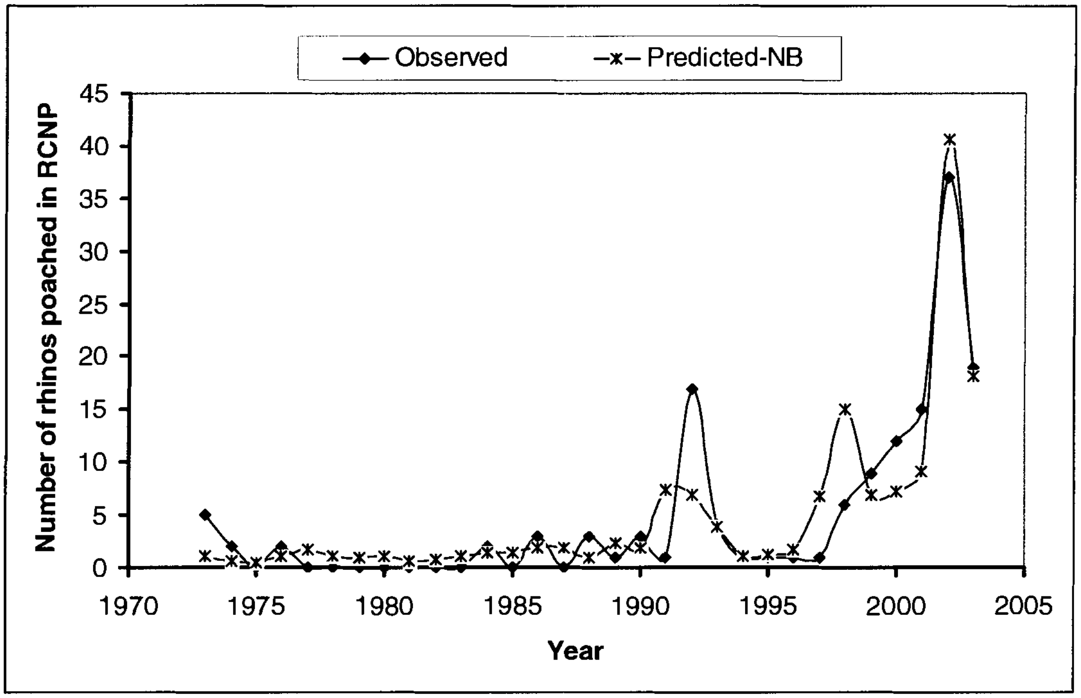

Figure 5-1 Observed poaching figures and predicted values from the estimation of reduced form poaching function

5.2 Discussion

Although the reduced-form poaching function is estimated only as an *ad hoc* model, it provides an important insight into the factors that are hypothesized to affect the levels of poaching in RCNP. Of the main factors considered, the penalty measured in real terms (REAL_PEN) remained highly insignificant in both the Poisson and Negative Binomial models. It is worth noting at this point that the level of penalty over the years has been fixed at two (nominal) levels. Thus, the penalty in real terms, which was used for the estimation, over the years has been decreasing significantly; and this could have resulted in reduced influence of this variable on the level of poaching. Furthermore, the reduced impact of this variable as shown by the model estimation could also be due to the fact that this variable only partially captures the penalties levied on convicted poachers, as the data on prison terms for the convicted poachers was unavailable, and hence could not be included in the estimation. Nevertheless, as the coefficient on REAL_PEN in the estimation stays highly insignificant in both models (i.e., Poisson and Negative Binomial), it can be argued that the level of fines has not been very effective in reducing poaching in RCNP. An alternative model was estimated dropping this variable from the original model, however, dropping this variable did not improve the model estimation (see **Appendix 3**).

The other factor that remained insignificant in both the Poisson and Negative Binomial models (although improved significantly in the Negative Binomial model compared to the Poisson model) was the lagged real per capita GDP for East Asia (GDPC_EA[-1]). This variable was included in the estimation as a proxy for price of rhino horn on international markets. Since the data on price of rhino horn over the period required for this estimation is almost non-existent, the only way to capture the influence of price on the level of poaching is by using alternative variables like GDPC_EA[-1] as proxy variables. The selection of this variable followed from the fact that East Asia is the major consumer of the rhino horns and horn-derived products. The demand for rhino horn (an expensive commodity), depends on the level of income in this region, thereby determining the price. The sign on the coefficient of this variable stayed positive over all the estimations, which shows the consistency of its effect on the dependent variable. Furthermore, the coefficient on this variable estimated with the Negative Binomial model was just on the borderline of 10% significance level, which for the model with only 31 observation points can be considered relatively significant.

Owing to the insignificant coefficient on the real per capita GDP for East Asia as a proxy for price of the horn, an alternative model using the real per capita GDP for Hong Kong lagged by a year (GDPC_HK[-1]) was also estimated to check if this could be a better proxy for the price of rhino horn. The use of per capita GDP for Hong Kong followed from the fact that it is the first international port for the trade of horns from the one-horned rhinoceros, as well as a significant consumer itself. However, the results from the estimation of this alternative model did not show any improvement over the original model (see **Appendix 4**). Thus, the original model that used the real per capita GDP for East Asia as a proxy for the price of rhino horn was retained for making inferences from the results. The scope of this study did not allow to explore other variables as proxy for the price of rhino horn; however, this could be an area of further exploration, helping to provide better estimates of the reduced form poaching function.

The population of rhino at the beginning of the year (POPN[-1]) provides the exploitable population for the poachers. As the rhino population in RCNP has been increasing ever since the establishment of the park, the poachers have higher numbers to poach from every year. However, the objective of the park authority is to have even higher levels of rhinoceros in the park. Thus, focus should be on other factors that increase or decrease the level of poaching within the park rather than the population, which, if increased, obviously helps poachers find the rhinos more easily, other factors remaining unchanged. One of the most important factors that influence poaching, both by local poachers and the organised gangs, is the level of anti-poaching efforts. The number of anti-poaching units active during the year was used to capture the level of anti-poaching efforts in estimation of the reduced form model. Although this variable represents only the partial anti-poaching efforts (the other part being the involvement of the RNA), it has a consistently negative and highly significant (statistical as well as economic) effect on the level of poaching in RCNP, indicating the importance of the APUs in rhino conservation.

It is possible that the impact of the APUs might have been overestimated in the model as it is the only variable used to capture anti-poaching efforts. The models estimated use the number of APUs involved in the anti-poaching activities to capture the anti-poaching efforts. It is worth noting that the other major part of the anti-poaching setup in RCNP, the number of RNA personnel and the guard posts, was relatively constant over much of the period analysed. This lack of variation could have reduced the potential impact that RNA might have on reducing the level of poaching in RCNP. Hence, it might not have made much difference in the estimated results had this variable been available and used in the estimation. A better measure of the anti-poaching efforts would have been the number of patrols by the APUs and RNA. This information could not be obtained and hence could not be used for the estimation. The availability of data such as this is likely to improve the estimation of the models considered.

The availability of alternative opportunities was captured by the real per capita GDP for Nepal (GDPC_NEP) in the model, as the local and regional economic indicators required for the estimation were unavailable. This factor also showed a consistent negative and highly significant effect on the level of poaching in RCNP, which indicates the importance of alternative economic opportunities in reducing the level of poaching. Furthermore, if local or regional economic indicators had been available and used for the analysis, they likely would have provided even better estimates of the influence of alternative economic opportunities on the level of poaching in RCNP, as the local economic indicators are more likely to capture local economic opportunities than the national economic indicators. Nevertheless, from the results obtained by using national per capita GDP, it is clear that economic opportunities elsewhere do affect the level of poaching in RCNP.

The ongoing Maoist insurgency in Nepal has been considered a major factor affecting poaching in RCNP in recent years (Yonzon 2002). This has especially affected the level of anti-poaching enforcement by the RNA stationed inside the park. The results from this analysis provide strong evidence that this factor has indeed affected the level of poaching in recent years. The estimation from the final model (Negative Binomial model) suggests that the level of poaching increased by nearly nine rhinoceros a year more during the years of the Maoist uprising, compared to the years before the uprising. This is a significant figure, given that the estimated rhino population in RCNP is less than 500 at present (Rothley *et al.* 2004). However, it has to be clarified that this study did not look into whether the Maoist rebels were themselves involved in the poaching. The only conclusion that can be drawn from the analysis is that the Maoist uprising has helped in poaching indirectly by making the anti-poaching efforts less effective, and by creating a climate of instability. This reflects the importance of political stability in biodiversity conservation, especially in the conservation of highly valuable species like the one-horned rhinoceros.

CHAPTER 6 POLICY IMPLICATIONS

6.1 Policy Implications

This analysis of the historic levels of poaching of the one-horned Indian rhinoceros in Nepal has provided valuable insights into the factors that have affected the level of poaching in RCNP over the years. Although factors like the international price of rhino horn cannot be affected by policies at the national level, there are a number of factors that can be influenced by national policy initiatives in order to help reduce the level of poaching in RCNP in years to come. The analysis presented in earlier chapters indicates that some of the policy-related factors, such as anti-poaching efforts, have significantly influenced the level of poaching in the past, while other factors, such as penalties, have not. In this chapter, I discuss the implications of these analyses for policies to reduce the level of poaching of the one-horned rhinoceros in RCNP, and in Nepal as a whole.

6.1.1 Anti –poaching Enforcement

Anti-poaching enforcement has been the single most important policy instrument used to control poaching ever since the establishment of RCNP. The anti-poaching setup in RCNP (and in the Chitwan Valley) can be termed 'varying' at best. The jurisdiction for protecting the park and the biodiversity within it has been divided among various authorities, and it has been changing, ever since the park's establishment. These changing enforcement policies and the anti-poaching efforts made it difficult to capture all aspects of this policy instrument in the analyses; however, the results based on the number of APUs as a variable to capture the effects of anti-poaching efforts imply a significant influence in reducing the level of poaching in RCNP. The APUs included in the analyses had specific organisational and operational structures. Each APU included a number of game scouts from the park and some informants from the local communities. These APUs were allowed to operate both inside and outside the park – mainly patrolling in and around the park and gathering information from the surrounding communities (Martin and Vigne 1996; Martin 1998; Maskey 1998; Adhikari 2002). This setup seems to have made these units very effective in deterring poachers and poaching activities, as the analyses suggest there could be an estimated reduction in poaching per year by about 21% for every additional APU deployed for the anti-poaching enforcement.

Although the RNA has been stationed inside the park since 1975, they are only allowed to patrol within the park boundary. Thus, patrolling operation of the RNA depends crucially on the information provided to them by the park authorities if they are to effectively patrol the park area, especially the areas that are most likely to be targeted by the poachers. These information regarding poachers and their poaching activities came from the APUs due to their information gathering operations. This complementary anti-poaching setup seemed successful in controlling rhino poaching in RCNP during much of the mid 1990s; and APUs have been credited for much of this success – especially for their intelligence/information gathering system based on local informants (see for example, Martin 1996; Martin and Vigne 1996; Martin 1998; Adhikari 2002). However, the poaching increased significantly from 1998. Martin (2001) points out the lack of coordination among anti-poaching enforcement authorities, especially due to ineffective management and supervision by the park warden at the time, as the main reason for this increase in poaching in the Chitwan Valley from mid-1998 to mid-2000.

The poaching in the Chitwan Valley worsened during 2002 and 2003 after the APU structure in RCNP was changed in 2001. The new organisational structure of the APU does not include local informants that were vital in intelligence operations in the communities surrounding RCNP and in gathering information about poachers and poaching activities (Adhikari 2002). Adhikari (2002) further points out that the removal of the local informants from the organisational structure of the APU weakened the anti-poaching operations, allowing poachers to operate easily from the communities surrounding RCNP. In line with the argument presented by Adhikari (2002), this analysis provides strong evidence in favour of a continued involvement of the APUs in combating poaching in RCNP in their original organisational and operational structures.

Another major change in the anti-poaching enforcement in RCNP after 2001 concerned the organisational and operational structures of the RNA stationed inside the park. After the deployment of the RNA to curb the Maoist insurgency elsewhere in the country, a number of small guard posts located at various parts of RCNP became increasingly susceptible to Maoist reprisals. This led to a consolidation of these smaller posts into larger units – all in all, 34 posts were reduced to just 8 larger posts (HMGN/DNPWC 2003a). In addition, Martin (2004) points out that patrolling by the RNA has been confined to small areas around these posts due to fear of Maoist attacks. This has reduced the effective coverage of the RNA patrols, thereby making it easier for the poachers to operate in the Chitwan Valley. This change, combined with the restructured APUs, has led to an alarming increase in poaching (Adhikari 2002; Martin 2004).

Meanwhile, the failure to control poaching in RCNP after 2001 led to a number of changes in the anti-poaching strategies. Recent reports by the DNPWC, such as the Greater One-horned Rhinoceros Conservation Action Plan (HMGN/DNPWC 2003b), and the Anti-poaching Strategy for RCNP (HMGN/DNPWC 2003a) highlight those changes. These reports also layout the plans for future conservation/anti-poaching strategies. Both these documents highlight the need to strengthen the anti-poaching capabilities through various measures. The Rhino Conservation Action Plan focuses on legislative measures to strengthen anti-poaching capabilities, such as by bringing into force the CITES bill; whereas, the Anti-poaching Strategy for RCNP focuses strictly on increasing anti-poaching capacity at the field level, such as by providing better resources to the APUs. A recent change in the anti-poaching patrol strategy has lead to a different form of patrol, termed the 'sweeping operation'. In a sweeping operation, instead of the APUs and the RNA patrolling specific areas of the park, all the resources are consolidated to create a large patrolling unit and anti-poaching patrols are conducted in suspected areas, often using elephants (HMGN/DNPWC 2003a; Martin 2004). This has reportedly led to a successful control in poaching from mid 2003 onwards; however, the long term effectiveness of this strategy is yet to be analysed.

In light of these developments, it seems that policies to control poaching in RCNP should focus on strengthening the APUs, and not weakening them. As suggested by this study, APUs have been highly influential in reducing the level of poaching in RCNP ever since their establishment. Similar suggestions have been made by a number of other studies on rhino conservation issues in Nepal (for example, Martin and Vigne 1996; Martin 2001, 2004; Adhikari 2002). The issues regarding the Maoist insurgency is a national issue, which the park authorities will not be able control or mitigate. However, they can adapt to the changed circumstance and focus on making other parts of the anti-poaching setup efficient to compensate for the reduced RNA activities. The obvious point to start would be by focussing on making the APUs effective as shown by this study.

6.1.2 Penalties

Penalties levied on the poachers captured and convicted of poaching is another policy instrument that has been used as a deterrent to poaching in Nepal. However, results from this study indicate that level of fines set for the convicted poachers does not significantly influence the level of poaching. The poachers in Nepal are fined a fixed amount if convicted, and this fixed level of fine has only been changed once since the establishment of RCNP (see Chapter 2). In light of this issue, the fine in real terms was used to capture the effects of this variable on the poaching, the results from which revealed that the level of fines has not significantly affected the level of rhino poaching in RCNP over the years. As discussed earlier (Chapter 2, Section 2.2), the level of penalties is generally thought to be a deterrent to poachers in terms of entering into poaching activities, but does not necessarily affect the level of poaching *per se*. In fact, a number of scholars argue that it might actually increase the level of poaching from the poachers that are already involved in poaching (Clarke *et al.* 1993). Whether the fixed level of fines have helped increase the level of poaching in Nepal could not be verified; however, it is clear from the analysis that the fixed level of fines set for convicted poachers has not been effective in reducing the level of poaching in RCNP.

Similar findings have been reported elsewhere, where the penalties have not been as effective in deterring the poachers and reducing the levels of poaching; whereas a higher probability of detection due to effective anti-poaching enforcement have been found to be more successful in deterring the poachers (Milner-Gulland and Leader-Williams 1992a; Leader-Williams and Milner-Gulland 1993). These studies have suggested that a variable penalty – rather than a fixed one – that varies with the level of output (i.e., the number of rhinos poached) could be more effective in deterring poachers (*ibid*). Furthermore, the ineffectiveness of the fines in influencing the level of poaching in Nepal could be due to the fact that a number of convicted poachers in the past are reported to have been given less severe sentences than they would have received according to the country's wildlife laws, a problem pointed out by Gurung and Guragain (2000). The evidence from this study, along with similar findings from other studies suggest that the policy regarding the penalty structure for the convicted poachers in Nepal is not effective in reducing poaching as it stands now. However, this study cannot make firm recommendations regarding whether a variable penalty structure would be more effective in controlling poaching in RCNP, for it requires a thorough analysis of the effects of variable penalty structure on the level of poaching in RCNP, and the data on variable penalty was not available to perform such analysis.

6.1.3 Alternative Economic Opportunities

Availability of alternative economic opportunities could be considered as the (opportunity) cost of poaching. As the economic opportunities elsewhere increase, poachers are expected to switch from risky poaching activities to alternative means of income. The results from this study have revealed a strong and consistently negative effect of this variable on the level of poaching in RCNP, indicating that a better prospect of alternative income opportunities could help reduce the level of poaching in RCNP significantly. This is especially important in deterring local poachers in the Chitwan Valley from poaching, as they are found to come from very poor and landless groups (Gurung and Guragain 2000). These alternative economic opportunities could take various forms, such as direct employment opportunities in the park or in the tourism sector in and around the park or any other income generating schemes at the local level, all of which provide an incentive to the poachers not to poach. In addition to creating alternative economic opportunities, incentives could be provided at the community level through community development programmes that could help gain community level support in reducing poaching. Indeed, a number of policy measures have been conceived and implemented in this respect in recent years. The revenue sharing mechanism with the buffer zone communities around RCNP is one such policy measure.

A number of earlier studies have also suggested that creating economic opportunities at the local level and providing incentives to the communities through community development initiatives could help reduce poaching (for example, Milner-Gulland and Leader-Williams 1992b; Leader-Williams and Milner-Gulland 1993; Martin 1998, 2004). Martin (1998) has suggested that the low levels of poaching in the Chitwan Valley between the years 1994 and 1997 could be due to the community development projects initiated around RCNP during that period, as well as local employment/income opportunities in the tourism sector (such as in Baghmara Community Forest in RCNP buffer zone). However, as Bookbinder *et al.* (1998) have suggested, a large number of jobs in the tourism sector in RCNP have been taken up by the outsiders reducing the opportunities for locals. This could increase the resentment, especially among the poorer households, towards the park and encourage them to enter into poaching. Thus, it is imperative not only to create opportunities in and around the park, but to create those for local people. Milner-Gulland and Leader-Williams (1992a, 1993), whose studies focused on Africa, report similar findings. They report a reduced level of poaching by the local poachers where (i) community development activities were initiated, and (ii) a greater number of jobs were provided for the locals in the tourism sector.

It is worth noting that a recent anti-poaching strategy document from the DNPWC has laid out strategies which aim to increase community participation to combat poaching through a series of measures, such as the formation of community-based APUs and a compensation scheme for human casualties from wildlife attacks etc. (HMGN/DNPWC 2003a). However, it does not go as far as creating other forms of economic incentives at the local level to deter poachers from poaching. Nevertheless, it is clear that the park authorities have come to realise the importance of the creation of economic opportunities at the local level, and the provision of incentives to the local communities and individuals so as to obtain support for the anti-poaching programs, and to deter poachers from poaching. The findings from this study, along with the findings from other earlier studies provide evidence towards this end and further emphasize the need for the creation of alternative economic opportunities locally.

6.2 Future Research

This study, as would any other studies involving analysis of a large amount of time series data, faced a number of limitations. Most of these limitations related to the availability of data required and suitability of the data available, as the analyses intended for this study relied entirely on the data acquired from secondary sources. This limited availability of data affected this study at two levels. Firstly, although theoretical models, such as oligopolistic poaching industry structure, could be developed, these models could not be estimated empirically due to data unavailability. Secondly, in the *ad hoc* model based upon the reduced-form poaching function that was estimated empirically, data on a number of variables were unavailable. This meant that proxy variables had to be used for some variables, such as the use of real per capita GDP for East Asia as a proxy for the international market price of the rhino horns; whereas, in some cases, less information had to be used, such as the use of only the number of APUs to represent anti-poaching efforts by dropping the anti-poaching efforts by the RNA, and the use of penalties based on fines only by dropping the prison sentences. These data limitations have certainly affected the level of analyses that could have been performed had the data been available; however, this study has analysed the available data rigorously before presenting the results and reaching its conclusions.

Alternatively, the limitations explained above have presented clear opportunities for further research on this important issue in the future. This research, in many ways, could be considered as an entry point for similar and more complex research on the issue of poaching in Nepal, for there have not been previous studies like this that have looked at poaching in Nepal from an economic perspective and have tried to model the level of poaching based on the socio-economic factors that could have affected poaching for the past few decades. Furthermore, there is a potential for the retrieval of data/information on a number of variables, such as anti-poaching efforts by the RNA and the level of penalties imposed on convicted poachers, when the political and security situation improves in the country. Increased availability of data in the future would create opportunities for further analyses of this issue in light of those additional data. Moreover, empirical analysis that could not be performed at present due to data limitations, such as the estimation of poaching functions under oligopoly conditions, could potentially be performed when the data become available.

Another area of future research could be to link the poaching model developed in this study with the population dynamics model, such as that developed by Rothley *et al.* (2004). Such a study would allow for dynamic analysis of the effects of poaching on the rhino population. These effects of poaching on the population could be simulated for different policy scenarios to help formulate better policies to control poaching and better conserve the one-horned rhinos in RCNP and elsewhere in Nepal. Finally, advancements in the methodological and empirical analysis in economic research has been one of the most important aspects of research in this field during the last few decades, especially due to rapid advancements in computer technologies allowing for the estimation of advanced models in a short period of time. Furthermore, interdisciplinary and multidisciplinary research have been gaining increasing acceptance in the mainstream. These trends could create further research opportunities in the future on this issue, such as the integration of spatial aspects of the problem – for example, location of poaching sites in the park, rhino population hot spots etc. – in the model through GIS techniques. All of these advancements in research could greatly assist in better policy formulation in the future to help control poaching and preserve rhinos.

CHAPTER 7 CONCLUSIONS

This study looked into one of the widely discussed issues in biodiversity conservation in Nepal – the problem of rhino poaching – and did so from a different perspective. Unlike any of the preceding studies, this study tried to empirically estimate the level of poaching in the Royal Chitwan National Park (RCNP) using econometric models, considering the factors that were thought to influence the level of poaching. Although the conservation of rhinoceros in Nepal, mainly in RCNP, has been considered exemplary, poaching has always been a serious problem; and especially so in recent years where more than 100 rhinos are recorded to have been poached since 1998. Given the fact that the largest share of the park budget and resources in RCNP are devoted to rhino conservation and that the one-horned rhino is an endangered species, it is important to understand the reasons behind the increasing levels of poaching. Understanding these reasons could subsequently help the authorities formulate effective policies and make better decisions with regard to rhino conservation in the park.

The main objective of this study was to assess the levels of poaching in RCNP since its establishment in 1973 within the context of theories about the motivations for poaching i.e., incentives to poach. It tried to do so by estimating a reduced-form poaching function that explained poaching in terms of a number of factors, such as anti-poaching efforts, penalties, price of horn etc., that are thought to influence the level of poaching in RCNP. On a more theoretical side, this study tried to model the poaching industry structure in Nepal as an oligopoly, where a few large traders operated at the top level and large number of independent poachers operated at the lower level. Although the oligopolistic industry structure is thought to represent the true nature of the poaching industry in Nepal, empirical estimation of the poaching functions to that respect was not possible due to data limitations. Thus, this study relied on the empirical estimation of an *ad hoc* model representing the reduced-form poaching function under open access conditions. Nevertheless, results from the estimation of this *ad hoc* model provide ample evidence of the impacts of various socio-economic factors on the level of poaching of the one-horned rhinoceros in RCNP.

In order to empirically estimate the reduced-form poaching function, Poisson and Negative Binomial models – forms of count data regression methods – were used. This was due to the fact that the dependent variable, the number of rhinos poached each year in RCNP, is count data. The explanatory variables were – (i) the population of rhinos in the park at the beginning of the year, (ii) number of anti-poaching units active in the park, (iii) the level of fines in real terms imposed on convicted poachers, (iv) real per capita GDP for Nepal, (v) real per capita GDP for East Asia, and (vi) a dummy variable to indicate the years of the Maoist insurgency in Nepal. Coefficients on all of the explanatory variables had expected signs; and of those all except the level of fines and per capita GDP of East Asia were highly significant.

Apart from the impacts of anti-poaching efforts, the results from the empirical estimation highlighted the importance of socio-economic factors, such as alternative economic opportunities (measured by the national per capita GDP in real terms), and political situation of the country (indicated by the Maoist insurgency years), in influencing the level of poaching in RCNP. The results indicated that anti-poaching units have been highly influential in reducing the levels of poaching since they were formed in 1993; these results support the stance of a number of earlier studies on rhino poaching in RCNP. On the contrary, the level of fines was found to have an insignificant impact on the level of poaching in RCNP, indicating that the level of fines imposed on convicted poachers might have been ineffective in reducing poaching of the one-horned rhinoceros in RCNP over the years. Although this study could not assess the impact of variable fines on the level of poaching due to data limitations, a number of earlier studies have suggested that variable fines might be more effective in deterring poachers than the fixed fines.

Another factor that the results indicated to have significant effect in reducing the level of rhino poaching is alternative economic opportunities, measured by real per capita GDP for Nepal. Again, these results support a number of earlier studies that the creation of jobs and other forms of alternative economic opportunities at the local level can help reduce poaching – either directly by deterring the poachers, or indirectly by gaining co-operation of the local communities in anti-poaching operations. Finally, the results show that the Maoist insurgency has had a significant impact in increasing the level of poaching in recent years. This has come about mainly due to the fact that the insurgency has severely affected the anti-poaching operations of the RNA. There was no proof, however, of the direct involvement of the Maoists in poaching activities.

This study has indicated that the level of poaching of the one-horned rhinoceros can be estimated empirically using econometric models, given the data availability. Such estimations can provide important information regarding the impacts of anti-poaching efforts, as well as the socio-economic factors on the levels of poaching, understanding of which could help formulate effective anti-poaching policies and better conserve endangered species like the one-horned rhinoceros. It is clear from the study that there are a number of factors that affect the level of poaching of the one-horned rhinoceros in RCNP. Furthermore, this study shows which of the factors has had the greatest impact on the level of poaching in RCNP during the past three decades since the park's establishment. This information will be very helpful in prioritising the use of resources among various options to control poaching, however, it should be noted that focussing on a single approach will not be an effective way of controlling poaching. Instead, anti-poaching policies in RCNP could be most effective if the resources are spent on influencing a number of factors that are considered to determine the level of poaching, either directly by deterring the poachers or indirectly by providing potential poachers with incentives not to poach.

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APPENDICES

Appendix 1 Data used in the analysis of rhinoceros poached in RCNP from 1973 – 2003

YEAR[1]	*POACH_CH*[2]	*POACH_NP*[3]	*POPN*[4]	*PENALTY (NRs)*[5]	*REAL_PEN*[6]	*APU*[7]	*MAOIST*[8]	*GDPC_EA (US $)*[9]	*GDPC_NEP (US $)*[10]	*CPI_NP*[11]
1972	-	-	216	-	-	-	0	437	91	8.28
1973	7	5	231	15000	1626.90	0	0	564	83	9.22
1974	4	2	241	15000	1357.47	0	0	611	103	11.05
1975	1	0	253	15000	1261.56	0	0	659	112	11.89
1976	2	2	267	15000	1302.08	0	0	709	102	11.52
1977	0	0	279	15000	1184.83	0	0	846	99	12.66
1978	0	0	293	15000	1103.75	0	0	1138	114	13.59
1979	0	0	305	15000	1066.10	0	0	1219	127	14.07

[1] RCNP was established in 1973, hence, complete set of data are only available from 1973 onwards.
[2] The number of rhinos killed in the Chitwan Valley is very well documented in Martin and Vigne (1996), Maskey (1998), and Dhakal (2002); and in a number of DNPWC Annual Reports, such as DNPWC (1999, 2000, 2001, 2002, 2003).
[3] Similarly the number of rhinos killed within the boundaries of RCNP is documented in the same sources (see footnote 2).
[4] The data on the rhino population listed here comes from Rothley *et al.* (2004).
[5] The information on the level of fines for convicted poachers comes from Maskey (1998), Gurung and Guragain (2000), among others.
[6] Calculated as PENALTY divided by CPI_NP (consumer price index for Nepal).
[7] The anti-poaching units (APUs) only came into existence from the year 1993. The data on the number of APUs in RCNP comes from Martin and Vigne (1996), DNPWC (1997), Maskey (1998), Chungyalpa (1998), and Gurung and Guragain (2000).
[8] The Maoist insurgency started in Nepal from the year 1996. Thus, this dummy variable takes a value of zero (0) up to 1996 and one (1) from the year 1997 onwards.
[9] The GDP per capita for East Asia in real terms obtained from UN Statistics Division website http://unstats.un.org/unsd/default.htm.
[10] The GDP per capita for Nepal in real terms obtained from same source as above (see footnote 9).
[11] The consumer price index for Nepal obtained from the same source as above (see footnote 9).

YEAR[1]	POACH_CH[2]	POACH_NP[3]	POPN[4]	PENALTY (NRs)[5]	REAL_PEN[6]	APU[7]	MAOIST[8]	GDPC_EA (US $)[9]	GDPC_NEP (US $)[10]	CPI_NP[11]
1980	0	0	317	15000	929.37	0	0	1292	131	16.14
1981	0	0	330	15000	836.12	0	0	1369	146	17.94
1982	0	0	344	15000	748.50	0	0	1285	151	20.04
1983	0	0	358	15000	666.07	0	0	1378	146	22.52
1984	6	2	373	15000	647.67	0	0	1441	148	23.16
1985	2	0	384	15000	599.52	0	0	1492	154	25.02
1986	3	3	400	15000	503.69	0	0	2006	155	29.78
1987	0	0	398	15000	454.82	0	0	2384	169	32.98
1988	3	3	408	15000	417.36	0	0	2862	186	35.94
1989	1	1	419	15000	383.44	0	0	2908	180	39.12
1990	6	3	434	15000	354.27	0	0	2925	189	42.34
1991	1	1	444	15000	306.56	0	0	3274	169	48.93
1992	18	17	434	15000	261.69	0	0	3579	179	57.32
1993	9	4	433	100000	1622.59	2	0	4075	177	61.63
1994	1	1	442	100000	1497.68	5	0	4371	197	66.77
1995	1	1	457	100000	1391.59	5	0	4868	202	71.86
1996	1	1	472	100000	1274.05	6	0	4534	205	78.49
1997	3	1	488	100000	1224.89	7	1	4275	220	81.64
1998	6	6	503	100000	1101.20	8	1	3882	203	90.81
1999	14	9	513	100000	1024.80	8	1	4309	218	97.58
2000	17	12	516	100000	1000.00	8	1	4590	227	100
2001	15	15	499	100000	973.80	8	1	4172	228	102.69
2002	37	37	495	100000	945.18	0	1	4122	220	105.8
2003	19	19	461	100000	894.13	0	1	4444	233	111.84

Appendix 2 Observed rhino poaching and predicted values from the Negative Binomial model

Observed Y	*Predicted Y*	*Residual*	*x(i)b*	*Pr[Y*=y]*
5	1.1485	3.8515	0.1385	0.0102
2	0.62328	1.3767	-0.4728	0.1024
0	0.49578	-0.4958	-0.7016	0.6233
2	1.0901	0.9099	0.0862	0.1793
0	1.7816	-1.7816	0.5775	0.2179
0	1.1536	-1.1536	0.1429	0.3542
0	0.95969	-0.9597	-0.0412	0.4157
0	1.0762	-1.0762	0.0735	0.3773
0	0.66489	-0.6649	-0.4081	0.5357
0	0.70802	-0.708	-0.3453	0.5157
0	1.1407	-1.1407	0.1316	0.3579
2	1.4535	0.5465	0.374	0.2124
0	1.4873	-1.4873	0.3969	0.272
3	1.8375	1.1625	0.6084	0.142
0	1.8114	-1.8114	0.5941	0.2131
3	0.95728	2.0427	-0.0437	0.0605
1	2.3464	-1.3464	0.8529	0.2332
3	1.8619	1.1381	0.6216	0.1436
1	7.3282	-6.3282	1.9917	0.0326
17	6.8677	10.1323	1.9268	0.0073
4	3.8613	0.1387	1.351	0.1443
1	1.0586	-0.0586	0.0569	0.3344
1	1.2402	-0.2402	0.2153	0.3282
1	1.7256	-0.7256	0.5456	0.2913
1	6.8118	-5.8118	1.9187	0.0392
6	15.109	-9.1085	2.7153	0.0359
9	6.8554	2.1446	1.925	0.069
12	7.2372	4.7628	1.9792	0.0379
15	9.0794	5.9206	2.206	0.0304
37	40.562	-3.5624	3.7028	0.0218
19	18.243	0.7573	2.9038	0.0409

Appendix 3 Estimation output from LIMDEP 7.0 for Poisson and Negative Binomial models with REAL_PEN dropped from the model

```
POISSON;LHS=POACH_NP
      ;RHS=ONE,POPN[-1],APU,GDPC_NEP,GDPC_EA[-1],MAOIST
      ;MODEL=N;DSP=0.2$
+---------------------------------------------+
| Poisson Regression                          |
| Maximum Likelihood Estimates                |
| Dependent variable              POACH_NP    |
| Weighting variable                  None    |
| Number of observations                31    |
| Iterations completed                   7    |
| Log likelihood function        -71.63267    |
| Restricted log likelihood      -176.1652    |
| Chi squared                     209.0650    |
| Degrees of freedom                     5    |
| Prob[ChiSqd > value] =          .0000000    |
| Chi- squared =     84.14066  RsqP=    .7942 |
| G  - squared =     76.17234  RsqD=    .7330 |
| Overdispersion tests: g=mu(i)   :  2.095    |
| Overdispersion tests: g=mu(i)^2:    .700    |
| Robust (sandwich) estimator used for VC     |
+---------------------------------------------+
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 Constant    -2.01154876     3.19209289     -.630   .5286
 POPN[-1]      .02257341      .01014707     2.225   .0261    385.350000
 APU          -.20138750      .03539724    -5.689   .0000    1.83870968
 GDPC_NEP     -.04110270      .01667208    -2.465   .0137    166.870968
 GDPC_EA[-1]   .00038525      .00036692     1.050   .2937    2502.45161
 MAOIST       1.79147859      .68787957     2.604   .0092     .22580645
+-----------------------------------------------------------------------+
+---------------------------------------------+
| Negative Binomial Regression                |
| Maximum Likelihood Estimates                |
| Dependent variable              POACH_NP    |
| Weighting variable                  None    |
| Number of observations                31    |
| Iterations completed                  11    |
| Log likelihood function        -65.15887    |
| Restricted log likelihood      -71.63267    |
| Chi squared                     12.94759    |
| Degrees of freedom                     1    |
| Prob[ChiSqd > value] =      .3203327E-03    |
+---------------------------------------------+
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
 Constant     -.40872548     1.47499902     -.277   .7817
 POPN[-1]      .02123085      .00779175     2.725   .0064    385.350000
 APU          -.21977649      .05522557    -3.980   .0001    1.83870968
 GDPC_NEP     -.05207382      .01731119    -3.008   .0026    166.870968
 GDPC_EA[-1]   .00066316      .00036549     1.814   .0696    2502.45161
 MAOIST       2.22528960      .50127340     4.439   .0000     .22580645
          Dispersion parameter for count data model
 Alpha         .20000000    ......(Fixed Parameter).......
+-----------------------------------------------------------------------+
```

Appendix 4 Estimation output from LIMDEP 7.0 for Poisson and Negative Binomial models with GDPC_HK as the proxy for price of rhino horns

```
POISSON;LHS=POACH_NP
      ;RHS=ONE,POPN[-1],APU,REAL_PEN,GDPC_NEP,GDPC_HK[-1],MAOIST
      ;MODEL=N;DSP=0.2$
```

```
+-------------------------------------------+
| Poisson Regression                        |
| Maximum Likelihood Estimates              |
| Dependent variable             POACH_NP   |
| Weighting variable                 None   |
| Number of observations               31   |
| Iterations completed                  7   |
| Log likelihood function       -72.51645   |
| Restricted log likelihood     -176.1652   |
| Chi squared                    207.2974   |
| Degrees of freedom                    6   |
| Prob[ChiSqd > value] =         .0000000   |
| Chi- squared =     94.86565  RsqP=   .7680|
| G  - squared =     77.93991  RsqD=   .7268|
| Overdispersion tests: g=mu(i)  :  1.902   |
| Overdispersion tests: g=mu(i)^2:   .522   |
| Robust (sandwich) estimator used for VC   |
+-------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	-3.56239661	3.42101708	-1.041	.2977	
POPN[-1]	.02659428	.00905638	2.937	.0033	385.350000
APU	-.19371964	.03537704	-5.476	.0000	1.83870968
REAL_PEN	.00016155	.00086156	.188	.8513	934.233349
GDPC_NEP	-.03664303	.01254979	-2.920	.0035	166.870968
GDPC_HK[-1]	.686114D-05	.00010943	.063	.9500	12268.5484
MAOIST	1.62298442	.68323984	2.375	.0175	.22580645

```
+-------------------------------------------+
| Negative Binomial Regression              |
| Maximum Likelihood Estimates              |
| Dependent variable             POACH_NP   |
| Weighting variable                 None   |
| Number of observations               31   |
| Iterations completed                 12   |
| Log likelihood function       -66.12581   |
| Restricted log likelihood     -72.51645   |
| Chi squared                    12.78128   |
| Degrees of freedom                    1   |
| Prob[ChiSqd > value] =     .3501042E-03  |
+-------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	-1.47852619	2.72151006	-.543	.5869	
POPN[-1]	.02239465	.01091209	2.052	.0401	385.350000
APU	-.20939313	.05770072	-3.629	.0003	1.83870968
REAL_PEN	.428204D-04	.00065307	.066	.9477	934.233349
GDPC_NEP	-.04316509	.01627922	-2.652	.0080	166.870968
GDPC_HK[-1]	.696534D-04	.869054D-04	.801	.4229	12268.5484
MAOIST	1.75851062	.53111182	3.311	.0009	.22580645
	Dispersion parameter for count data model				
Alpha	.20000000	......(Fixed Parameter).......			