SUSTAINABLE DEVELOPMENT, POACHING, AND ILLEGAL WILDLIFE TRADE IN INDIA

by

Shekhar Kumar Niraj

A Dissertation Submitted to the Faculty of the

SCHOOL OF NATURAL RESOURCES

In Partial Fulfillment of the Requirements
For the Degree of

DOCTOR OF PHILOSOPHY
WITH A MAJOR IN RENEWABLE NATURAL RESOURCES STUDIES

In the Graduate College

THE UNIVERSITY OF ARIZONA

2009

THE UNIVERSITY OF ARIZONA
GRADUATE COLLEGE

As members of the Dissertation Committee, we certify that we have read the dissertation prepared by Shekhar Kumar Niraj
entitled Sustainable Development, Poaching, and Illegal Wildlife Trade in India
and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy

____ Date: 01/30/2009
Paul R. Krausman

____ Date: 01/30/2009
William W. Shaw

____Date: 01/30/2009
Randy R. Gimblett

____Date: 01/30/2009
John L. Koprowski

Final approval and acceptance of this dissertation is contingent upon the candidate's submission of the final copies of the dissertation to the Graduate College.

I hereby certify that I have read this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

____ Date: 01/30/2009
Dissertation Director: Paul R. Krausman

STATEMENT BY AUTHOR

SIGNED: Shekhar Kumar Niraj

ACKNOWLEDGEMENTS

I thank my advisor, Paul. R. Krausman, for his involvement, support, and constant encouragement. I joined the Ph.D. program for mid career professionalism. I gained more than what I expected, under the dedicated supervision of Paul R. Krausman, whose untiring effort of mentoring, critical comments, and constructive criticism transformed my thinking and attitude towards a better accomplished professional. His own dedication to wildlife profession, research, and scientific writing is par excellence and I learned every bit from his attributes.

I thank William W. Shaw for his unstinted support, guidance and help at all stages of my Ph.D. right from the beginning of my research at the University of Arizona. Bill Shaw had the unmatched patience of going through my proposal, questionnaires, results, analysis, and the write ups offering valuable comments which led to a much improved product. I am indebted to the help Bill Shaw gave me all through the program.

Randy R. Gimblett and John W. Koprowski, my research committee members have been a great source of support, help, and motivation during my research program at the School of Natural Resources. There were always there when I needed them, willing to support me in all my research endeavors. I am grateful to my committee and will cherish my association with them throughout life.

I was grateful to Patrick Reed and David Cox for their support during the initial, but the most crucial phase, of my Ph.D. program. I thank Phillip Guertin and Mark Bosgstrom for their help with spatial and statistical analysis. Phillip Guertin provided a great opportunity to deepen interests in learning geographical information analysis under his highly accomplished but very humble supervision. He always simplified the most intricate problems with great ease and made the learning easy and interesting. I have been grateful to Mickey Reed for his always-ready attitude of help in spatial analysis. In fact working with him was such a pleasure that many times I would just go to him and then think about the questions for clarification. I am thankful to Andy Honaman and for his pleasant smile for any help that I ever needed. Cheryl Craddock has been a great source of help right from the day one of my association with the School of Natural Resources. I learned a great deal from Stephen R. Yool, Stuart Marsh and Kurtis Thomas.

I thank the University of Arizona, College of Agriculture, Arizona Agricultural Research Station, University of Arizona; and the Ministry of Environment and Forests, Tata Education Trust, and the Department of Personnel and Training, Indian Government for funding and sponsoring my research. I thank the faculty and staff of School of Natural Resources, the Agricultural Research Station, University of Arizona, Tucson; and the Boone and Crocket Club, University of Montana for their support to my research program.

A number of individuals, organizations and professionals helped with my research. They were all invaluable links in the successful completion of this task. Vikram Dayal, a coauthor in the dissertation papers was a great source of support, help, and motivation. I express my deepest gratitude for the multifaceted role he assumed during the course of my whole research program. Vikram was a friend and a philosopher, a critique and a facilitator, an untiring doer and an unstinting enabler.

I am thankful to A. N. Prasad for his useful suggestions for the field work in India and great help in data collection. I express my gratitude to H. S. Pabla, S. Sen, Ashok Kumar, A. Sahu, R. K. Dogra, and many other senior officials in the state governments in India for their help in facilitating the field work and in collecting protected area level data.

I am grateful to Meetu Gupta, M. Shakthivel and S. Barnaiah for their help in field surveys in different protected areas in India. The officials of the regional Convention of International Trade in Endangered Species of Wild Fauna and Flora enforcement authorities in India, particularly, S. Tiwari, and S. Subramaniam, were immensely helpful with the data and interpretation.

I am deeply grateful to my parents, my brothers and my sister for their constant support, encouragement, help, and trust in my abilities that brought my full strength out. I am indebted to my two sons (Harsh and Ashmit) from whom I took away many years of our togetherness to complete this work. Their understanding and patience at their age can not be paralleled. Last but not the least, I am grateful to my wife Sanjana who assumed greater responsibility, taking over my share also, in bringing up the children when I was away to the University or field for this research. Without the support of all I would not be writing these final few lines.

DEDICATION

This dissertation is dedicated to my parents, the late Durgeshwari Prasad and Jairani Prasad, whose love, affection, conviction in me and their good virtues, which I always tried to inculcate since childhood.

TABLE OF CONTENTS

ABSTRACT

Wildlife poaching is directly associated with illegal wildlife trade. Although poaching is recognized as a major threat to wildlife in India, it has not been analyzed quantitatively, because of a lack of data. Thus, the understanding of poaching or illegal wildlife trade and its true implications on conservation has not been considered by policy makers. The deficiency of data on poaching in the public domain also hampered scientific research on poaching. The lack of a scientific approach to analyze poaching creates a gap between reality and an effective solution to reduce its implications on wildlife conservation. Poaching has also been affected by fast economic development in India and the region, which has given rise to increased demand of wildlife. Protected areas, created to conserve wildlife, face pressure from poaching and demographic growth. Economic developments affect poaching and demographic changes and affect conservation. Analyzing this trend at the country and the global level can help predict future scenarios and develop effective strategies to reduce loss to biodiversity.

We examined stakeholders' perspectives on wildlife policy development in India (Part 1) and analyzed poaching and other emerging threats to 3 different protected areas in India (Part 2). This analysis is based on the perceptions of the village communities living inside and on the fringe of the protected areas. We also conducted a temporal and spatial analysis of poaching in India from 1992-2006 (Part 3). This period sees the transformation of Indian economy following an economic liberalization process, which increased the development process. Finally, we analyzed the relationship between growth in the economy and wildlife conservation in India from a historical and statistical perspective (Part 4). This part also develops system feedback loop diagrams to determine possible

relationships between variables that are connected to conservation. The relationships are then assessed at the global level to understand the impact of economic growth on wildlife conservation and understand how it influences the endangered mammals and birds.

INTRODUCTION

Explanation of the Problem

Wildlife trade, considered a post WWII phenomenon (Mackenzie 1988), is likely a major cause for the decline of wild fauna and flora worldwide. Global trade in wildlife and their products, estimated at approximately $12 billion (U.S.) annually (Menon and Kumar 2002, Oldfield 2002), and ≥ 30% is illegal (Oldfield 2002), second only to narcotics and illegal arms trade (Reeve 2002, Hanfee 1998). Since 1987, consumer demands for wildlife have increased and diversified. Interestingly, wild animals and their products assumed astronomical price tags since the 1990s due to their increased rarity and other factors enhancing their demands (Broad et al. 2002, Hillstorm and Hillstorm 2003). However, a deeper analysis of the illegal trade will likely reveal much more. Several contemporary studies (Menon et al. 1997, Menon and Kumar 1998, Freese and Trauger 2002, Hillstrom and Hillstrom 2003, Thapar 2003) suggest that the demands for imported wildlife in Europe, North America, China, South Korea, and Japan are high. For example, there is a huge demand for elephant ivory in Japan and Thailand. Western Europe and North America have consistent demands for medicinal plants (Marshall 1998), reptile skins, and pet animals including birds. Australia, East Asians, and Central American countries constitute significant markets for marine species including seahorses (family syngnathidae), sea cucumbers (*Holothuroidae* spp.), sharks (family laminidae), corals (family faviidae and mussidae), and molluscan species of economic value. A ubiquitous Chinese minority creates a market for everything that breathes from tigers (*Panthera* spp.), high on the food chain, to turtles and snakes (Terborgh 1999). However, unregulated, often illegal, hunting is less easily quantifiable but probably a more severe threat to population survival of many endangered species (Stewart and Hutchings 1996).

Literature Review

Species loss and extinctions versus subsistence and commercial uses.**—**At least 100 species of fresh water turtles and tortoises native to Asia are actively traded (Van Dijk 1999, Bhupathy et al. 2000, Choudhury 2001); 33 of these are listed as threatened (World Conservation Union 2000). Collection of turtles for trade is the most significant threat for most Asian species (Van Djik 1999). Hunting for subsistence is being replaced by a steadily increasing harvest for commercial trade in wildlife to supply markets in China, Thailand, Vietnam, and other countries (Bradley et al 1996).

In the last 2 decades illegal trade in animal parts emerged as the single greatest threat (Stuart and Stuart 1996) to some of the most seriously endangered and highly valued species including tiger (*Panthera tigris*), the rhinoceros (*Diceros bicornis* and *Rhinoceros unicornis*), sloth bear (*Ursus ursinus*; Wagener 2001) and snow leopard (*Panthera uncia)*. The conservation of rhinoceros has become a matter of critical importance as the species population has become dangerously low due to excessive trade in horns (Chris and Stuart 1996). Asia’s rapid economic development has expanded the number of people who are able to afford traditional medicines and other wildlife products (Wood et al. 2001, Hillstrom and Hillstrom 2003). In India, illegal trade raised critical questions about the survival of many species and may be affecting populations genetically of some of them (Kenney et al. 1995). It appears that uncontrolled international wildlife trade has led to drastic depletion of some wildlife species (Stewart and Hutchings 1996, Erickson 2000).

There is a huge demand for tiger skins and body parts in East Asian markets. However, other cat species are also declining, which raises serious concern about their survival (Maccarthy and Dorfman 2004). Three of 8 species of tigers were reported extinct in the 1900s (Kenney et al. 1995). India is home to the largest population of tigers in the world and reports a decline of its populations from 40,000, at the beginning of 20th century, to about 3,500 in 2000 (Jain 2001), and then to 1400 in 2006-2007, roughly 60 % of the global population. Sariska tiger reserve reported complete elimination of tiger from its habitat, thus initiating a country wide debate on the decline (Rangarajan and Shahabuddin 2006). India loses 1 tiger every 18 hours (Day 1995). Various studies suggest that ≥ 123 tigers were poached between 1994 and 1997 and 50 tigers were poached/ year between 1998 and 2002 (Mishra 2004); the tiger trade may be worth $ 25 million (U.S.) (Day 1995).

Ivory markets in Africa and Asia continue to drive illegal trade in ivory. An annual average of 270 kg raw ivory was seized in India between 1996 and 2001. The international community imposed the ivory ban through Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 1989, when the reports of ≥ 100,000 slaughtered elephants were reported. The statistical analysis under the Elephant Trade Information System (ETIS) reports 9,426 seizures from 75 countries worldwide in illicit trade between 1989 and 2003. African elephant's (*Loxodonta africana*) populations dropped by 60% between 1979 and 1987 from an estimated 1.3 million to 500,000 (Dublin et al. 1995, Chris and Stuart 1996). This is largely attributed to ivory poaching. Controlling wildlife trade in the face of strong market forces and organized crime is a monumental task (Reeve 2002). Asian elephant (*Elephas maximus)* are at risk due to its vulnerable populations through out its ranges due to poaching (Menon et al. 1997, Nash 1997, Sukumar et al.1998, Menon and Kumar 1998). In Periyar Wildlife Sanctuary in southern India, selective poaching of males with tusks (i.e., tuskers) has rendered male to female sex ratio as 1:125 (Sukumar et al. 1998). Poaching is directed and mostly selective looking for the best available individual in the population for profit maximization. This, along with other factors, may have deleterious genetic impact on the species. Demographic consequences of poaching might not be immediately obvious because extinction may occur many years after poaching is reduced or eliminated (Kenney et al. 1995). This makes the situation intriguing and necessitates the need for a thorough analysis.

Other species endangered by illegal trade include leopard (*Panthera pardus*), sambar (*Cervus unicolor*), spotted deer (*Axis axis*), antelopes (mainly Antelope cervicapra), Indian star tortoises (*Geochelone elegans*), reptiles, particularly the endangered snakes, great Indian one-horned rhinoceros (*Rhinoceros unicornis*), and Tibetan antelope (*Pantholops hodgsonii*). Plant species including red sanders (*Pterocarpus santinilus*), agar wood (*Aquilaria* spp.; Chakrabarty et al. 1994), and kuth root (*Saussurea lappa*) also face high illegal trade pressure.

Economic issues.—India and the other developing countries in Asia have been witness to rapid economic development accompanying economic globalization since 1991. The result of this development is expansion and diversification of markets for wildlife products (Freese and Trauger 2000). The Veblen ideas of conspicuous consumption (Friedman and Ostrov 2008) hold that the demand is strengthened with a rise in price or weakened with a fall in price. While a rising demand curve with rising prices is unusual (Dewet and Chand

1976), with wildlife products, particularly those found in illegal trade, this appears to be a common scenario.

It may be important for conservation biologists and policymakers to expand their dimensions of vision to consider the impacts, the newer economics related development, which might influence wildlife conservation. Consumption of natural resources and high per capita demand of resources continues to cause loss of biodiversity (Gossling 1999). Market forces impact wildlife transactions. Genetic resources are occasionally exploited through the market place (Myers 1979) and under the market influence. Japanese imports of fish and fish products declined in the late 1990s as a result of economic recession (Broad et al 2002). Bison (*Bos bison),* passenger pigeon (*Ectopistes migratorius*) and whale populations' declines (Clark 1973) have been the result of market forces (Bolen and Robinson 1999). The free market is an incredibly powerful economic force (Moulton and Sanderson 1997) and directly affects wildlife.

Economists frequently use gross domestic product (GDP), gross national product (GNP), and per capita GDP as a proxy for human well being (Hall et al. 2000). In an economically linked region, this indicator could serve the purpose of developing a flow diagram of illegal wildlife trade movements. If rate of growth of the economy (as measured by GDP) exceeds the growth rate in population, per capita income takes a steady growth rate (Virmani 2002). This is accentuated that many developmental economists predict that in all the 4 quarters of the 21st century, Asian countries led by India and China will dominate the best economic growths in the world (Bloom and Williamson 1998; Swaminathan 2001; World Bank 1994, 1997; Virmani 1999, 2004). Will such economic growth influence illegal wildlife harvest and threaten conservation in India and other developing countries?

Policies issues.—In a largely integrated economic world the policies made in one country may influence other regions. When mere talk of permitting one time ivory sale pertaining to only 3 countries (e.g., Namibia, Botswana, and South Africa), prior to the CITES meeting in 2002, an increase in elephant poaching occurred in South and South East Asia (Menon 2002).

The CITES lists ≥ 32,000 species of animals and plants, thus, regulating international trade. However, within the CITES regime, conservation has always been a poor relation to science and management from an institutional and financial point of view (Cooney 2001, Reeve 2002). Is CITES implementation in India effective to minimize illegal trade in, at least, the flagship species such as tiger, elephant, leopard, rhinoceros and bears? Efforts to create a common meeting ground between the Indian laws, CITES and policies from the Convention of Biological Diversity (CBD) have been unclear and discordant (Mishra 2002).

The strategic plans of CITES and CBD is to conduct trade at sustainable levels (CITES 2003, Ruiz et al. 2003). However, sustainability has different connotations when applied to different fields (Worester 1993, Gowdy 2000, Weddell 2003). Are the developing countries, exemplified by the Indian scenario, ready to adopt the new regime? A study on wildlife sustainability by Bennett and Robinson (2000) concludes that what is economically sustainable may not necessarily be biologically sustainable. The issue of sustainability is linked to carrying capacity and we are unsure about how to accurately estimate the carrying capacity in a wilderness setting (Worester 1993). In the face of uncertainty about sustainability many developing countries, on the threshold of economic transformation, may be tempted to adopt this concept; new- paradigm thinking will be critical to formulate actions.

In many tropical countries well-planned eco-tourism has paid dividends (Gossling 1999, Isaacs 2000, Nelson 2000) to reduce illegal harvest pressures on various species. Kenya's Wildlife Service is operating successfully and the revenues generated from tourism in the national parks are substantial (Leakey and Morell 2001). How far these alternatives could help to contain illegal trade could be examined in India. The issue of consumptive and non-consumptive trade is being debated in relation to livelihood issues (Roe et al. 2002, Sinclair-Brown 2002). In India, the policy seems to have touched this issue only peripherally. But can the societal or conservation needs be juxtaposed within this? This issue was examined by evaluating international policies in India to predict whether Indian conservation policies need to be reoriented along these lines for better conservation.

Explanation of Dissertation Format

Manuscripts of the appendices of the dissertation are the results of research on impact of macroeconomic factors on wildlife poaching analyzed at the protected area level, policy level, and national and global level. The primary objectives of this research were to determine the impact of growth in economy in India during 1992-2006 on: 1) wildlife policy development in India; 2) poaching and illegal trade and other factors affecting 3 protected areas in India; 3) on time and spatial trend of poaching of 18 species or categories of species in India, and 4) on historical development of wildlife conservation in India and the impact of the economy on wildlife conservation globally.

All manuscripts in this dissertation are the result of the research I conducted as a Ph.D. student at the University of Arizona. My major professor and committee members provided advice and guidance, however, I was responsible for study design, data collection and analysis, and the presentation of results in this dissertation. I am the senior author on all manuscripts resulting from my dissertation research; coauthors include others, including committee members, who made contributions to this research.

PRESENT STUDY

Descriptions of the methodologies, results, and conclusions are contained in the manuscripts in 4 appendices. The following is a summary of the major results of these manuscripts.

Study Area

India has 28 states, regions that are provincially administered, and 7 union territories that are federally administered, covering an area of 32 million km^2. For the Part1 (i.e., stakeholder perspective into wildlife policy development in India), which was based on the questionnaire surveys, we conducted surveys among 4 stakeholders (i.e., the field officials, non-governmental organizations, policy makers, and conservation scientists) based throughout India.

Part II (i.e., poaching and other threats to 3 Protected Areas [PAs] in India) consisted of household surveys in Achanakmar Wildlife Sanctuary (i.e., Achanakmar WS), Kanha National Park (i.e., Kanha NP), and the Mudumalai Wildlife Sanctuary (i.e., Mudumalai WS). Achanakmar WS has an area of 553 km^2 in the state of Chattisgarh (17^o46' N to 24^o5'N, 80^o15' E to 84^o20' E) in central east India, Kanha NP, has an area of 941 km^2 in the state of Madhya Pradesh (17º 47' and 26º 52' N and 74º 02' and 84º 24' E) in central India, and Mudumalai WS has an area of 321 km^2, in the state of Tamil Nadu (8° 04' and 13° 34' N and 76° 14' and 80° 21' E) in south India. Kanha NP is also a tiger reserve (TR) with the country’s largest single tiger population (Narayan et al. 2005), Mudumalai, a Project Elephant Reserve and a TR, an existing national park (NP), and a wildlife sanctuary (WS). Achanakmar WS is being considered as a TR. Part III (i.e., the temporal and spatial analysis of poaching in India from 1992-2006) is a study on 18 different species or categories of species (e.g., 15 of wild fauna and 3 of wild flora) found in India and reported in illegal wildlife trade.

Policy Analysis by Stakeholder Perspectives

We found significant differences among stakeholders in identifying major threats to wildlife, use of science in policy, impact of poaching in conservation, and composition of species in illegal trade. Policy processes use a rigid top-down approach and are largely non-inclusive. Policy makers and field officials differed in their views with non-governmental organizations (NGOs) and conservation scientists on assessing impact of economic growth on poaching, response of wildlife policies to community and various threat perceptions to different wildlife species in India.

Habitat destruction, in addition to poaching, was considered a major threat to wildlife by most stakeholders: 84, 88, 67.5, and 72% of scientists, policy makers, field officials and NGOs respectively. Less than 25% of policy makers and field officials viewed Indian wildlife policies as adequate, but the implementation of policies in the field was poor. More than 77% policy makers viewed conservation policies as strengthened since the 1990s, but this view was least shared by scientists. Among the NGOs, field officials, policy makers, and scientists; 74, 50, 62, and 50% respectively, considered poaching as a major threat to wildlife conservation.

Only few policy makers (9%), in contrast with the scientists (55%) considered that the policy development lacked a scientific approach, indicating bias in policy formation. Most stakeholders, except conservation scientists, considered only a few species (e.g., tiger, leopard, elephant, and rhino) as the species threatened by poaching for illegal trade, indicating a more centric view. Scientists considered several other species such as marine arthropods, marine turtles, fruit bats, coral fishes, sea horses, sharks, tarantulas, beetles, lion-tailed macaque (*Macaca silenus*), Coleopterans, mygalomorph spiders, also facing serious threats from poaching. Scientists also reported greater concern of poaching of several bird species including white-rumped swiftlet (*Apus caffer*), great pied hornbill (*Buceros bicornis*), and hill myna (*Gracula religiosa*).

Protected Area and Major Threats to Wildlife

We evaluated poaching and other emerging threats to 3 PAs in India and measured poaching as a threat in relation to the other threats to wildlife in the PA. We surveyed 216 randomly selected village households in 3 different PAs along 2 strata (i.e., enclave and fringe villages) to assess the households' perception on poaching and illegal trade of key wildlife species among other threats in PAs. We used structured questionnaires and interviews to obtain responses of households and then compared the perceptional data with data from PA management to compare and contrast the difference in observations and to assess how this difference affects conservation efforts. We found that the fringe and enclave villages did not have significant attitudinal differences on most issues across 3 PAs. However, the PAs differed significantly on growth in household income, problems the households faced in the PA, and on perception of the benefits such as collection of timber from the PA. Only Mudumalai WS households considered environmental satisfaction as an important benefit from the PA. The Mudumalai WS households also reported an increase in wildlife populations and forest cover as factors leading to improvement in the PA. Kanha NP and Achanakmar WS households were more concerned with illegal harvest of trees and non-timber forest produces (NTFP) than the Mudumalai WS households. Achanakmar WS households had significantly less sighting of wildlife animals than Kanha NP and Mudumalai WS households. Mudumalai WS households encountered more poaching incidences than Achanakmar WS or Kanha NP households despite reporting a higher growth in income from 1992-2006. Both Kanha NP and Mudumalai WS households considered sustainable use of wildlife a potentially useful policy more than Achanakmar WS households. However, the majority of the households across all PAs regarded sustainable harvest useful as a conservation and management tool. On the whole, higher economic growth and development was found positively associated with poaching and threat to conservation.

Poaching Trends of Species from 1992-2006

We studied tiger, leopard, elephant, great Indian rhinoceros, Tibetan antelope (i.e., chiru; *Pantholops hodgsonii*), star tortoise, otters (*Aonyx cinerea*, *Lutra lutra*, and *L. perspicillata*), and mongoose (*Herpestes avanicus*, *H. vitticollis*, and *H. edwardsii*), and the bears (*Melursus ursinus, Ursus arctos, and U. thibetanus*). The categories of multiple species included the deer, snakes, reptiles other than snakes and other than the star tortoise, birds, and shells.

The wild flora included red sanders, Agarwood, and kuth root. We compiled information on trade composition of the species, geographical distribution, habitat, destination markets, prices in illegal international markets, and legal protection from field enforcement units, based on the published literature and the electronic resources available on the website of the World Conservation Union (IUCN) and the CITES.

The prices of species varied from a few dollars (US) per specimen of a bird or shell to >$60,000 (US) for a rhino horn. China was assumed the main destination market for many species including tiger, leopard, elephant ivory, otters, reptiles, and birds. Tiger or its derivatives or leopard or its derivatives are used, primarily, in the traditional Chinese medicines (TCM; Kenney et al. 1995). The fur containing skins of snow leopard (*Panthera uncia*) and the clouded leopard (*Neofelis nebulosa*) are traded for making winter clothing, which has strong demand in the Western Europe, Russia, Hong Kong, and North America. Malaysia, Singapore, and Thailand import star tortoise and reptiles, whereas Singapore also has large market for birds. Western Europe and North America have strong demands for shawls made of the wool from chiru, star tortoise, medicinal plants, shells, and birds. The markets in Arabic countries in the Middle East make demand for rhino horns and agarwood or its extracts. Japan has strong demands for elephant ivory for making name seals ‘henko’. Among the flora, kuth is imported to China and Western Europe for the use in traditional medicines. The red sanders are largely imported to Japan for making traditional musical instruments (e.g., shamisen). China and Taiwan also import red sanders for medicinal preparations, dying food items, and coloring beverages.

India has been a consumer market for birds (Ahmad 1996), trophies of tiger, leopard, and deer. The gall bladder of bears has been used in traditional medicines for the domestic markets (Gupta 2007) and the international markets in East Asian countries. The hair of mongoose is used in paint brushes and sold in the domestic markets in addition to exporting it (Hanfee 1998).

The legal protection on some of the charismatic species (e.g., tiger, leopard, rhino, elephant) are strong under the Wildlife Protection Act (WPA 1972) and the CITES. But many other species (e.g., star tortoise, turtles) do not receive adequate legal protection. There are special protection programs aimed at conserving tiger, elephant, and the rhino. However, many other species (e.g, leopard, star tortoise, and the floral species) do not have strong conservation focus as part of the government policies or in scientific research. Trade in some of the economic flora species (e.g., kuth roots, agarwood, and red sanders) is significant, but the species do not have strong legal or legislative measures for protection from illegal harvest in the WPA or the CITES.

Trend Analysis of Poaching

We used a time series analysis of poaching of 18 species or categories of species using a 3 stage analysis. For the species with high frequency poaching, we carried out detailed trend analysis, by (1) dividing time (1992 to 2006) into 3 equal periods and plotting box plots for each time period, (2) plotted loess scatterplot smoothers of seizures against time, and (3) carried out tests of whether the seizures, and in turn poaching, had deterministic or stochastic trends and structural breaks. We recorded date wise seizures, and converted all date wise seizures into quarterly seizures

Tiger, leopard, bears, rhino, elephant, birds, and snakes were the most frequently poached species during 1992-2006. There was a decline in tiger poaching around 2001, leopard around 1998, and rhino poaching declined consistently after 1994 but increased slightly around 2000. The level of seizures of elephants fluctuated randomly, with little pattern, reaching a peak in the last quarter of 2001. The leopard data showed 5 distinct peaks or spikes. For rhinos, the initial years saw peak seizures: 31 in the first quarter of 1993 and 24 in the first quarter of 1994. Thereafter, there were some fluctuations, but no notable spikes. Birds, snakes, shells, and turtles have a sporadic increase and decrease in poaching over 1992-2006. Star tortoise had an increased poaching frequency after 2004. Among the flora, frequency of red sanders seizures increased significantly after 2002, whereas agarwood and kuth root seizures were periodic during 1992-2006.

For the most frequent seized species we tested the trend whether that was stochastic or deterministic following Lee and Strazizich (2004). The Lee and Strazicich test rejects the null hypothesis of stochastic trends for all the species except elephant.

Tigers, elephants, leopards, deer, and antelope witnessed a change in slope at the break point that had a *P* value <10%. Tigers and rhinoceros experienced a change in intercept at the break point that had a *P* value <5%.

Spatial Pattern of Poaching

The northern border of India abutting Nepal, Tibet, China, and Bhutan is used for wildlife trafficking. We classified all states into border, if they fell along the northern land border, and non-border states, if they did not fall along the land border. We ignored the international maritime border. We used geospatial analysis, employing geographical information system (GIS; O'Sullivan and Unwin 2002) and local indicators of spatial indicators (ESDA; O’Sullivan and Unwin 2003), to evaluate the spatial associations of poaching at the scale of states in India. Since we also had a time series data, to examine the effects of different time periods on the spatial pattern of seizures we computed t statistics on spatial mean difference at the state scale using Arc map (ArcGIS 9.3). We also computed t statistics to evaluate the state mean seizure of species in 3 different time periods over 1992-2006. This was used to compare and contrast with the results from the time series regression analysis. Four types of hot spots were identified and described as high value associated with other high values in the neighborhood (HH), high value associated with other low values in the neighborhood (HL), low value associated with other high values in the neighborhood (LH), and low value associated with other low values in the neighborhood (LL). We looked at the clustering pattern globally and locally

(O'Sullivan and Unwin 2003). Whereas the global autocorrelation suggested the overall pattern of clustering of seizures and indicated if there is a spatial dependence on poaching of species, the local effects were able to locate where in the space the cluster was located. The measurement of global spatial autocorrelation is based on Moran's *I* statistic (Le Gallo and Ertur 2003). Leopard skin seizures have near significant differences between border and non-border states in 1992-2006 and 1997-2001, whereas bone seizure increases near significantly in border states than the non-border states in 2002-2006. Overall, leopard seizures have higher state mean seizures among border states than the non-border states and recorded near significance in time periods 1992-1996 and 2002-2006. The border state mean seizure of tiger bone is higher than the non-border states and records near significance in 1997-2001. Elephant ivory seizure is more significant for the non-border states than the border states in 1997-2001 and 2002-2006 indicating different geographic factors influencing their illegal demands than those affecting tiger and leopard. Deer follows a pattern similar to elephant and has significant seizures in non-border states than in the border states in 1997-2001 and 2002-2006.

We examined differences in mean seizures between 3 time periods over all states. Leopard seizures increased in 2002-2006 than in 1992-1996. Tiger bone seizures picked up significantly in 2002-2006. We recorded a rise in elephant tusk seizures in 2002-2006 as compared with 1992-1996. Mean seizure of antler and deer poaching was higher in 2002-2006 than in 1992-1996. Snake skin seizures remained similar in all 3 periods from 1992-2006. We found these results similar to that we obtained in the time series analysis. We also recorded higher seizures for star tortoise in 2002-2006 from the level of 1992-1996. The red sanders seizures recorded a decline in 2002-2006 as compared to1992-2006.

However, we found mean seizure higher in 2002-2006 than the preceding 1997-2001. The state mean seizure in 1992-1996 was boosted by 2 large seizures in 1996 and 1997 in the state of Andhra Pradesh in southern India.

Spatial Associations of Poaching of Species

In case of deer skins and antler seizures 6.90% of states along the northern land border produced HH clustering (i.e., high poaching region in the neighborhood). The overall deer poaching remained spatially significant with respect to these states. The spatial clusters of seizures in the case of tiger skin and tiger bone produced statistically significant seizures along the northern border. For leopard, 10.90% of the border states produced HH spatial clustering, and is highly significant along the northern border. For tiger bone, leopard skin, and leopard bone the clusters remained significant even at the 0.01 level along the northern border. In the case of elephant and birds, we do not observe significant clustering along the border. For the snakes, clustering of seizures was significant, but not along the border. For red sanders and star tortoise, the spatial associations of seizures were significant but not along the border.

Association between Tiger and Leopard Poaching

We used feedback loop diagram from the field of System Dynamics (Homer 1996, Saeed 1996), to develop conceptual framework in analyzing relationship between tiger and leopard poaching. We hypothesized that tiger and leopard seizures were related because of overlapping geographical distributions (i.e. leopard occurs the edges of tiger habitat), and both were in demand. The contemporaneous relationship was substantively and statistically strong, indicating an elasticity of 0.39—a 10% increase in leopard poaching detection or seizures is associated with a 3.9% increase in tiger poaching detection or seizures. We have a similar picture in case of the regression of log of leopard on current and lagged log of tiger poaching. The contemporaneous elasticity estimate in this case was 0.89. A 10% increase in leopard poaching was associated with an 8.9% increase in tiger poaching detection or seizures.

A survey of the economic growth pattern during the 1992-2006 indicated that during 1998-2000, there was an economic downturn in the major Asian economies (e.g., Thailand, China, Malaysia, Singapore, Japan; World Bank Indicators 2007). Some of these are the main destination markets for the illegal wildlife products from India. We found that the economic downturn was accompanied by a downward trend in poaching or seizures of wildlife in India in the same period indicating a relationship between the economic growth and the demand for wildlife.

Wildlife and the Economy

We used system dynamics feedback loop diagrams to develop an analytical framework linking different key economic and wildlife variables. We reinterpreted historical narratives of India's wildlife history from the time of the British to the 1990s, relating these to our feedback loop diagrams. We used cross-country data to examine the interactions between key economy and wildlife variables in our feedback loop diagrams. We used a bivariate quantile regression in our analysis. We found that internal GDP, that is the GDP of the country in which the wildlife exists, has direct effects on the habitat of a species and the density of the species in its habitat. The growth of GDP leads to a fall in the abundance of species. Increases in external and internal GDP can increase incomes and the demand for poached wildlife species.

Although GDP has several effects at different points of the wildlife economy system, its direct effects were the strongest. Per capita GDP was positively correlated with the proportion of birds that are threatened. The coefficients of the 0.1, 0.25, 0.5 and 0.9 quantile regressions of log of birds threatened against the log of per capita GDP were statistically significant. We found that per capita GDP was positively correlated with the proportion of total land area under PA and that per capita GDP was negatively correlated with rural population density. We finally found that rural population density was positively correlated with bird and mammal proportions that were threatened. This result was important in context of the developing countries where the threat to wildlife also comes from demographic pressures near the PAs, which are created for protection and conservation of wildlife.

Management Implications

Policy development is an important aspect of wildlife management. Policy has a far reaching and quick impact on wildlife management. Therefore, the wildlife policy must take a comprehensive, balanced and objective approach to conservation and protection. It is evident that problems in wildlife management are not only technical but also social, political, and economic.

There are many stakeholders in wildlife conservation. The field officials, NGOs, policy makers, and conservation scientists are important among them. Each one of them has a certain degree of specialized knowledge in conservation and protection of wildlife and can contribute significantly to policy making. The current system of policy making does not include a stakeholder approach and may miss the opportunity of systemic gain from the stakeholder participation in managing wildlife conservation and protection.

Involving stakeholders, who are concerned with wildlife conservation, could be a process of shared learning and self-correcting. Involving stakeholders will improve the base line knowledge for conservation in India.

International conventions such as the CITES and the CBD are the global focal points of shared learning and experiences. To effectively participate in their processes it is important that India strengthens its own national and regional institutions that carry out globally agreed principles and strategies.

Research in wildlife policy development is important as policy development is an evolving and dynamic process. We found that the scientists are not systematically involved in the policy processes and therefore the scientists and policy makers have divergent views on most policy questions.

The PAs in India face immense pressures of demographic development inside the PA and along the fringes. India permits human-wildlife coexistence in its PAs. Human and wildlife coexistence is not easy to manage as human demography is a highly dynamic process. The policy of wildlife and human coexistence in PA could become unstable in the long run as the demographic structure keeps changing along the fringes of the PA. The programs for rehabilitation of the villages from the core and other ecologically sensitive habitats of the PA, to reduce the pressure from within, need to be facilitated.

Our study provided evidence that poaching is facilitated by better infrastructure and is influenced from the outside such as ivory poaching in Mudumalai WS and tiger poaching in Kanha NP. Therefore, the local level trade remains invisible and can be deceptively represented in the official records. Anti-poaching strategies to combat illegal extraction of wildlife, which is the most hidden pressure on PA, will not be effective without a well organized intelligence network involving motivated individuals from among the households. This is possible with a system of incentives and rewards.

Poaching of prey species is as detrimental as the predator as it reduces the food base of the predator. To ensure a healthy prey-predator ratio it is important that special conservation and protection program for the prey species also be initiated along with the predators.

Analysis of trends in poaching, poaching correlations among species, and their spatial association could be vital in improving policy and field level capabilities to counter threats from poaching of wildlife. Scientifically analyzed information will also provide a stronger basis in policy changes for strengthening anti-poaching measures. Poaching should be scientifically monitored. We demonstrated that all poaching and seizures need to be well documented at a fine spatial and temporal scale, which will improve the quality of analysis and confidence in results. We will be able to accurately determine the factors that influence poaching and illegal movements of wildlife. This will, in turn, help in reprioritizing resources for conservation. An optimal anti-poaching strategy will need to include these protocols for greater effectiveness in controlling them.

A constant growth in economy in India and other developing countries have direct impact on illegal demand of wildlife. Therefore, the resources available to law enforcement must match the quantum of threats posed by the economic growth. In our cross-country statistical analysis we found evidence that there is a strong positive relation between GDP per capita and proportion of area under PAs. One aspect that is often neglected is that an increase in GDP in developing countries is associated with a decrease in rural population density and biomass pressures. In developing countries, wildlife managers should try to utilize the positive features of increasing GDP while trying to design mechanisms so that local people can benefit from wildlife conservation, which will, in turn, be more effective.

REFERENCES

Ahmad, A. 1997. Live bird trade in northern India. TRAFFIC and WWF, New Delhi, India.

Bennett, L. E., and G. J. Robinson. 2000. Hunting of wildlife in tropical forests, Environment Department papers. World Bank, Biodiversity series–Impact studies 76.

Bhupathy, S., B. C. Choudhury, F. Hanfee, Kalyar, S. M., M. H. Khan, S.G. Platt, and S. M. A. Rashid. 2000. Turtle trade in South Asia: regional summary (Bangladesh, India and Myanmar) in Asian Turtle Trade. Pages 101-105 in P. P. Van Dijk, B. L. Stuart, and A. G. J. Rhodin, editors. Asian Turtle Trade: Proceedings of a Workshop on Conservation and Trade of Freshwater Turtles and Tortoises in Asia, Phnom Penh, Cambodia, 1-4 December 1999. Chelonian Research Monographs 2.

Bloom, D. A., and J. G. Williamson.1998. Demographic transitions and economic miracles in emerging Asia. The World Bank Economic Review 12:3.

Bolen, E. G., and W. L. Robinson. 1999. Wildlife ecology and management. Fourth edition. Prentice Hall, New Jersey, USA.

Bradley, E. M., and M. Phipps. 1996. A review of the wild animal trade in Cambodia. TRAFFIC Bulletin 16:45-60.

Broad, S., T. Mulliken, and D. Roe. 2002. The nature and extent of legal and illegal trade in wildlife. Pages 3-22 in Sara Oldfield, editor. The trade in wildlife: regulation for conservation. Earth scan, London, United Kingdom.

Chakrabarty, K., A. Kumar, and V. Menon. 1994. Trade in Agarwood. WWF / TRAFFIC India Report, New Delhi, India.

Choudhury, B. C., and S. Bhupathy. 1993. Turtle trade in India: a study of tortoises and freshwater turtles. TRAFFIC/ WWF, New Delhi, India.

Chris, and T. Stuart. 1996. Africa's vanishing wildlife. Smithsonian Institution Press, USA.

Clark, C. W. 1973. The economics of overexploitation. Science 181:630-634.

Convention of International Trade in Endangered Species of Wild Fauna and Flora Decisions. 2003. Decisions of the Conference of Parties to CITES in effect after the 12th meeting, CITES and UNEP, Geneva, Switzerland.

Cooney, R. 2001. CITES and CBD: tensions and synergies. RECIEL 10:2001.

Day, M. 1995. The big cat cover up: the truth behind the Indian tiger crisis. Queensbury, Suffolk, United Kingdom.

Dewett, K. K., and A. Chand. 1986. Modern economic theory. S. Chand, New Delhi, India.

Dublin, H. T., T. Mulliken, and R. F. W. Barnes. 1995. Four years after the CITES ban: Illegal killing of elephants. Ivory and stockpiles. TRAFFIC Bulletin 15:61-62.

Erickson, J. D. 2000. Endangering the economics of extinction. Wildlife Society Bulletin. 28:34-41.

Freese, C. H., and D. L. Trauger. 2000. Wildlife markets and biodiversity conservation in North America. Wildlife Society Bulletin 28:42-51.

Friedman, D., and D. N. Ostrov. 2008. Conspicuous consumption behavior. Games and Economic Behavior 64:121-145.

Gossling, S. 1999. Ecotourism: a means to safeguard biodiversity and ecosystem function? Ecological Economics 29:303-320.

Gowdy, J. M. 2000. Terms and concepts in ecological economics. Wildlife Society Bulletin 28:26-33.

Gupta, B. K. 2007. Wildlife in the crosshairs. Science Reporter 43:11

Hall, A. S. C., W. P. Jones, T. M. Donavan, and J. P. Gibbs. 2000. The implications of mainstream economics for wildlife conservation. Wildlife Society Bulletin 28(1):16-25.

Hanfee, F. 1998. Wildlife trade: a handbook for enforcement staff. TRAFFIC- WWF, New Delhi, India.

Hillstrom, K., and L. C. Hillstrom. 2003. Asia: a continental overview of environmental issues. ABC-CLIO, California, USA.

Homer, J. B., 1996. Why we iterate: scientific modeling in theory and practice. System Dynamics Review 12:1-19.

Isaacs, J. C. 2000. The limited potential of ecotourism to contribute to wildlife conservation. Wildlife Society Bulletin 28:61-69.

Jain, P. 2001. Project Tiger Status Report, Ministry of Environment and Forests, New Delhi, India.

Kenney, J., L. James, D. Smith, A. M. Starfield, and C. W. McDougal. 1995. The long term effects of Tiger Poaching on Population Viability. Conservation Biology 9:1127-1133.

Leakey, R., and V. Morell. 2001. Wildlife wars: my fight to save Africa's natural treasures. Macmillan Press, London, United Kingdom.

Le Gallo, J., and C. Ertur. 2003. Exploratory spatial data analysis of the distribution of regional per capita GDP in Europe, 1980-1995. Papers Regional Science 82:175-201.

Lee, J., J. A. List, and M. C. Strazicich. 2006. Non-renewable resources prices: deterministic or stochastic trend? Journal of Environmental Economics and Management 51:354-320.

Marshall, N.T. 1998. Searching for a cure: conservation of medicinal wildlife resources in east and southern Africa. TRAFFIC International. Cambridge, United Kingdom.

Myers, N. 1979. The sinking ark: the new look at the problem of disappearing species. Pergamon Press, United Kingdom.

Maccarthy, T., and A. Dorfman. 2004. Nowhere to roam, Wildlife reserves alone cannot protect big cats: A look at the new ways to save them. TIME (August) 2004: 44-53.

Mackenzie, J. M. 1988. The empire of nature: hunting, conservation and British imperialism. Manchester University Press, United Kingdom.

Menon, V., R. Sukumar, and A. Kumar. 1997. A God in distress: threats of poaching and the ivory trade to the Asian elephants in India. Asian Elephant Conservation Center and Wildlife Protection Society of India, New Delhi, India.

_____, and A. Kumar. 1998. Signed and sealed: the fate of the Asian elephants. Asian Elephant Conservation Center and Wildlife Protection Society of India, New Delhi, India.

_____. 2002. Tusker: the story of the Asian elephants. Penguin Enterprise with WTI and IFAW, New Delhi, India.

Ministry of Environment and Forests 1972. Wildlife Protection Act 1972. Government of India, New Delhi, India.

Mishra, M. 2002. Evolution, impact, and effectiveness of domestic wildlife trade ban in India. Pages 78-88 in Sara Oldfield, editor. The trade in wildlife: regulation for conservation. Earth Scan, London, United Kingdom.

Moulton, M. P., and J. Sanderson. 1997. Wildlife issues in a changing world. St. Lucie Press, Florida, USA.

Myers, N. 1979. The sinking ark: the new look at the problem of disappearing species. Pergamon Press, United Kingdom.

Nash, V. S., editor. 1997. Still in Business: the ivory trade in Asia, seven years after the CITES ban. TRAFFIC Network Report, Cambridge, United Kingdom.

Nelson, F. 2000. Sustainable development and wildlife conservation in Tanzanian Massailand. Environment, Development and Sustainability 2:107-117.

Oldfield, S., editor. 2002. The trade in wildlife: regulation for conservation. Fauna and Flora International, Resource Africa and TRAFFIC International, Cambridge, United Kingdom.

O'sullivan, and D. J. Unwin. 2003. Geographic information analysis. John Wily and Sons, New Jersy, USA.

Rangarajan, M., and G. Shahabuddin. 2006. Displacement and relocation from protected areas: towards a biological and historical synthesis. Conservation and Society 4:359-378.

Reeve, R. 2002. Policing international trade in endangered species: the CITES treaty and compliance. The Royal Institute of International Affairs, London, United Kingdom.

Roe, D., T. Mulliken, S. Milledge, S. Mosha, J. Mremi, and M. Grieg-Gran. 2002. Making a killing or making a living? Wildlife trade, trade controls and rural livelihood. Biodiversity and Livelihood 6, TRAFFIC, Cambridge, United Kingdom.

Ruiz, M., C. Fernandez, and T. Young. 2003. Regional Workshop on the synergies between the Convention on Biological Diversity and the CITES regarding access to genetic resources and distribution of benefits: The role of the certification of origin. A Preliminary Report (November):17-18.

Saeed, K. 1996. Sustainable development: old conundrums, new discords. System Dynamics Review 12:59-80.

Sinclair-Brown, N. 2002. Regulatory design. Pages 33-40 in Sara Oldfield, editor. The trade in wildlife: regulation for conservation. Earthscan, London. United Kingdom.

Stewart, A. J. A., and M. J. Hutchings 1996. Conservation of populations. Pages 120-140 in Ian F. Spellerberg, editor. Conservation biology. Longman, Essex, United Kingdom.

Stuart, C., and T. Stuart. 1996. Africa’s vanishing wildlife. Smithsonian Institution Press, Washington D.C., USA.

Sukumar, R., U. Ramakrishnan, and J. A. Santosh. 1998. Impact of poaching on an Asian elephant population in Periyar, southern India: a model of demography and tusk harvest. Animal Conservation 1:281-291.

Swaminathan, S. S. A. 2001. India outperforms the tigers. Economic Times. October 29:9.

Terborgh, J. 1999. Requiem of nature. Island Press, Washington D.C., USA.

Thapar, V. 2003. Battling for survival: India’s wilderness over two centuries. Oxford University Press, New Delhi, India.

Van Djik, P. P. 1999. The status of turtles in Asia: Asian Turtle Trade. Proceedings on Conservation and Trade of Freshwater Turtles and Tortoises in Asia. Pages 1-15 in P. P. Van Dijk, B. L. Stuart, and A. G. J. Rhodin, editors. Asian Turtle Trade: Proceedings of a Workshop on Conservation and Trade of Freshwater Turtles and Tortoises in Asia, Phnom Penh, Cambodia, 1-4 December 1999. Chelonian Research Monographs 2.

Virmani, A. 1997. Potential stars of the 21st century: India, China and the 'Asian Century'. Occasional Paper 15. ICRIER, New Delhi, India.

Virmani, A. 1999. Star performers of the 20th (21st) century: Asian tigers, dragons or elephants. Occasional paper, China, September 2000.

_____. 2002. Star performers of the 20th (21st) century: Asian tigers, dragons or elephants. Occasional paper, China, September 1999.

_____. 2004. Economic performance, Power, potential and global governance: towards a new international order; ICRIER Working Paper 150, December 2005.

Wagener, A. 2001. Endangered species: traded to death. Earth Trends: World Resources Institute, Washington, USA.

Weddell, B. J. 2002. Conserving living resources: in the context of changing world. Cambridge University Press, London, United Kingdom.

Worester, D. 1993. The wealth of nature: environmental history and the ecological imagination. Oxford University Press, New York., New York, USA.

Wood, A., P. Stedman-Edwards, and, J. Marg. 2001. The root cause of biodiversity loss. Earthscan, London, United Kingdom.

World Bank. 2007. World Development Indicators 2007 CD. Washington D. C., USA.

World Bank. 1997. China 2020: development challenges in the new millennium, Oxford University Press, New York, New York, USA.

World Bank. 1993. The East Asian miracle: economic growth and public policy: a public policy research report. Oxford University Press, New York, New York, USA.

World Bank 2007. The World Bank indicators. Washington D.C., USA.

World Conservation Union. 2000. IUCN red list of threatened animals, Gland, Switzerland.

APPENDIX A. DRAFT MANUSCRIPT TO BE SUBMITTED TO THE JOURNAL OF WILDLIFE MANAGEMENT.

NIRAJ, S. K., P. R. KRAUSMAN, AND V. DAYAL. A STAKEHOLDER PERSPECTIVE INTO WILDLIFE POLICY DEVELOPMENT IN INDIA.

8

30 January 2009
Shekhar K. Niraj
School of Natural Resources
University of Arizona
Tucson, Arizona 85721
(520) 621-7255; Fax (520) 621-8801; Email shekhar.niraj@gmail.com

RH: Niraj et al.• Wildlife Policy Development

A STAKEHOLDER PERSPECTIVE INTO WILDLIFE POLICY DEVELOPMENT IN INDIA

SHEKHAR K. NIRAJ[1,2], School of Natural Resources, Biological Sciences East Building, University of Arizona, Tucson, AZ 85721, USA

P. R. KRAUSMAN[3], School of Natural Resources, 325, Biological Sciences East Building, University of Arizona, Tucson, AZ 85721, USA

VIKRAM DAYAL, Institute of Economic Growth, University of Delhi Enclave, North Campus, Delhi 110007, India

ABSTRACT Wildlife policies in India have not been adequate to control poaching and illegal wildlife trade. We investigated both problems through questionnaire based surveys with 148 individuals among 4 stakeholders in wildlife conservation: policy makers, conservation scientists, non-governmental organizations (NGOs), and field officials.

---

[1]Corresporndding author e-mail: shekhar.niraj@gmail.com

[2]Present address: Indian Forest Service, Conservator of Forests (Tamil Nadu Afforestation Project 1), 8 D, Panagal Building, 1 Jeenis Road, Saidapet, Chennai 600015, India

[3]Wildlife Biology Program, 32 Campus Drive, University of Montana, Missoula, Montana 59812, USA

There were significant differences among stakeholders in identifying major threats to wildlife, use of science, role of poaching in conservation and composition of species in illegal trade. Policy processes use a rigid top-down approach and are largely non-inclusive. Policy makers and field officials differed in their views with NGOs and scientists on impact of economic growth on poaching, community response and varying threat perceptions to different species. There was ambiguity among stakeholders about sustainable use principles in India. Policies have to be more effective in conservation and the process of making policies needs to be broad-based and participatory. Involving all stakeholders will improve the base line knowledge for conservation in India.

KEY WORDS biodiversity conservation, India, poaching, stakeholders, sustainable use, wildlife policy, wildlife trade

The Journal of Wildlife Management: 00(0): 000-000, 2009

Developing wildlife policy in India has evolved since 1865 during the British occupation of the subcontinent (Rosencrantz et al. 1991, Thapar 2003, Rangarajan 2006). However, prior to independence in 1947 conservation of wildlife was not an important national concern but an emphasis was placed on timber production (Rosencrantz et al. 1991). Since the 1970s, with a noticeable decline of the tiger (*Panthera tigris*) population (i.e., from an estimated 40,000 in the 1900 to ≥ 1000;Kenney et al. 1995, Hillstrom and Hillstrom 2003, Narayan et al. 2005, Damania et al. 2008), there has been a shift in conservation priorities. Project Tiger (PT), an exclusive program to conserve tiger populations, was established in 1973, which started with programs and strategies to conserve the tiger. Since the inception of PT, conservation efforts (e.g. establishing tiger reserves [TR], conducting long term field research, mapping and monitoring tiger habitat and population distribution) have enhanced the population. Beginning in 1990, however, there was an increase in poaching pressure across the species range from Siberia to India (Kenney et al. 1995, Thapar 2003, Mishra 2004). This decline in the tiger population and increase in poaching was instrumental in the evolution of wildlife policy in India.

The evolution of wildlife policy in India can be divided into 3 phases: 1947-1970, 1971-1990, and 1990-present. The first phase generally ignored wildlife, most conservation policies were the subsets of the national forest policy. During 1973-1990 major initiatives were established to protect tigers, crocodiles (*Crocodylus porosus*) and to develop a network of protected areas (PAs). Protected areas are constituted to conserve biodiversity, natural resources and associated cultural values, and managed legally or through other effective means (Weeks and Mehta 2006). National wildlife action plans were developed to emphasize wildlife conservation. The last phase was the most dynamic as it addressed the problems affecting wildlife influenced by poaching (Mishra 2002), habitat loss, and increasing human-wildlife conflicts.

As the negative anthropogenic influences on India's wildlife increased, the policy to mitigate theses impacts was uncertain, fluid, and under stress. In 1991, a complete ban on trade and hunting of wildlife was a major amendment to the Wildlife Protection Act of (WPA) in India. A new schedule was added to the WPA to protect certain plant species. The policies emphasized the involvement of people in conservation and community participation became the key word. A major amendment of the WPA schedules in 2002 included whale sharks (*Rhincodon typus*), mollusks and crustaceans to the list of protected species. In amendments to WPA in 2003, the punishment for wildlife crimes was enhanced (WPA Amendment Act 2003, Mishra 2004, Damania et al 2008). The new initiatives in wildlife expanded the PA network in 2007 to include 99 national parks (NP), 513 wildlife sanctuaries (WS), 41 conservation reserves, and 4 community reserves (Ministry of Environment and Forests [MoEF] 2007-08). All 4 are categories of PAs in India and were established for biodiversity under different sections of the WPA. A NP has the highest legal protection (e.g., grazing is not permitted) followed by WS where grazing could be permitted. The conservation and community reserves are new initiatives through amendments to the WPA in 2003 to encourage community and individual participation in conservation (WPA 1972). The National Wildlife Action Plan (2002-16) emphasized people's participation in wildlife conservation (MoEF 2007-08).

India remained active with Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES) and Convention of Biological Diversity (CBD) to maintain international conservation. The CITES and CBD support sustainable use as a more effective means to conserve wildlife than by enforcement alone. Convention of International Trade in Endangered Species of Wild Fauna and Flora and CBD began efforts for synergizing their efforts for more effective conservation across the world (Cooney 2001, Jenkins 2004). Within India, however, CITES and CBD were not considered in the policy framework.

Since 1990, the number of NGOs increased and they have become an important pressure group to influence policy related to wildlife conservation at the national level in India. There was an increase in wildlife research and wildlife issues became important for public discourse nationally and internationally. At the same time tigers were eliminated from Sariska (a TR), and became critically low in other tiger reserves (Narayan 2005, Damania et al 2008). A new law was also passed in India (i.e., Tribal Bill [Recognition of Forest Rights] 2005). This intended to give property and livelihood rights to the forest dwellers inside reserves and protected forests. The Tribal Bill was opposed by conservation NGOs and scientists because it would lead to additional loss of habitats and an increase in human-wildlife conflicts. However, in important policies such as these the stakeholders did not seem to be involved.

Stakeholders are important in contemporary society and there is a worldwide interest in involving them in policy processes (Oldfield 2003). In addition, industry and community (Schmidt-Soltau 2004) should also be important stakeholders in India's forests because PA and forests overlap (Taneja 2001). We identified 4 key stakeholders for our survey that emphasized involvement in wildlife management and shared learning (Riley et al. 2003): field officials, NGOs, policy makers and conservation scientists. The field officials implement policies and enforce laws and regulations including CITES (Menon and Kumar 1998). The NGOs are actively involved in conservation and in detecting illegal wildlife activities. The policy makers are the officials, present or past, with the central and state governments who are responsible to develop policies for wildlife conservation in India. The conservation scientists, who are actively involved in research concerned with biodiversity conservation, formed another stakeholder group that we included in our surveys.

Our objectives for the survey were to assess the perceptions of the 4 key groups of stakeholders. We wanted to better understand 4 issues.

1. The key problems that threaten wildlife conservation in India.

2. Whether there is a collective thinking and collective approach in efforts for solving these problems.
3. Whether wildlife policy development in India is an inclusive process.
4. Whether approach including different stakeholders will lead to a more effective policy framework.

METHODS

We used pre-structured questionnaires with most questions common to the 4 groups and some specific to professional interests of individual stakeholder groups. Although, to meet the above objectives the questionnaire could include more questions, there was a likelihood of this resulting in a large non-response rate (Adams and Darwin 1982, Roszkowski and Bean 1990, Singleton et al. 1993).

Addresses of stakeholders were obtained from the records maintained by MoEF and through the internet, which was one effective source to get the contact addresses (Dillman 2007). We sent the questionnaires to all field officials, who implement the CITES and WPA (i.e., about 20 of the present and past officials), and to other field officials, who were involved in anti-poaching and seizure operations jointly with CITES officials on different occasions. We obtained the list of the policy makers, past and present, from the MoEF, and sent the questionnaires to 45 of them. The contact addresses of the conservation scientists were obtained from the databases of scientific institutions in India from their websites. We also sent the questionnaires to the heads of scientific institutions inviting wider response. Similarly, we obtained the addresses of NGOs, active in conservation, from the databases of MoEF, regional CITES offices, and NGO websites. We sent questionnaires to all 40 of them. The NGO questionnaire was also placed on discussion websites (e.g., Nathistory) by some of the respondents inviting wider response (Dillman 2007).

The responses were received by mail and electronically, and in few cases, personally. The responses were classified and converted into binary response variables. We tested differences between different groups of stakeholders using logistic regressions. Responses from stakeholders were binary variables, which helped in easing respondent recall and would have reduced errors. Taking into account the binary nature of the responses, we used logistic regressions to statistically test for differences in variables among stakeholders (Deaton 1997, Verbeek 2004). Our specification for logistic regression was:

$$P\{y_i = 1 \mid x_i\} = F(x_i'\beta) = \frac{e^{x'\beta}}{1+e^{x'\beta}}$$

where, P denotes probability, y is the dependent variable, i denotes the ith observation, x is a vector of independent variables, F is the standard logistic distribution function, β is the vector of regression coefficients, $e^{x'\beta}$ is the exponential function applied to x'β, with e = 2.718. Our independent variables were dummy variables for 3 of the 4 stakeholders. The statistical significance of the coefficients on the dummy variables is a test for statistical significance of the difference between the stakeholder represented by the dummy and the base stakeholder (on the y-axis). The Change in probability (Δ) is the difference in probability of y = 1 between categories represented by the dummy and the base category, holding other variables at the mean value.

We used each thematic question as a variable (Appendix 1- 4). We computed the response rate by counting the responded cells in the response matrix and calculated the percentage.

In the policy case study, we examined the files at MoEF in New Delhi. We collected time series data on seizures of sea cucumbers (*Holothurians* spp.) and budget allocations on wildlife and forestry from MoEF and regional CITES enforcement office at Mumbai.

RESULTS

The response rate was >95% for all 4 groups surveyed; 95.2% (n = 35), 97.2% (n = 38), 99% (n = 40) and 99.3% (n = 35) for NGO, scientists, field officials and policy makers, respectively.

How Adequate are Wildlife Policies in India in Controlling Poaching and Illegal Trade?

Scientists and NGOs agree that that the policies in India do not control illegal trade and poaching (Fig.1). Less than 25% of policy makers and field officials stated that the wildlife policies are adequate, but implementation of policy is poor (Fig. 2). A majority of policy makers (>77%) responded that India's conservation policies have been strengthened since 1990. This view is least shared by scientists (Fig.3).

The likelihood of a scientist agreeing that policy is adequate to control poaching and illegal trade is much less than that of a policy maker (Coefficient = -3.673, $P \leq 0.001$, change in probability Δ = -.5937). Non-governmental organizations also disagreed (Coefficient = -1.045, P = 0.047, Δ = -0.231) that the policies have been made stronger since 1990, but to an extent less than field officials (Coefficient = -1.519, P = 0.003, Δ = -0.323).

Major Threats to Wildlife Conservation in India

Habitat destruction is considered a major threat to wildlife by most stakeholders: 84, 88, 67.5 and 72% of scientists, policy makers, field officials and NGOs, respectively. The probability of a field official, NGO, or a scientist considering this as an important threat to wildlife is less than that of a policy maker and is statistically significant between the field officials and policy makers (P = 0.036; Table 1).

Non-governmental organizations considered poaching as a greater threat to wildlife (>74%) than the other 3 stakeholders. However, 50% of field officials and scientists considered poaching a major threat to wildlife in India. Among policy makers > 62% considers poaching a major threat to wildlife. The likelihood of a field official or a scientist associating with poaching as a major threat is lower than a policy maker. The likelihood of considering poaching and illegal trade as major threat is higher for an NGO than the policy maker (Table 1). The field officials and NGO consider lack of resources for wildlife conservation as a major threat than a policy maker will, a scientist will not likely consider lack of resources being a major threat and is statistically significant (P = 0.046; Table 1). In fact, very few scientists (18%) considered lack of infrastructure a bottleneck in effective implementation of wildlife policies and controlling poaching. Most field officials (58%) agree that lack of infrastructure is a deterrent to wildlife conservation in India. The NGO and scientists will likely consider poor policy on wildlife as a major threat than a policy maker will likely do (Table 1). A NGO also considers unscientific management of wildlife an important threat more than a policy maker. A NGO will more likely include a number of other threats to wildlife conservation in India than a policy maker (Table 1). Non-governmental organizations included political and bureaucratic corruption, inefficiency, and lack of awareness among other threats to wildlife.

Is Wildlife Conservation a Government Priority?

Field officials, policy makers, NGOs and scientists stated 37, 45, 60 and 73%, respectively, that there was low priority for wildlife conservation in India, and was not significantly different among the stake holders. However, the majorities of scientists and NGOs did not consider wildlife conservation a government priority.

Scientific Approach in Wildlife Policy and Management

A majority of the scientists (55%) view wildlife policies and management in India lacking a scientific approach, which creates deterrence to conservation. This is not an issue with policy makers (8.6%). In contrast, none of the field officials considers threats caused by an unscientific approach in management and in conservation. Fewer scientists than the policy makers admitted that there are enough scientific inputs in policy making (Coefficient = -1.731, $P = 0.002$) or that there was adequate participation of scientists in policy making process (Coefficient = -1.099, $P = 0.025$).

Is Poaching an Important Factor in Conservation?

Nearly all stake holders consider poaching an important detrimental factor in wildlife conservation (Fig. 4). The likelihood of an NGO (Coefficient = 1.587, $P = 0.057$, $\Delta = 0.1269$) or a scientist (Coefficient = 1.674, $P = 0.044$, $\Delta = 0.1358$) considering poaching an important factor detrimental to wildlife populations is higher than a policy maker and is statistically significant. Likelihood of a field official to recognize this, however, is less than a policy maker (Coefficient = -0.118, $P = 0.828$, $\Delta = -0.0127$)

All NGOs stated that poaching has increased since 1990 in contrast to only 50% of policy makers (Fig. 5), and 67% of field officials. The likelihood of an NGO reporting wildlife poaching has increased since 1990 is higher than a policy maker and is statistically significant (Coefficient = 1.019, $P = 0.034$).

How Does Wildlife Policy Relate to Human Communities?

Most (57%) policy makers do not agree that there is any institutionalized process of community involvement in developing policies. Some (16%) who indicated there was an institutionalized process pointed to the involvement through the national board for wildlife, which has a cross sectional representation. Some (11%) of the respondents suggested that the methods are indirect such as representations in the state wildlife advisory boards in various states and through the system of appointing honorary wildlife wardens. Few policy makers (7%) stated that local communities are involved through the institution of Joint Forest Management and Eco-development Committees. Some (7%) also suggested that all policy changes are placed on public domain for comments.

A NGO will more likely state that wildlife policy is not sensitive to the communities' aspirations (Table 2). However, field officials and conservation scientists have a higher likelihood than the policy makers of reporting wildlife policy is responsive to community's aspirations. Both NGOs and scientists considered that the nature of response of policies to social communities affect the level of conservation (Table 2).

We evaluated stakeholders' rating of success of conservation policies since 1992 (Table 2). The likelihood of a NGO or a scientist awarding a low rate of success to government policies or the government's efforts in conservation since 1992 on a 1-10 scale (1 = highest and 10 = lowest) is significantly higher than a policy maker (Table 2).

Problems at the Implementation Level

The majority of scientists (73.7%) and some NGOs (37.2%) reported that wildlife policy is poorly implemented in India. The likelihood of a scientist viewing that that poor implementation of the laws and policies are the chief cause for policy failure is higher than a policy maker (Coefficient = 1.556, $P = 0.002$, $\Delta = 0.365$). Majorities of scientists (55.3%) and NGOs (62.9%) suggested that policies and laws are also inadequate to deal with the problems in present circumstances. Some scientists (44.7%) and NGOs (48.6%) stated inadequate infrastructure with the enforcement and implementing agencies as problems at the implementation level but the differences between a scientist or an NGO from a policy maker is not statistically significant. A majority of scientist (52.6%) and NGOs (60%) viewed bureaucratic inefficiency and corruption as deterrents to effective implementation of wildlife laws and policies in India. Scientists (84%) and NGOs (71%) also stated many other problems in effective implementation of law and policy, which included lack of involvement of local communities in conservation, lack of awareness of wildlife among people, poorly equipped and ill-trained enforcement officials with lack of motivation, political interference, poorly defined policies, poor science in management, slow judicial action, and low conviction rates.

Enforcement

We examined the views of policy makers and field officials on problems with enforcement of wildlife laws in India. The field officials (87.5%) and policy makers (40%) reported poor infrastructure as a major problem in the implementation of wildlife laws and policy.

A majority of field officials(52.5%) and some policy makers (11%) considered policies and laws as inadequate to handle the ground level problems and the difference is statistically significant (Coefficient = 2.148, $P < 0.001$). Policy makers (46%) and field officials (32.5%) also stated low political priority for wildlife conservation a problem in poor implementation of laws and policies. A similar proportion of policy makers (34%) and field officials (32%) viewed lack of awareness among the masses as a problem in implementation of law and policy. Policy makers (49%) and field officials (62.5%) also stated other reasons for the problem of enforcement of wildlife laws. These included lack of resources and funds, lack of coordination among various agencies dealing with implementation of laws and policies, poverty and population pressure, low prosecution and conviction rates, and lack of training and inadequate infrastructure at enforcement levels. A field official will likely assign a high rank to the need for scientific support (e.g., forensic laboratories and research support for the wildlife enforcement units; Coefficient [for dummy on a 1-5 scale, where 1 = highest, 5 = lowest] = -2.674, $P < 0.001$).

Can Sustainable Use Support Biodiversity Conservation in India?

Among the NGOs, policy makers and conservation scientists, 80, 77 and 74%, respectively, opposed the idea of practicing sustainable use of wildlife in India. Most field officials (60%) admitted that sustainable use could be useful in conservation management (Coefficient = 1.622, $P = 0.002$, $\Delta = 0.37$). Some (40%) policy makers, however, suggested that sustainable use could be practiced in India only for certain species on which sufficient scientific data have been generated. In contrast, only 5 (13%) scientists supported sustainable use of wildlife in India (Coefficient = -1.269, $P = 0.02$, $\Delta = -0.18$). Non-governmental organizations (57.1%), policy makers (60%) and scientists (60.6%)

viewed sustainable use policy as impracticable in India, while only 25% of field officials suggested the same. Among the field officials (77.5%), policy makers (77%), NGOs (69%), and scientists (55%) reported that sustainable use in India was not feasible due to the lack of effective monitoring and regulatory mechanism. The likelihood of a policy maker reporting that inadequate scientific protocols developed for wildlife management in the country could be the main deterrent to practicing sustainable use in wildlife, is higher than scientists, NGOs, and field officials (Table 3). The probability of a policy maker stating that there is not enough research conducted in applied aspects of wildlife science that could be useful for management, is significantly higher that a scientist (Coefficient [for dummy on a 1-5 scale, where 1 = highest, 5 = lowest] = -2.920, $P \leq 0.001$, $\Delta = -0.580$).

Sustainable harvest as a management tool.— Overall, only 25% of stakeholders who reported that sustainable use will be useful associated with sustainable harvest as a good management tool ($\chi^2_3 = 69.52$, $P < 0.001$). The likelihood of a field official reporting that sustainable harvest will work for better conservation is significantly higher than a policy maker (Table 3), but will not be useful as a wildlife management tool. A policy maker is more likely to report that sustainable harvest could be useful as a management tool than a scientist, field official, or a NGO and is significantly different between the policy maker and the NGO (Table 3). Likelihood of a policy maker suggesting it will work only selectively with species (e.g., wild flora) is significantly higher than field officials ($P < 0.001$) and NGOs ($P = 0.008$). The likelihood of reporting sustainable harvest could be useful in wildlife management is higher for a policy maker than the other 3 stakeholders (Table 3). The role of policy makers in the following case contradicted this position and highlighted 3 issues; the process of policy amendment followed in India, non-involvement of stakeholders (e.g., fishing community), and a mindset against using sustainable use principle without scientific and socio-economic considerations.

Case Study on Sea Cucumber (*Holothurians* spp.).**—**All edible species of sea cucumber harvested by the fishing communities along the coasts in the Indian Ocean (Ngoile and Francis 2001, Conand 2004) and in Indian seas (Asha and Muthaiah 2007) were included in WPA 1972 in a major amendment in 2002, thus prohibiting the harvest of sea cucumbers. There was no consultation with the fishing communities. The process of amendment was initiated on the recommendation of an environmentally activist minister from another ministry (Fig. 6). Due to opposition by the fishing communities, as it affected their livelihood, the MoEF began a process of review of its own decision along the line that it conflicted with the livelihood of the fishermen communities; about 500,000 of them (based on the MoEF files) lived along the coasts and depended on coastal resources in southern India. Sea cucumber is not a protected or regulated species under CITES. However, the process of review of the ministry was turned down by its standing committee, with a presence of NGOs and scientists continuing the ban on its fishing. The ban also escalated illegal trade in the species (Appendix 5). The process followed in this major policy change (Fig. 6) demonstrates that resource users were rarely considered but the policies were imposed upon them.

Sustainability Issues and CBD Implications in India

Only 7% of field officials reported that an effective coordination has been made at the national and state levels to achieve the CBD objectives (e.g., sustainable use, equity and equitable sharing of biodiversity produces) in India, whereas none of NGOs and only 5%

of scientists reported a credible effort of coordination having been made at any level in India. Among policy makers (26%) stated that the efforts have been good. In contrast 37.5% of the field officials, 26% of NGOs, 49% of policy makers, and 50% of conservation scientists reported that no effort has been made to implement CBD principles in India. The likelihood of reporting that good efforts of coordination have been made to achieve the CBD objectives in India is less for a field official (Coefficient = -1.451, P = 0.042) and for a scientist (Coefficient = -1.829, P = 0.026) than a policy maker. A NGO is likely to be emphatic that no efforts have been in India for CBD implementation (Coefficient = -1.004, P = 0.051, Δ = -0.222). A policy maker is less likely to state that the CBD principles are impractical for India than a field official (Coefficient = -0.176, P = 0.745) and a scientist (Coefficient = -0.109, P = .841), but a NGO will more significantly state that CBD objectives are not implementable in India (Coefficient = -1.004, P = 0.051, Δ = 0.223). Among the stakeholders, only policy makers reported that some concrete efforts, although inadequate, have been made for implementing the sustainable use principles under the CBD. A field official (Coefficient = 0.313) or an NGO (Coefficient = 0.256) is also less likely aware of CBD related development in India than a policy maker.

Relevance of CITES and CBD in India

All policy makers and 72.5% of field officials reported non-existence of an exclusive CITES legislation in India. Among field officials, 22% reported that there is a separate CITES Act in India and 5% did not respond. Among the field officials 45% admitted that CITES has remained ineffective in India since 1990, while 25% reported CITES has been an average achiever in India. Only 22% of field officials rated CITES effectiveness as high. Among the policy makers, 40% believed that CITES performance in India has been poor, about 17% reported an average performance and > 25% reported that CITES has been highly effective in India. The likelihood of a field official considering CITES as highly effective trade regulatory instrument in India is lower than a policy maker (Coefficient [using dummy variable for a scale of 1-10, 1 = highest; 10 = lowest] = 0.025, P = 0.662, Δ = 0.05).

Does the Emerging Economic Scenario Tend to Influence Wildlife Policy Making?

Among field officials, NGOs, policy makers, and scientists, 70, 82.7, 51.4, and 60.5%, respectively, stated that the sustained economic growth in India since 1992 has been making significant impact on wildlife conservation. Field officials (Coefficient = 0.790, P = 0.102, Δ = 0.1493) and scientists (Coefficient = 0.597, P = 0.215, Δ = 0.1149) have a higher likelihood than a policy maker of reporting that increasing economic growth has noticeable impact on wildlife conservation and illegal demand on wildlife. The likelihood of an NGO reporting positive to this impact is also significantly higher than a policy maker (Coefficient = 1.119, P = 0.002, Δ = 0.3135). In response to this, about 27% of policy makers reported that wildlife polices have been adequately modified to respond to new challenges posed by sustained economic growth since 1992. However, 28.6% of policy makers asserted that the response has been adequate to deal with emerging economic growth, while a majority (60%) reported that the response has been poor to deal with new challenges from a growing economy. Overall, 21% of all stakeholders who reported that the policy is stronger since 1990 associated with the argument that the policy response is adequate to deal with the new economic impact (χ^2_1 = 40.6984, P < 0.001).

Diversity of Species in Trade and Poaching from India

About 87% of field official, policy maker and scientists, and all NGOs reported tiger as a major species in trade and poaching. The probability that a field official will consider tiger as a species threatened by poaching for illegal trade is significantly less than that of a policy maker (Table 4a). A majority of the stakeholders (71%) reported leopard (*Panthera pardus*) as another species which is commonly poached for illegal trade. All NGOs will likely include leopard as a species that faces serious threats from poaching and illegal trade more so than a policy maker (Table 4a). Poaching of elephants (*Elephas maximus*) for ivory is also reported by 74% of the stakeholders. Though, a NGO or a conservation scientist has as much of a probability as a policy maker to include elephants as the species that is facing serious threat from illegal harvest, a field official has less likelihood to do so. For the great Indian rhino (*Rhinoceros unicornis*), a field official has less likelihood than a policy maker to identify as a species facing imminent threat due to poaching (Table 4a). Field officials and scientists will have marginally higher likelihood than a policy maker of considering the Tibetan antelope (*Pantholops hodgsonii*) as being under serious threat of poaching. The NGO and field officials will have higher likelihood than policy makers of considering birds threatened by poaching for illegal trade. A NGO will likely include bears as trade-threatened species than a policy maker will likely do, whereas a field official or a conservation scientist will less likely consider bears.

The field officials, NGO and conservation scientists have higher likelihood than of policy makers of listing Asiatic lion (*Panthera leo persica*) as a species that faces threat of poaching and illegal trade. An NGO has a much higher probability, and statistically significant, than that of a policy maker of considering otter (*Lutra perspicillata*) as a species targeted by the illegal harvesters for its fur (Table 4a). Otter is mentioned by 40% of the NGOs, and has a significantly higher likelihood than a policy maker. Only 16% of the other 3 stakeholders considered otter poaching significant. A NGO or a scientist has greater likelihood than policy makers or field officials of considering snow leopard (*Uncia uncia*) and clouded leopard (*Neofelis nebulosa*) to be facing a serious threat from illegal harvest.

For all the deer species, and particularly a musk deer (*Moschus moschiferus*), a policy maker will have higher probability than the other 3 stakeholders of reporting their threat due to poaching and trade (Table 4a). For smaller species such as mongoose (*Herpestes javanicus, H. vitticollis and H. edwardsii*) and butterflies the NGO and conservation scientists have greater likelihood of including them in the list of poaching affected species than a policy maker. A NGO or scientists will also likely report a number of other species threatened by illegal trade more than the other 2 groups.

Among the plants, 11% of NGOs listed orchids (fam. *orchidacae*) as facing pressure of illegal trade while 21% of policy makers and field officials considered orchids subjected to illegal trade. Among all 4 stakeholders, only a conservation scientist will have higher probability than a policy maker of listing orchids as threatened by illegal harvest (Table 4b).

Only 8% of NGOs considered red sanders (*Pterocarpus santalinus*) and sandal wood (*Santalum album*) and only few stakeholders considered medicinal plants as threatened by illegal harvest (Table 4b). The likelihood of considering marine species, other than shells and corals, as trade-threatened is greater among NGOs and scientists than among policy makers (Table 4c). A field official perceives shells and corals as threatened (Table 4c).

Scientists have also reported a greater diversity of species such as marine arthropods, marine turtles, fruit bats, coral fishes, sea horses, sharks, tarantulas, beetles, lion-tailed macaque (*Macaca silenus*), Coleopterans, mygalomorph spiders, as facing poaching or trade threats and have also reported concern about several bird species including white-rumped swiftlet (*Apus caffer*), great pied hornbill (*Buceros bicornis*), and hill myna (*Gracula religiosa*).

The majority of policy makers and field officials considered wildlife policies as adequate in dealing with all challenges including poaching and illegal trade. The scientists and NGOs believed wildlife policies in India are poor and did not control illegal trade and poaching. Non-governmental organizations more than the other 3 stakeholders believed poaching is the biggest threat to wildlife in India. Field officials, more than the other 3 stakeholders, considered lack of resources a bottleneck in implementing law and policy in India. Policy makers do not seriously consider there is greater need of scientific inputs in policy development to make them more effective. Scientists are concerned about the low priority given to wildlife conservation in India and the low scientific inputs in policy development. They are also concerned about non-involvement of scientists in serious policy reviews. The stakeholders were ambiguous about sustainable use principles in biodiversity. Non-governmental organizations and scientists are highly skeptical about its usefulness in India. Development related to CBD in India has been poor with no involvement of the scientists and NGOs at the national or state levels. Policy makers do not take a serious view of the challenges posed by sustained economic growth on wildlife conservation in India including more illegal demand on species for trade. The NGOs remained focused on tiger, leopard and other charismatic species in their concern for conservation. The scientists stated their concern for several other species that are facing serious concern of poaching for illegal trade. The policy development has not been able to use the scientific knowledge developed by conservation scientists.

DISCUSSION

Conservation scientists have studied species in India and have become an important stakeholder in conservation. Though NGOs associated with conservation in 1990s, they have become proactive since 1998. Policy makers conduct all works related to policy changes, whereas field officials are responsible for implementing them. Wildlife policies in India have been repeatedly amended since 1980. However, there is no defined mechanism for monitoring their implementation in the field and assessing their success in reaching objectives. Therefore, though the policy makers stated India's conservation policies have been strengthened since 1990, this view is least shared by scientists. Interestingly, some of the former policy makers who work with NGOs rated the current policies as inadequate and inconsistent. Views of the scientists are significant in this context as they consider lack of a scientific approach a major lacuna in policies. Coherence, knowledge-based and authority are important attributes of policy development (Dickson 2003).

The present model of policy development is not very inclusive, though some efforts have been made to incorporate the views of NGOs and conservation scientists from time to time in policy making. However, no policy has been developed to institutionalize this process. The National Wildlife Board, that guides the national level policies, has a cross-sectional representation, but its meetings are dependent on political command and political mood of the nation. A wide range of stakeholders can usefully contribute to the process of reviewing, developing and implementing those policies and the process is likely to be more effective when accomplished (Dickson 2003).

Poor involvement of scientists in the policy making process, where their views could be incorporated as policy inputs, could result in a subjective assessment of issues and a conjectural decision making. In North America, scientific inputs in policy making were ensured since the 1970s (Noss et al. 1997). In CITES reviews of animals and plant lists, year round monitoring by the scientists form a strong basis for reviews (Zimmermann 2003).

The NGOs and the scientists respond to poaching issues with greater sensitivities than the field officials and the policy makers. A resurrection of poaching in the 1990s (Kenney et al. 1995) and elimination of tiger from Sariska, and the overall population becoming critically low (Narayan et al. 2005), however, match their concern. If we believe this argument then it naturally flows to- whether the policy makers or the field officials are prejudiced or unrealistic in not recognizing this threat to an extent expressed by the NGOs. Data from another study (Niraj et al. 2009) suggests that the recognization of threat perceptions by the policy makers and the field officials is understated. One would get a fairly quick idea that the wildlife laws and policies have not been able to achieve the intended goals.

Tiger poaching has declined, but that could be related to a population decline, which, in turn, gives rise to poaching of other similar species to replace tigers. A delayed recognition of these effects could be risky in the long term. Commercial markets for consumptive use of wildlife have led to numerous population declines and a few extinctions in North America (Tober 1981, Freese and Trauger 2000, Wagener 2001).

The stakeholders, particularly, the wildlife scientists and the NGOs reported a number of other threats (e.g., human population growth, destruction of corridors between the protected areas, political interference and encroachment of forest land) to conservation in India. Encroachment takes away from the prime habitat of the endangered species and also creates various levels of disturbances.

Some of the NGOs and the conservation scientist viewed policies as strong on paper, but implementation on the ground as unsatisfactory. Some of the policy makers too have rated the polices low and point out that lack of, or limited, transparency, public participation and stakeholder involvement in issues related to species and habitat conservation could weaken policies. Some others pointed out that policy response has not been adequate especially in terms of implementation, capacity building, awareness, and funding. This would indicate that policy development will not be solely in the hands of policy makers and could be influenced by political decisions.

Resource prioritization is important if the policy objectives are to be met. The budget allocation for wildlife and forest conservation demonstrates a declining trend in the recent years of the period from 1992 to 2006, in comparison with the overall budget of the MoEF; the nodal agency for conservation management in India (Fig. 7). This indicates a reducing government priority for wildlife conservation in India.

The NGOs reported official corruption and inefficiency blocking effective field implementation of policies. Surprisingly, some of the policy makers also agreed that corruption and bureaucratic inefficiency caused sub-optimal achievement of the policy objectives, but added that the genesis of the problems lied in non-integration of wildlife conservation and trade issues with other sectors, including lack of use of tools such as the precautionary principles. The policy makers point out poor research base and data deficiencies on important species also being the retrograding aspects of sound policy management in the country, the divergence in views would indicate a lack of coordinated approach in policy processes.

Taken individually the NGOs and conservation scientists are not regularly involved in policy processes. Taken collectively policy development has not been very objective or scientific. Stakeholder participation is stressed upon by the international policy framework conventions such as CITES and CBD where NGOs and conservation scientists are major role players (Reeve 2002) with the government representatives. This has worked well in international policy evaluation. On the other hand, the local level has become important for effective implementation and in providing the experiences and reflections needed to fine-tune the best practices and identify dysfunctional policies. Insights gained can be fed to other decision making bodies and aided by the NGOs (Sinclair-Brown 2003). Similarly, keeping the field officials away from direct participation in policy process can result in losing the track with ground truthing in policy. Often, the distance between the policy-makers who establish regulations and the enforcement agencies that apply them is vast (Oldfield 2003).

One of the effective ways of conservation management could be that the bonafide resource users (e.g., the village communities) is identified as a stakeholder and involved in the process of policy change from the beginning. In the case of the sea cucumber this rationale was not followed, which apparently resulted in trade becoming illegal and the real benefits moving from the stakeholders to unscrupulous traders and smugglers. This is not to suggest that we could think of every species in terms of use, but there are alternatives that could be worked out more effectively with the stakeholder participation. A focus on impact, guided by a structured decision process, will orient wildlife management toward rigorous, integrative decision making (Riley et al. 2003).

The issue of base line data on species, life history and other related ecological aspects is important in the context of sustainable use. Even when practiced with careful scientific details, sustainable harvest has a risk of going into an over-harvest mode (Clark 1973, Fresse and Trauger 2002), giving rise to preservation philosophy (Noss 1991, Freese and Trauger 2002). This could be a fear borne on the minds of the policy makers and the NGOs. However, Stiles (2004) presented a counter argument that a complete ban on species trade and harvest only pushes the trade underground, which benefits the unscrupulous and not the genuine stakeholders. There is not much evidence of a population obtaining stability by a complete ban on harvest (Martin and Stiles 2003, Stiles 2004). Due to the rampant poaching of Asian elephants for ivory, despite a complete ban on ivory trade since 1991, the male to female ratio has precariously gone down to 1:110 in south India (Sukumar et al 1998). Sustainable harvest has been practiced successfully for certain reptiles in different regions of the world (Jenkins and Broad 1994), but has not been recommended for species of high economic values with low reproductive capabilities (Clark 1973).

The sustainable use proponents consider that this could be the only means to save endangered species in the wild (Reeve 2002). The opponents propose that this could be a way to further destroy wildlife (Madhusudan and Karanth 2002). Most conservationists are, however, convinced that if the continent's natural heritage is to survive, local communities must be able to profit from wildlife and have a greater say in management decisions (Getz et al.1999, Hulme and Murphree 1999, Nelson 2000). Banning all scheduled wild animals for consumption or trade since 1991 implied that enforcement needed increased resources and their allocation to prevent the illegal harvest and trade. In addition this could be counter to sustainable use principles and could throw unmanageable challenges in growing economies (Czech 2000, Virmani 2004)

Indian policies are bureaucracy driven (Thapar 2003, Rangarajan and Shahabuddin 2006). A large number of NGOs are critical of the way the bureaucrats handled wildlife policies. Wildlife law enforcement needs a very specialized training to strengthen the human resource base. The training of foresters needs improvement and professional development (Narayan et al. 2005). There is not much scientific rigor to their investigations; hence they adopt very crude methodologies in investigations. Resource allocation, human resource development, and a sensitive institution have far reaching consequences (Schmidt-Soltau 2004). A minor improvement in local enforcement during 1979-1986 had a significant impact in reducing elephant poaching of the African elephant (*Loxodanta africana*) in Zambia (Jachmann 2002). In their study on hunting, in 2 major protected areas in southern India, Madhusudan and Karanth (2002) concluded that large mammals thrive under scrupulous protection, but continue to decline under intense pressures of local hunting. Understanding the need for strengthening the local level resource base would be easier if the stakeholders remained involved in the planning process.

The policy makers believe only limited species are threatened by illegal trade and have emphasized tiger, leopard, elephant, and Tibetan antelope. The NGOs also underlined concern on these species. The scientists have come up with a number of other species; not so well known to common people, but threatened by illegal trade. This is significant as this brings out the information that is generally not considered in developing various conservation and protection strategies for species. At this time there are specialized conservation programs limited only to tiger, elephant, and crocodiles. Other species have to be considered to enhance biodiversity in India.

Plants are more unrepresented in the responses of the stakeholders despite the evidence of their composition in trade from historical time (Shahabuddin and Prasad 2004). We have highlighted an unusual rise in illegal export of red sander (*Pterocarpus santinilus*) during 1992-2006 (Niraj et al. 2009). Agarwood (*Aquileria malaccensis*) has also been regularly confiscated in international trade from India, which has skipped trade control due to incorrect listing in the Trade Control Orders of the Indian government conflicting with its legal position in CITES regulations. The undermining of protection to plants is further underlined by the fact that only 6 species have been listed in the WPA and there has been no review or change since 1991.

Most stakeholders are not aware of the government’s initiatives on implementing CBD principles in India. India has legislated its first comprehensive Act on CBD in 2002 (i.e., Biodiversity Conservation Act 2002), which focuses on sustainable use, benefit sharing and equity in biodiversity use which is the central focus in CBD (Cooney 2001, CBD Working draft 2003). Convention of Biological Diversity encourages broad participation of stakeholders, where the role of NGO and the conservation scientist are particularly emphasized. In contrast, of all the stakeholders, the NGO and the conservation scientists are least aware of the developments related to CBD in India. In recent time CBD and CITES have taken serious initiatives to synergize their efforts as they considered their approaches complementary (Ruiz et al. 2003). The efforts for synergy called for strong national level focal points that would coordinate their activities across the nation in member countries. We do not come across evidence of such efforts in India for strengthening CITES or institutionalizing CBD. India has not been able to establish a separate national level legislation so far, despite having signed and ratified CITES in 1976 (Mishra 2004). Having a separate legislation is a requirement under CITES compliance (Reeve 2002) and is aimed at strengthening its regulations (Zimmerman 1991, Oldfield 2003).

The southern regional CITES agency at Chennai has been functioning with 1 field enforcement official since 1995 (M. Maranko, wildlife inspector, personal communication 2008) and the unit reports only 4 cases of seizures in 2006. The western region at Mumbai has been functioning with 2 or 3 enforcement officials since 1992 (Fig. 8). The financial allocations for the western regional CITES enforcement unit has been revised occasionally but most of the fund was spent on salaries or other heads other than strengthening infrastructure related to enforcement. Each CITES region, on an average, has 5-7 states under its jurisdiction (i.e., based on MoEF files 2007) with few enforcement officials (Fig. 8).

India now has an extensive network of PAs, established to conserve species in the representative ecosystems (Rodgers et al. 2005). However, research holds that the creation of national parks does not automatically contribute to conservation goals if the authorities in charge mismanage the area (due to inadequate training, staff, motivation, equipment or finances), and if the local population is not invited to participate in such projects (Adams and McShane 1992, Schmidt-Soltau 2004, Wells and McShane 2004).

MANAGEMENT IMPLICATIONS

Research in wildlife policy development is important as policy development is an evolving and dynamic process, which gains much from the interactions of stakeholders. Policies have far reaching consequences and can have irreversible effects. Therefore, policy processes needed to be robust and adequate in response to the emergent situations. Involving stakeholders who are concerned with wildlife conservation could be a process of shared learning and self-correcting. This could help the existing knowledge system. Although, there are coordination committees that fulfill the paper requirements, they will not have a real effect unless the process is institutionalized.

Monitoring and evaluation should be an ongoing process for any policy in vogue. It is evident that problems in wildlife management are not only technical but also social, political, and economic. Scientists, NGOs and human communities now are regarded as important stakeholders in conservation, first in the forestry sector, but increasingly in PA management. A bottom-up approach will strengthen the overall policy development regime.

International conventions such as CITES and CBD are the global focal points of shared learning and experiences. To effectively participate in their processes it is important that India strengthens its own national and regional institutions which carry out globally agreed principles and strategies. Rather than rejecting a concept (e.g., sustainable use) it will be important to examine and evaluate various positive and negative aspects along scientific and socio-economic philosophies (Ahmad 1997, Broad et al. 2002, Roe et al 2002), which, in turn, will help understand the linkage between the communities and conservation.

ACKNOWLEDGEMENTS

We thank W. W. Shaw, R. R. Gimblett, and J. L. Koprowski for useful comments in formative stages of this research. We thank A. N. Prasad for his valuable comments on policy issues, on questionnaires and in data work. We thank the administration and faculty at the School of Natural Resources, University of Arizona for institutional support that facilitated this work. We thank H. S. Pabla, S. Thakur, and many other senior officials in the state and central governments in India for their valuable comments on the concepts behind this paper and during discussions. The officials at CITES regional offices in India offered useful suggestions. The Ministry of Environment and Forests, Government of India, New Delhi; Arizona Agricultural Experiment Station and School of Natural Resources, University of Arizona, Tucson sponsored this research.

LITERATURE CITED

Adams, L. M, and G. Darwin. 1982. Solving the quandary between questionnaire length and response rate in educational research. Research in Higher Education 17:231-240.

Adams, J. S., and T. O. McShane. 1992. The myth of wild Africa: conservation without illusion. Norton and Company, New York, New York, USA.

Ahmad, A. 1997. Live bird trade in northern India. TRAFFIC India and WWF, New Delhi, India.

Asha, P. S., and P. Muthiah. 2007. Reproductive biology of the commercial sea cucumber Holothuria spinifera (Echinodermata: Holothuroidea) from Tuticorin, Tamil Nadu, India. Aquaculture International 16:231–242.

Broad, S., T. Mulliken, and D. Roe. 2002. The nature and extent of legal and illegal trade in wildlife. Pages 3-22 in Sara Oldfield, editor. The trade in wildlife: regulation for conservation. Earth Scan, London, United Kingdom.

Convention of Biological Diversity Secretariat. 2005. Report on the workshop on promoting CITES-CBD cooperation and synergy. Note by Executive Secretary in First Meeting 5-9 September 2005(UNEP/CBD/WG-RI/1/1). Montréal, Canada.

Convention of International Trade in Endangered Species of Wild Fauna and Flora Secretariat 2000. Strategic vision through 2005. CITES Secretariat, Geneva. Switzerland.

Clark, C. W. 1973. The economics of overexploitation. Science 181:630-634.

Conand, C. 2004. Present status of world sea cucumber resources and utilization: an international overview. Pages 10-13 in Lovatelli, C. Conand, S. Purcell, S. Uthicke, J.F. Hamel, A. Mercier, editors. Advances in sea cucumber aquaculture and management. Fisheries Technical Papers No 463, FAO, Rome.

Cooney, R. 2001. CITES and CBD: tensions and synergies. RECIEL 10: 2001.

Czech, B. 2002. Economic growth as the limiting factor for wildlife conservation. Wildlife Society Bulletin 28:4-15.

Damania, R., J. Seidensticker, T. Whitten, G. Sethi, K. Mackinnon, A. Kiss, and A. Kushlin. 2008. A future for wild tigers. The World Bank and Smithsonian National Zoological Park, Washington, D.C.

Deaton, A. 1997. The analysis of household surveys: a micro econometric approach to development policy. The Johns Hopkins University Press, Baltimore, USA.

Dickson, B. 2003. Methodologies for national wildlife trade reviews. Draft background paper to CITES, Geneva, Switzerland.

Dillman, D. A. 2007. Mail and internet surveys: the tailored design method. Second edition. John Wiley, New York, New York, USA.

Freese, H. C., and D. L. Trauger. 2002. Wildlife markets and biodiversity conservation in North America. Wildlife Society Bulletin 28:42-51.

Getz, W. M., L. Fortmann, D. Cumming, J. Du Toit, J. Hilty, R. Martin, M. Murphee, N. Owen-Smith, A. M. Satrfield, and M. J. Westphal. 1999. Sustaining natural and human capital: villages and scientists. Science 284:1855-1856.

Hillstrom, K., and L. C. Hillstrom. 2003. Asia: a continental overview of environmental issues. ABC-CLIO, California, USA.

Hulme, D., and M. Murphree. 1999. Communities, wildlife and the “new conservation” in Africa. Journal of International Development 11:277–285.

Jachmann, H. 2002. Elephant poaching and resource allocation for law enforcement. Pages 100-107 in Sara Oldfield, editor. The trade in wildlife: regulation for conservation. Earth Scan, London, United Kingdom.

Jenkins, M. 2004. CITES and the CBD: potential for synergy. Working draft prepared for the CITES-CBD Synergy Experts Workshop, April 19-24, Isle of Vilm, Germany.

Kenney, J. S, J. L. D. Smith, A. M. Starfield, and C. W. McDougal. 1995. The long term effect of tiger poaching on population viability. Conservation Biology 9:1127-1133.

Madhusudan, M. D., and K. U. Karanth. 2002. Local hunting and conservation of large mammals in India. Embio 31:49-54.

Martin, E., and D. Stiles. 2003. The ivory markets of East Asia. Report, Save the Elephants, Nairobi, Kenya and London, United Kingdom.

Menon, V., and A. Kumar. 1998. Wildlife crime: an enforcement guide. Wildlife Protection Society of India, Natraj, Dehradun, India.

Ministry of Environment and Forests 1972. Wildlife Protection Act 1972. Government of India, New Delhi, India.

Ministry of Environment and Forests. 2008. The Annual Report 2007-08. Government of India, New Delhi, India.

Ministry of Environment and Forests. 2002. The Biodiversity Act 2002. Government of India, New Delhi, India.

Mishra, M. 2002. Evolution, impact, and effectiveness of domestic wildlife trade ban in India. Pages 78-88 in Sara Oldfield, editor. The trade in wildlife: regulation for conservation. Earthscan, London, United Kingdom.

Mishra, M. 2004. Research report on wildlife trade regulation, CITES and law enforcement in South Asia. TRAFFIC, WWF and IUCN, New Delhi, India.

Narayan, S., S. Singh, H. S. Pawar, and M. Gadgil. 2005. Joining the dots: the report of the tiger task force. Ministry of Environment and Forests, Government of India, New Delhi, India.

Nelson, F. 2000. Sustainable development and wildlife conservation in Tanzania's Maasailand. Environment Development and Sustainability 2:107-117.

Niraj, S. K., P. R. Krausman, and V. Dayal. 2009. Temporal and spatial analysis of wildlife poaching in India from 1992 to 2006. Dissertation, University of Arizona, Tucson, USA.

Noss, R. E. 1991. Sustainability and wilderness. Conservation Biology 5:120-122.

_____, M. A. O'Connell, and D. D. Murphy. 1997. The science of conservation planning: habitat conservation under the Endangered Species Act. The island Press. Washington, D.C., USA.

Oldfield, S., editor. 2003. The trade in wildlife: regulation for conservation. Fauna and Flora International, Resource Africa and TRAFFIC International. Earthscan, London, United Kingdom.

Rangarajan, M. 2006. India's wildlife history: an Introduction. Permanent Black, New Delhi, India.

Raghunathan, T. E., and J. E. Grizzle. 1995. A split questionnaire survey design. J. of the American Statistical Association 90:54-63

Reeve, R. 2002. Policing international trade in endangered species: the CITES treaty and compliance. The Royal Institute of International Affairs, London, United Kingdom.

Riley, S., W. Seimer, D. Decker, L. Carpenter, J. Organ, and L. Bercheilli. 2003. Adaptive Impact management: an integrative approach to wildlife management. Human Dimensions of Wildlife 8:81-95.

Rosencrantz, A., S. Divan, and M. L. Noble. 1991. Environmental law and policy in India: cases, materials and statutes. Tripathy, New Delhi, India.

Roszkowski, M. J., and A. G. Bean. 1990. Believe it or not: longer questionnaires have lower response rates. Journal of Business and Psychology 4:495-509

Roe, D., T. Mulliken, S. Milledge, J. Mremi, S. Mosha, and M. Grieg-Gran. 2002. Making a killing or making a living? Wildlife trade, trade controls and rural livelihood. Biodiversity and Livelihood. TRAFFIC International, United Kingdom.

Ruiz, M., C. Fernandez, and, T. Young. 2003. Regional Workshop on the synergies between the Convention on Biological Diversity and the CITES regarding access to genetic resources and distribution of benefits: The role of the certification of origin. A Preliminary report. CITES Secretariat, Geneva, Switzerland.

Schmidt-Soltau, K. 2004. The costs of rainforest conservation: local responses towards integrated conservation and development projects in Cameroon. Journal of Contemporary African Studies 22:94-116.

Shahabuddin, G., and S. Prasad. 2004. Assessing ecological sustainability of non-timber forest produce extraction: the Indian scenario. Conservation and Society 2:235-250.

Sinclair-Brown, N. 2003. Regulatory design. Pages 33-40 in Sara Oldfield, editor. The trade in wildlife: regulation for conservation. Earth Scan, London, United Kingdom.

Singhleton, R. A., B. C. Straits, and M. M. Straits. 1993. Approaches to Social Research. Oxford University Press, New York, New York, USA.

Stiles, D. 2004. The Ivory trade and elephant conservation. Environmental Conservation 31:309-321.

Sukumar, R., U. Ramakrishnan, and J. A. Santosh. 1998. Impact of poaching on an Asian elephant population in Periyar, southern India: a model of demography and tusk harvest. Animal Conservation 1:281-291.

Taneja, B. 2001. Biodiversity planning support program: integrating biodiversity into the forestry sector, India case study. International workshop on Integration of biodiversity in national forestry planning program, Bogor, Indonesia, 13-16 August 2001.

Thapar, V. 1997. The tragedy of the Indian tigers: starting from scratch in Learning from the tragedy of the Indian tigers 296-306.

_____. 2003. Battling for survival: India's wilderness over two centuries. Oxford University Press, New Delhi, India.

Tober, J. A. 1981. Who owns the wildlife? The political economy of conservation in nineteenth-century America. Greenwood, Westport, Connecticut, USA.

Verbeek, M. 2004. A guide to modern econometrics. John Wiley and Sons, Singapore.

Virmani, A. 2004. Economic performance, Power, potential and global governance: towards a new international order; ICRIER working paper 150, December 2005.

Wagener, A. 2001. Endangered species: traded to death. Earth Trends: World Resources Institute. Washington, D.C., USA.

Weeks, P., and S. Mehta. 2004. Managing people and landscapes: IUCN protected areas categories. Journal of Human Ecology 16:253-263.

Wells, M., and T. McShane. 2004. Integrating protected management with local needs and aspirations. Ambio 33:513-519.

Zimmermann, M. E. 2003. The Black Market for Wildlife: Combating Transnational Organized Crime in the Illegal Wildlife Trade.

Table 1. Logit regression on responses from 4 stakeholders in India on major threats to wildlife conservation in India. Field officials, NGOs, and scientists were dully variables and the results compared with the base variable (i.e., policy makers).

Variable	Parameter	Field	NGO	Scientist	Constant	*N*	ll[a]
Habitat Destruction	Coefficient	-1.317	-0.987	-0.374	2.048	148	-74.19
	P-value	0.036	0.133	0.590	<0.001		
	Change in probability	-0.248	-0.183	-0.063			
Poaching and illegal trade	Coefficient	-0.325	0.535	-0.421	0.526	148	-96.85
	P-value	0.491	0.305	0.378	0.133		
	Change in probability	-0.078	0.121	-0.101			
Lack of Resources	Coefficient	0.708	0.348	-1.083	-0.405	148	-93.23
	P-value	0.133	0.471	0.046	0.240		
	Change in probability	0.172	0.084	-0.238			
Low priority	Coefficient	-0.339	0.577	-0.256	-0.172	148	-99.64
	P-value	0.472	0.233	0.590	0.613		
	Change in probability	-0.083	0.1433	-0.0628			
Poor Policies	Coefficient	-1.616	1.522	3.077	-2.048	148	-62.11
	P-value	0.158	0.017	<0.001	<0.001		

Table 1. Contd.

Variable	Parameter	Field	NGO	Scientist	Constant	N	ll[a]
	Change in probability	-0.214	0.301	0.614			
Unscientific Management	Coefficient		-1.159	2.578	-2.367	108	-40.91
	P-value		0.326	<0.001	<0.001		
	Change in probability		NA	NA			
Other threats	Coefficient	-0.405	0.511	1.269	0.405	148	-88.79
	P-value	0.386	0.316	0.024	0.240		
	Change in probability	-0.091	0.105	0.240			

[a]Log likelihood from logit regressions

Table 2. Logit regression on responses from 4 stakeholders in India on policy response to community aspirations, participation, and evaluation of government efforts in participatory management and conservation. Field officials, NGOs, and scientists were dummy variables and the results compared with the base variable (i.e., policy makers).

Variable	Parameter	Field	NGO	Scientist	Constant	N	ll[a]
Responsive wildlife policy?[b]	Coefficient	-0.331	1.030	-0.209	-0.288	143	-93.83
	P-value	0.486	0.045	0.664	0.400		
	Change in probability	-0.080	0.252	-0.0513			
Yes, response factor affects conservation	Coefficient	0.634	2.610	1.974	0.916	148	-51.86
	P-value	0.257	0.016	0.016	0.014		
	Change in probability	0.051	0.154	0.1292			
Rate success in community involvement[b]	Coefficient		1.056	0.300	-0.405	108	-99.26
	P-value		0.013	0.455	0.085		
	Change in probability		0.256	0.0749			
Rate government efforts in conservation?[c]	Coefficient	0.405	1.938	1.079	-0.916	146	-92.58
	P-value	0.414	<0.001	0.031	0.014		
	Change in probability	0.101	0.433	0.2613			

[a]Log likelihood from logit regressions

[b]Measured on 1-10 ordinal, where 1 = Highest, 10 = Lowest; dummies were created for these variables, ≥ 6 = High; ≤ 6 = Low, for incorporation in the logit regressions.

Table 3. Logit regression on responses from 4 stakeholders in India on likely problems in sustainable use and sustainable harvest practices in India. Field officials, NGOs, and scientists were dummy variables and the results compared with the base variable (i.e., policy makers).

Variable	Parameter	Field	NGO	Scientist	Constant	*N*	ll [b]
Poor control	Coefficient	0.020	-0.300	-1.005	1.216	148	-87.21
	P-value	0.971	0.585	0.052	0.003		
	Change in probability	0.004	-0.064	-0.223			
Poor scientific Protocols	Coefficient	-0.042	-0.469	-0.370	-0.057	148	-100.5
	P-value	0.926	0.335	0.435	0.866		
	Change in probability	-0.010	-0.112	-0.089			
Unsustainable Demand	Coefficient	0.651	0.708	-0.003	-0.651	148	-98.89
	P-value	0.172	0.150	0.995	0.068		
	Change in probability	0.160	0.174	-0.000			
Socio-cultural problems	Coefficient	0.188	0.405	-0.366	-0.288	147	-99.50
	P-value	0.687	0.403	0.449	0.400		
	Change in probability	0.046	0.100	-0.088			
Sustainable harvest will work	Coefficient	1.981	0.515	0.288	-1.576	147	-82.22
	P-value	<.0001	0.385	0.632	<.0001		

Table 3. Cont.

Variable	Parameter	Field	NGO	Scientist	Constant	N	ll [b]
	Change in probability	0.4448	0.1134	0.0622			
Sustainable harvest will work selectively	Coefficient	-3.116	-1.388	-0.785	0.172	147	-74.87
	P-value	<.0001	0.008	0.104	0.613		
	Change in probability	-0.3818	-0.2	-0.1248			
Sustainable harvest will not work	Coefficient	-0.214	0.811	0.134	-0.405	147	-98.32
	P-value	0.655	0.097	0.78	0.24		
	Change in probability	-0.0523	0.200	0.033			
Sustainable harvest good for Management	Coefficient	-0.245	-1.056	-0.223	0.651	148	-98.47
	P-value	0.610	0.033	0.647	0.068		
	Change in probability	-0.0605	-0.258	-0.055			

[a]Log likelihood from logit regressions

Table 4a. Logit regressions on responses from 4 stakeholders on composition of species in illegal wildlife trade from India. Field officials, NGOs, and scientists were made dummy variables and compared with the base variable (i.e., the policy makers)

Variable	Parameter	Field	NGO	Scientist	Constant	*N*	ll[a]
Tiger	Coefficient	-1.398		0.089	2.367	113	-44.26
	P-value	0.046		0.916	0.000		
	Change in probability	NA		NA			
Leopard	Coefficient	-0.511	1.131	-0.018	0.916	148	-83.16
	P-value	0.301	0.082	0.972	0.014		
	Change in probability	-0.103	0.186	-0.003			
Elephant	Coefficient	-0.597	0.170	0.105	1.216	148	-81.78
	P-value	0.252	0.771	0.852	0.003		
	Change in probability	-0.117	0.030	0.019			
Rhino	Coefficient	-1.025	-0.577	0.022	0.405	148	-99.08
	P-value	0.032	0.233	0.963	0.240		
	Change in probability	-0.247	-0.142	0.005			
Star tortoise	Coefficient		0.137	0.080	-0.080	148	-102.5
	P-value		0.738	0.841	0.729		
	Change in probability		0.034	0.020			
Turtle	Coefficient	-0.319	0.708	-0.123	-0.651	148	-93.97

Table 4a. Continued.

Variable	Parameter	Field	NGO	Scientist	Constant	*N*	ll[a]
	P-value	0.526	0.150	0.806	0.068		
	Change in probability	-0.071	0.168	-0.027			
Chiru	Coefficient	0.118	-0.170	0.443	-1.216	148	-82.52
	P-value	0.828	0.771	0.405	0.003		
	Change in probability	0.022	-0.030	0.086			
Snakes	Coefficient	0.028	0.354	-0.826	0.172	148	-99.16
	P-value	0.951	0.467	0.086	0.613		
	Change in probability	0.007	0.087	-0.202			
Monitor lizard	Coefficient	0.214	-2.57e-17	0.163	-1.061	148	-87.20
	P-value	0.680	1.000	0.757	0.006		
	Change in probability	0.043	0.000	0.033			
Birds	Coefficient	0.506	0.811	-1.083	-0.405	148	-92.94
	P-value	0.280	0.097	0.046	0.240		
	Change in probability	0.124	0.199	-0.242			
Bears	Coefficient	-0.234	0.344	-0.147	-0.172	148	-101.0
	P-value	0.618	0.474	0.756	0.613		
	Change in probability	-0.057	0.085	-0.036			

[a]Log likelihood from logit regressions

Table 4b. Logit regressions on responses from 4 stakeholders on composition of plant species in illegal wildlife trade from India. Field officials, NGOs, and scientists were dummy variables and the results compared with the base variable (i.e., policy makers).

Variable	Parameter	Field	NGO	Scientist	Constant	*N*	ll[a]
Sandal wood	Coefficient		-0.389	0.488	-1.658	108	-66.22
	P-value		0.528	0.324	<0.001		
	Change in probability		-0.05	0.072			
Red sander	Coefficient	-3.93e-17	-0.661	0.064	-1.386	148	-69.53
	P-value	1.000	0.330	0.911	0.001		
	Change in probability	<0.001	-0.087	0.0096			
Medicinal plants	Coefficient	-0.321	-0.690	-0.372	-0.526	148	-89.20
	P-value	0.513	0.196	0.457	0.133		
	Change in probability	-0.064	-0.132	-0.074			
Orchids	Coefficient	-0.334	-0.575	0.187	-1.216	148	-73.62
	P-value	0.564	0.360	0.732	0.003		
	Change in probability	-0.050	-0.083	0.030			

[a]Log likelihood from logit regressions

Table 4c. Logit regression on responses from 4 stakeholders on composition of marine species in illegal wildlife trade from India. Field officials, NGOs, and scientists were dummy variables and the results compared with the base variable (i.e., policy makers).

Variable	Parameter	Field	NGO	Scientist	Constant	*N*	ll[a]
Marine species	Coefficient		0.654	0.766	-1.305	148	-86.39
	P-value		0.150	0.081	<0.001		
	Change in probability		0.140	0.164			
Shells and corals	Coefficient	0.325	-0.254	-0.962	-0.526	148	-90.56
	P-value	0.491	0.615	0.078	0.133		
	Change in probability	0.072	-0.054	-0.189			

[a]Log likelihood from logit regressions

LIST OF FIGURES

31March of the next year. An implicit deflator was used for each year to account for the inflation with an approximation for the year 2006-07.

8. Total budget allocated for the Convention of International Trade in Endangered Species of Wild Fauna and Flora regional enforcement unit, western region, India and the number of enforcement officials employed for prevention of illegal trade from the fiscal years 1992-1993 to 2006-2007. The fiscal years run from 1April of the preceding year to 31March of the next year.

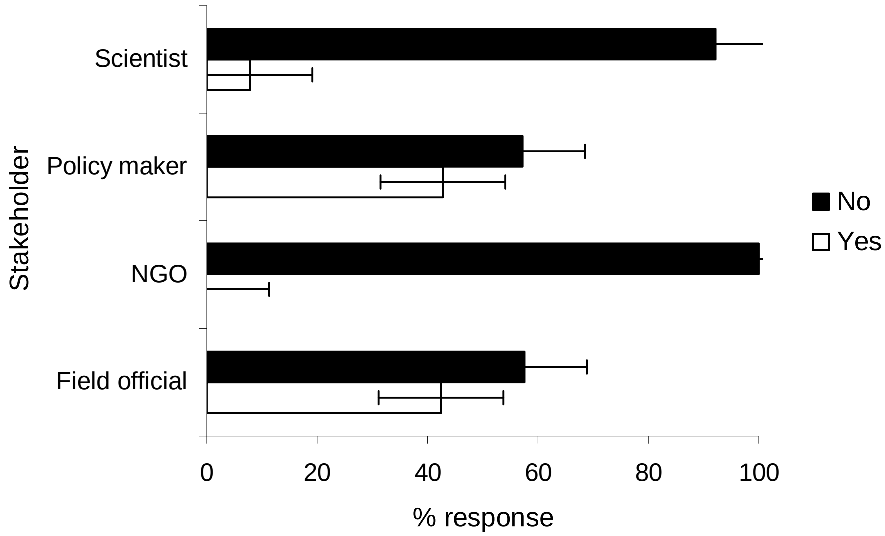


Figure 1. Responses from 4 stakeholders in India on the question “Is the wildlife policy adequate for controlling poaching and illegal trade in wildlife in India?” 2007. The standard error is reported at the 95% confidence interval.

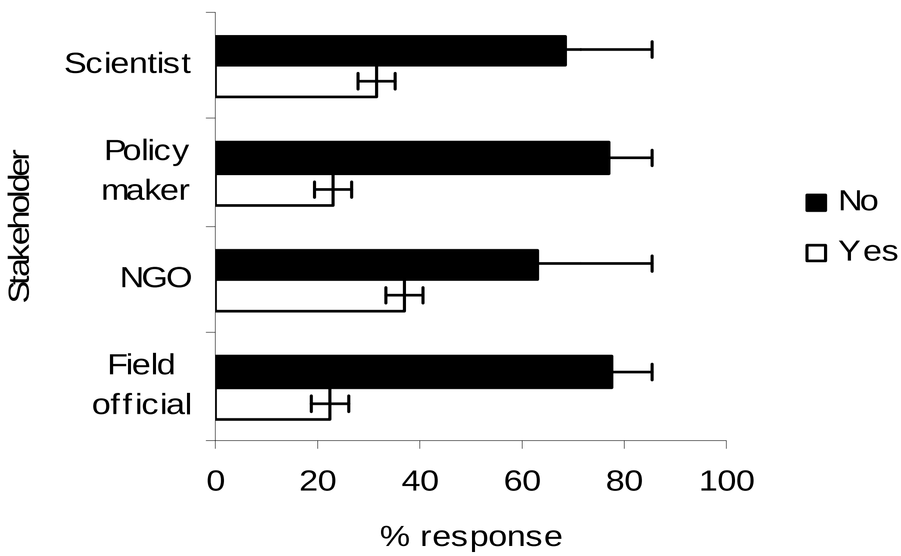


Figure 2. Responses from 4 stakeholders in India on the question “Adequate wildlife policy but poor implementation of policy in India?” The standard error is reported at the 95% confidence interval.

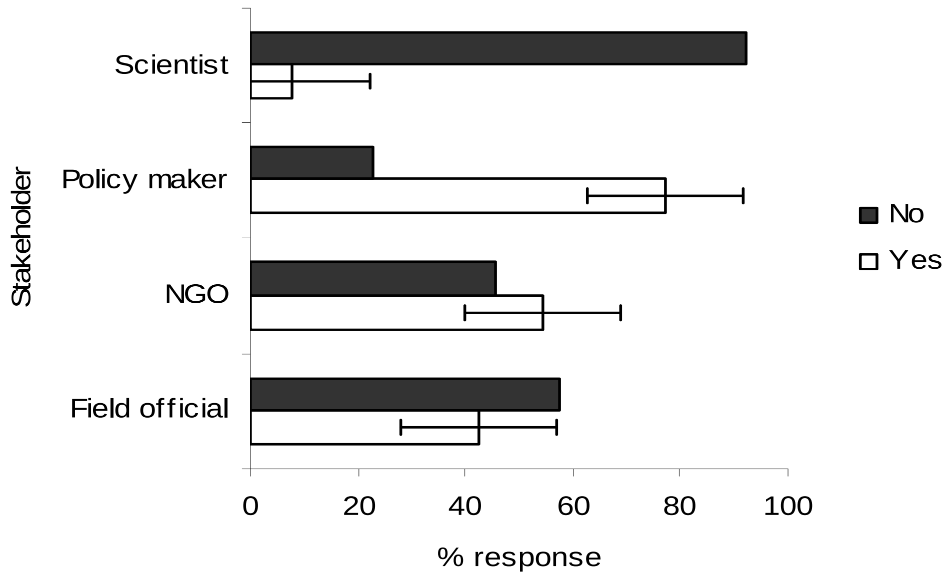


Figure 3. Responses from 4 major stakeholders in India to the question “Have wildlife policies been strengthened in India since 1990?” The standard error is reported at the 95% confidence interval.

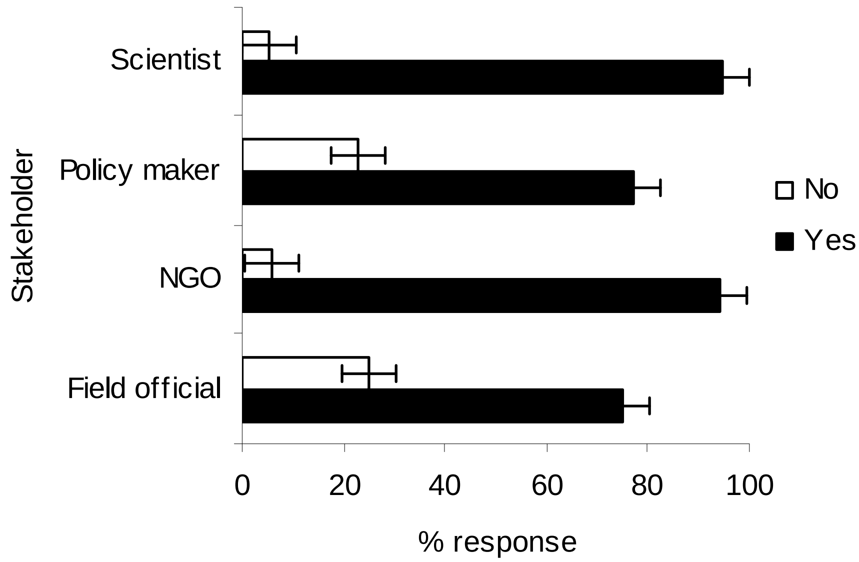


Figure 4. Responses from 4 major stakeholders in India to the question “Is poaching an important issue in wildlife conservation in India?” The standard error is reported at the 95% confidence interval.

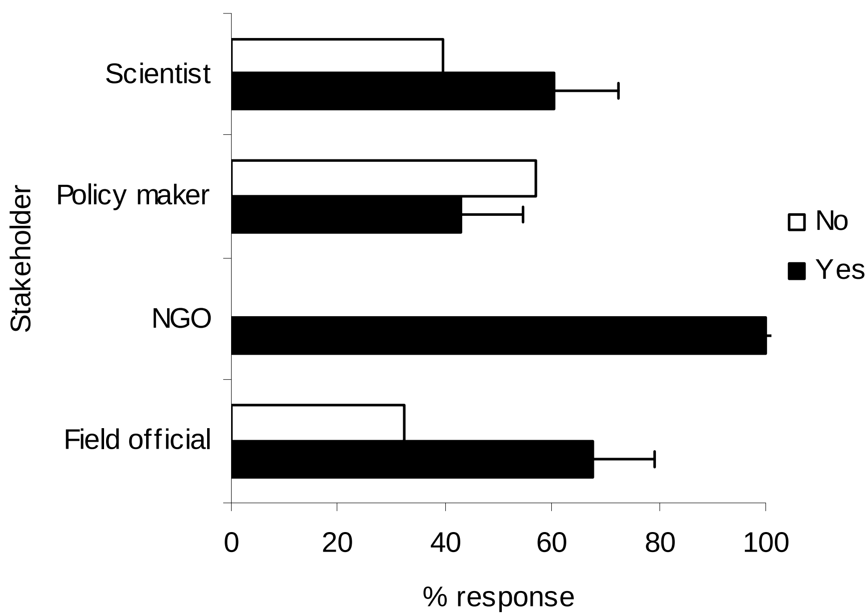


Figure.5. Responses from 4 major stakeholders in India to the question “Has poaching increased in India since 1992?” The standard error is reported at the 95% confidence interval.

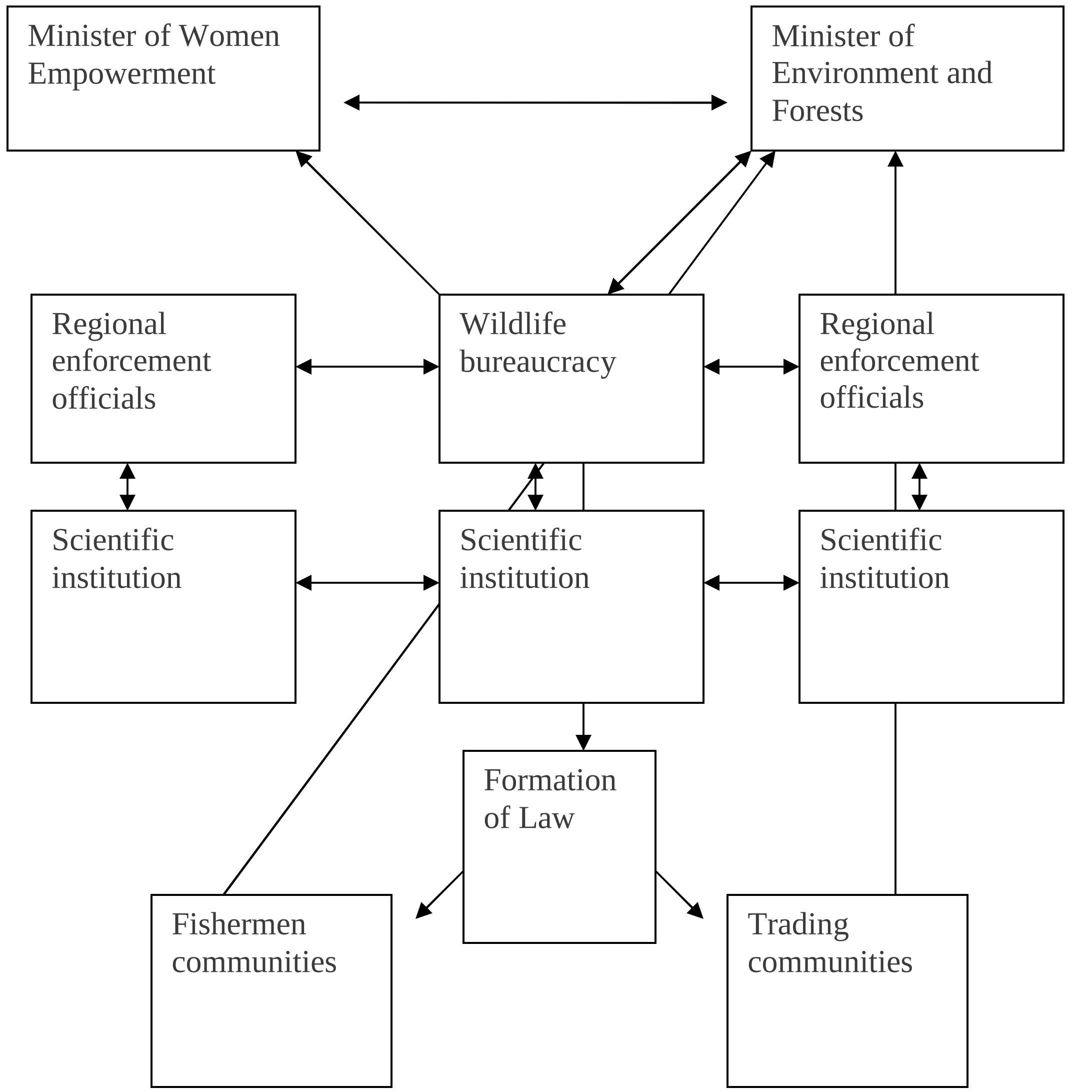


Figure 6. Model followed for a major amendment to Wildlife Protection Act 1972 in India during 2001-2002. Sea cucumber, which was harvested by the fishing communities in south India, was included in schedule 1 to WPA by legislation, thus legally banning its harvest.

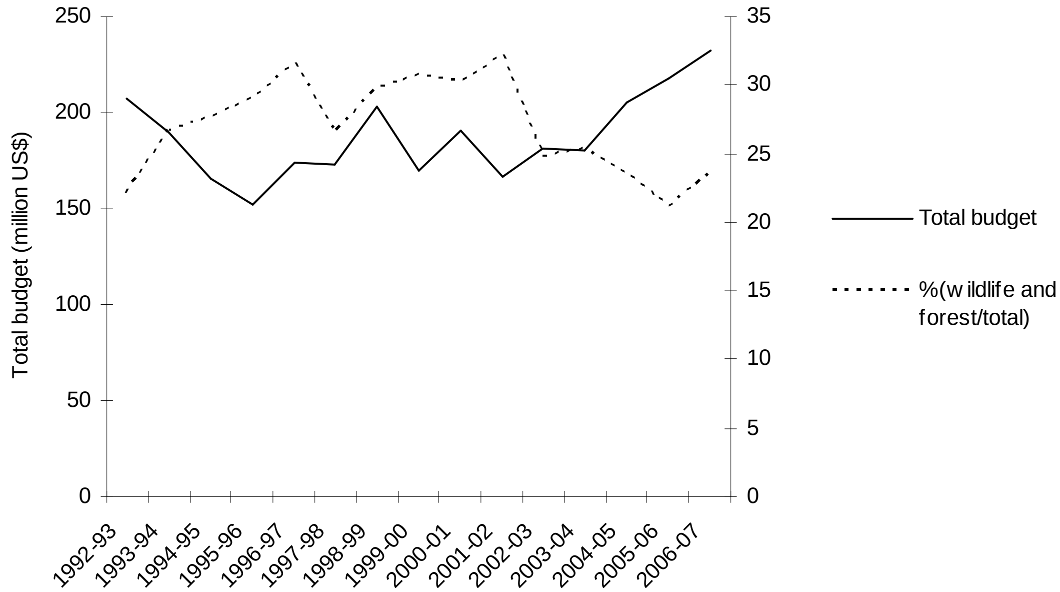


Figure. 7. The budget allocations on all environmental programs (total budget) and the proportion of wildlife forestry budget to the total budget from 1992-1993 to 2006-2007 (fiscal years) for India. The fiscal years run from 1April of the preceding year to 31March of the next year. An implicit deflator was used for each year to account for the inflation with an approximation for the year 2006-2007.

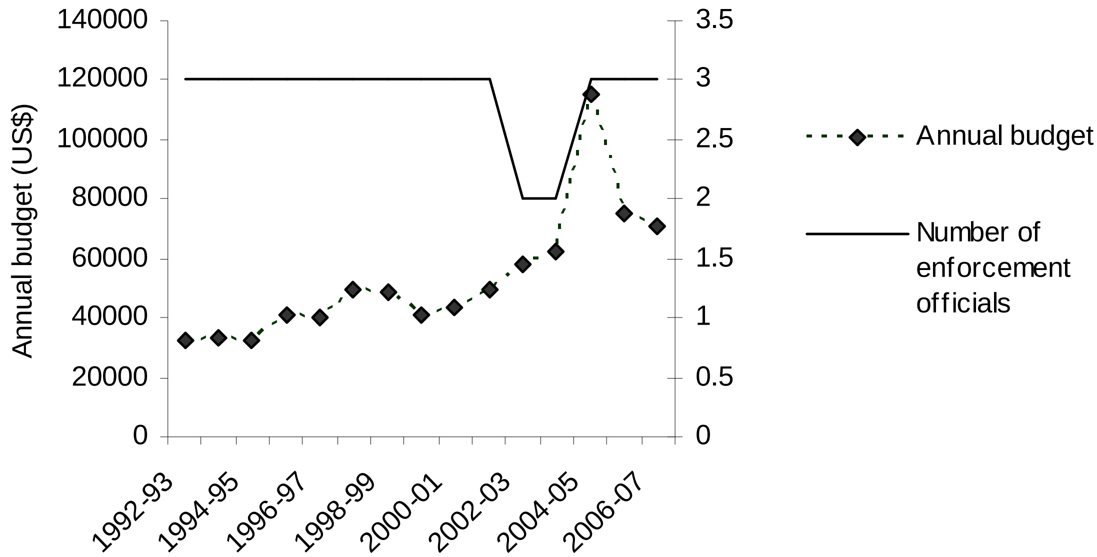


Figure 8. Total budget allocated for the Convention of International Trade in Endangered Species of Wild Fauna and Flora regional enforcement unit, western region, India and the number of enforcement officials employed for prevention of illegal trade from the fiscal years 1992-1993 to 2006-2007. The fiscal years run from 1April of the preceding year to 31March of the next year.

APPENDIX 1

Policy Related Questionnaire (Field official) Code:

Name:
Designation (present / past):
Organization:
Date:

1a. Do you think that wildlife poaching and illegal trade in wildlife is an important factor leading to decline of wildlife species?

b. Has poaching and illegal trade in wildlife increased in last 20 years (since 1987)?

2. Are current policies for wildlife adequate in controlling poaching and illegal trade?

3. On a scale of 1 to 10 (1= highest, 10= lowest) how would you rate the effectiveness of CITES (Convention of International Trade in Endangered Species of Wild Fauna and Flora) in controlling illegal wildlife trade (emphasis on cross- border trade- air, land and water) in India?

b. Is there a specific CITES legislation in India?

4. What are the major problems in enforcement of wildlife laws including CITES to control poaching and illegal trade in wildlife? (Note: in terms of priority)

1.
2.
3.
4.
5.

5. A strong institutionalized training support is very important for wildlife enforcement in the country. This is a-

1. A strongly relevant argument
2. A relevant argument
3. Neutral, no comments
4. An irrelevant argument
5. A strongly irrelevant argument

My answer (   )
Additional observation, if any:

6. Training inputs to wildlife enforcement staff are adequate for handling wildlife crimes and investigations

I. Strongly agree
II. Moderately agree
III. Neutral
IV. Disagree
V. Strongly disagree

My answer ( )
Additional observation, if any:

7. Handling of wildlife crime investigation in India often lacks sufficient scientific inputs (Please tick mark one or pick up one)

I. Strongly agree
II. Moderately agree
III. Neutral
IV. Disagree
V. Strongly disagree

My answer ( )
Additional observations, if any:

8. Wildlife crime detection and investigations need full coordination with other - law enforcement agencies. This is a-

1. A strongly relevant argument
2. A relevant argument
3. Neutral, no comments
4. An irrelevant argument
5. A strongly irrelevant argument

My answer ( )
Additional observation, if any:

9. Coordination with other law enforcement agencies is often lacking and requires more institutionalized efforts

I. Strongly agree
II. Moderately agree
III. Neutral
IV. Disagree
V. Strongly disagree

My answer (   )
Additional observations, if any:

10. There is an institutional mechanism in place to receive the views of wildlife enforcement officials in policy matters. Do you?

I. Strongly agree
II. Moderately agree
III. Neutral
IV. Disagree
V. Strongly disagree

My answer (   )
Additional observations, if any:

11. Wildlife policies and laws will become more reflective of field realities if views of enforcement officials are received and incorporated regularly and routinely in an institutionalized manner. This is-

1. A strongly relevant argument
2. A relevant argument
3. Neutral, no comments
4. An irrelevant argument
5. A strongly irrelevant argument
6. Such system is already in place

My answer (   )
Additional observation, if any:

12.a. Are you aware that the Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES) in consonance with the Convention of Biological Diversity (CBD) strongly advocates sustainable use of wildlife for better conservation?

b. Do you think that this will help in controlling the illegal wildlife trade and help in conservation?

c. If not, what are the major likely problems in practicing this in India?

13. Convention of biological Diversity has strong mandate of sustainable use, access and benefit sharing, research and technology transfer; how the Indian policies are being reoriented to achieve these? Both the CBD and CITES advocate greater coordination at the national level and at the field level; how are these proposed to achieve in India

14.a. Do you think that NGOs have important role in collaboration with government agencies in controlling wildlife poaching and illegal trade in wildlife in India?

b. Do you think that the poaching and illegal trade data compiled by the government agencies reflect the true field pictures?

15. Non Governmental Organizations (NGOs) are often consulted for support in wildlife crime detection and investigations by enforcement official

I. Strongly agree
II. Moderately agree
III. Neutral
IV. Disagree
V. Strongly disagree

My answer (   )
Additional observations, if any:

16. Do you think that sustained economic growth in the country is making a direct or indirect impact on illegal demand of wildlife?

17.a. On a scale of 1 to 10 (1= highest, 10= lowest) how would you rate the responsiveness of conservation policies to the communities' rising aspirations (socio-economic) in India?

b. Does this factor influence wildlife poaching and illegal trade in India?

18. What are the major threats to Indian wildlife conservation?

19. What are the species largely in illegal wildlife trade in India?

1.
2.
3.
4.
5.
6.
7.
8.
9.

(Note: Numbers do not indicate rank and could be more)

20. Are scientific and research findings adequately incorporated in policy developments?

1. Strongly agree
2. Moderately agree
3. Neutral
4. Disagree
5. Strongly disagree

21. Indian wildlife laws and policies will become more effective if the scientific and research findings are adequately incorporated in the process of their review and formulations (Please tick mark one or pick one).

1. A strongly relevant argument
2. A relevant argument
3. Neutral, no comments
4. An irrelevant argument
5. A strongly irrelevant argument

My answer (   )
Additional observation, if any:

22. In India wildlife policies reviews are largely based on scientific judgments and field research findings. Do you (Please mark one or pick one of the following)?

APPENDIX 2

Policy Related Questionnaire (NGO) Code:
Name:
Organization:
Date:

1. Do you think that NGOs have important roles in controlling wildlife poaching and illegal trade in wildlife?

2. Are NGOs involved in policy revisions and formulations on wildlife conservation including control of poaching and wildlife trade?

3.a. During the last 20 years has wildlife protection been strengthened with strong policy inputs?

b. Is poaching a major threat?

4. On a scale of 1 to 10 how would you rate the success of current policies on wildlife conservation? (1= highest, 10= lowest)

5. On a scale of 1 to 10 how would you rate the responsiveness of conservation policies to the communities' aspirations in India? (1= highest, 10= lowest)

b. Does this factor affect wildlife poaching in any way?

6. What are the major threats to Indian wildlife conservation?

7. Do you think that during the last 20 years (since 1987) wildlife trade and poaching has increased in India and the current policies are not adequate to deal with the problems? Do these policies reflect the true field situations?

8.a. Do you think that the poaching and illegal trade data compiled by the Government agencies reflect the true field pictures? How can this be improved so as to be realistic?

b. What could be an NGO's role in that?

9. CITES (Convention of International Trade in Endangered Species of Wild Fauna and Flora) advocates sustainable use of wildlife for better conservation. Is it practicable in India in wake of overpopulation of certain species vis-à-vis lack of resources?

10. CBD (Convention of Biological Diversity) has strong mandate of sustainable use, access and benefit sharing, research and technology transfer – how the Indian policies are being reoriented? CITES is also looking for greater synergies with CBD, this calls for

greater coordination at the national level at field level. In your view how are these proposed to be achieved in India?

11. On a scale of 1 to 10, how would you rate the efforts made by the Government in last ten years in terms of policies and laws to control poaching and illegal trade in India? (1= highest, 10= lowest)

12. On a scale of 1 to 10, how would you rate the responsiveness of conservation policies to changing socio-economic aspirations in present day's India? (1= highest, 10= lowest)

b. Does this factor affect wildlife poaching and illegal trade?

13. Could sustainable harvest of certain species work to create resources for conservation? Why or why not?

b. Could this be a management tool?

c. What would be the likely problems in practicing this as conservation tool in the country?

14. In India wildlife policies reviews are based on scientific judgments and field research. Do you (Please mark one or pick one of the following)?

I. Strongly agree
II. Moderately agree
III. Neutral
IV. Disagree
V. Strongly disagree

My answer (   )
Additional comments (if any):

15. What are the species largely in illegal wildlife trade in India?

1.
2.
3.
4.
5
6.
7.
8.
9.
.

(Note: Numbers do not indicate rank and could be more.)

16. Is sustained economic growth (or socio-economic changes) in the country making a direct or indirect impact on poaching and illegal wildlife trade?

17. Indian wildlife laws and policies will become more effective if the scientific and research findings are adequately incorporated in the process of their review and formulations (Please tick mark one or pick one).

1. A strongly relevant argument
2. A relevant argument
3. Neutral, no comments
4. An irrelevant argument
5. A strongly irrelevant argument

My answer ( )
Additional observation, if any:

18. In India wildlife policies reviews are largely based on scientific judgments and field research findings. Do you (Please mark one or pick one of the following)?

1. A strongly relevant argument
2. A relevant argument
3. Neutral, no comments
4. An irrelevant argument
5. A strongly irrelevant argument

My answer ( )
Additional observation, if any:

19. In absence of strong policy inputs for controlling wildlife crimes and illegal trade wildlife conservation will suffer.

I. Strongly agree
II. Moderately agree
III. Neutral
IV. Disagree
V. Strongly disagree

APPENDIX 3

Questionnaire (Policy maker) Code:

Name:
Designation (present or past):
Organization/Affiliation:
Date:

1. a. In the last 20 years, since 1987, has wildlife protection been strengthened with stronger policy inputs?

   b. Is poaching a major threat to wildlife conservation in India?

   c. Has poaching and illegal wildlife trade increased in India in the last 20 years?

2. Are the current wildlife policies adequate to conserve important species and their habitats?

3. Do you think that NGOs have important roles in controlling wildlife poaching and illegal trade in wildlife in India?

4. Are NGOs involved in policy revisions and formulations on wildlife conservation including control of poaching and wildlife trade?

5. a. Do you think that sustained economic development in the country is making a direct or indirect impact on illegal demand of wildlife?

   b. If this is the case what is the policy level response to this scenario?

6. Is there any institutionalized mechanism to involve the communities, directly or indirectly, in the process of wildlife policy formulation and interim revisions?

7. a. On a scale of 1 to 10 (1= highest, 10= lowest) how would you rate the responsiveness of conservation policies to the communities' rising aspirations (socio-economic) in India?

   b. Does this factor affect wildlife poaching or illegal trade?

8. a. On a scale of 1 to 10 (1= highest, 10= lowest) how would you rate the effectiveness of CITES (Convention of International Trade in Endangered Species of Wild Fauna and Flora) in controlling illegal wildlife trade (emphasis on cross-border trade- air, land and water) in India?

   b. Is there a specific CITES legislation in India?

9. CITES advocates use of sustainable use of wildlife for better conservation. Is it practicable in India in wake of overpopulation of certain species vis-à-vis lack of resources?

10. CBD (Convention of Biological Diversity) has strong mandate of sustainable use, access and benefit sharing, research and technology transfer-how the Indian policies are being reoriented to achieve these? CITES also looks for greater synergy with the CBD, which calls for greater coordination at the national level and at field level-how are these proposed to be achieved in India?

11. a. Will sustainable harvest policies work for certain species to create resources for conservation? Why or why not?

    b. Could this be a management tool?

    c. What would be the likely problems in practicing this as conservation tool in the country?

12. Indian wildlife laws and policies will become more effective if the scientific and research findings are adequately incorporated in the process of their review and formulations (Please tick mark ne or pick one).

    1. A strongly relevant argument
    2. A relevant argument
    3. Neutral, no comments
    4. An irrelevant argument
    5. A strongly irrelevant argument

    My answer (   )
    Additional observation, if any:

13. Scientists are adequately consulted by the policy makers while developing or reviewing conservation policies including those on controlling illegal wildlife trade and poaching.

    I. Strongly agree
    II. Moderately agree
    III. Neutral
    IV. Disagree
    V. Strongly disagree

    My answer (   )
    Additional observation, if any:

14. In India wildlife policies reviews are largely based on scientific judgments and field research findings. Do you (Please mark one or pick one of the following)?

    I. Strongly agree
    II. Moderately agree
    III. Neutral
    IV. Disagree
    V. Strongly disagree

    My answer (   )
    Additional observation, if any:

15. Do you think that the poaching and illegal trade data compiled by the Government agencies reflect the true field pictures? Can NGOs have significant collaborating role with the government agencies in improving them?

16. What are the major threats to Indian wildlife conservation?

17. On a scale of 1 to 10 (1= highest, 10= lowest) how do you rate the success of current polices on wildlife conservation?

18. What are the species largely in illegal wildlife trade in India?

    1.
    2.
    3.
    4.
    5
    6.
    7.
    8.
    9.
    .

    (Note: Numbers do not indicate rank and could be more.)

19. How would you rate the efforts made by the governments in last 10 years in terms of policies and laws to control poaching and illegal wildlife trade? (1 = best efforts, 10 = worst efforts)

20. What are the major problems in enforcement of wildlife laws including CITES to control poaching and illegal trade in wildlife? (Note: in terms of priority)

    1. Poor infrastructure and resources including lack of training

2. Inadequacy of law and policies
3. Lack of political support and corruption
4. Lack of awareness
5. Others including lack of coordination among law enforcement authorities

21. Training inputs to wildlife enforcement staff are adequate for handling wildlife crimes and investigations

I. Strongly agree
II. Moderately agree
III. Neutral
IV. Disagree
V. Strongly disagree

My answer (   )
Additional observation, if any:

22. Handling of wildlife crime investigation in India often lacks sufficient scientific inputs (Please tick mark one or pick up one)

I. Strongly agree
II. Moderately agree
III. Neutral
IV. Disagree
V. Strongly disagree

My answer (   )
Additional observations, if any:

23. There is an institutional mechanism in place to receive the views of wildlife enforcement officials in policy matters. Do you?

I. Strongly agree
II. Moderately agree
III. Neutral
IV. Disagree
V. Strongly disagree

My answer (   )
Additional observation, if any:

24. Wildlife policies and laws will become more reflective of field realities if views of enforcement officials are received and incorporated regularly and routinely in an institutionalized manner

1. A strongly relevant argument
2. A relevant argument

3. Neutral, no comments
4. An irrelevant argument
5. A strongly irrelevant argument

My answer ( )
Additional observation, if any:

25. Not enough research is done in India in the area of wildlife law enforcements, illegal trade phenomena and wildlife crimes and therefore policies remain skewed. Do you?

I. Strongly agree
II. Moderately agree
III. Neutral
IV. Disagree
V. Strongly disagree

My answer ( )
Additional observation, if any:

APPENDIX 4

Policy Related Questionnaire (Scientist) Code:

Name:
Organization/ Affiliation:
Date:

1. Wildlife poaching and illegal trade is among the most significant factors for decline of species in India at present? Do you (Please mark one or pick one of the following)?

I. Strongly agree
II. Moderately agree
III. Neutral
IV. Disagree
V. Strongly disagree

My answer ( )

2.a Do you think that during the last 20 year (since 1987) wildlife trade and poaching has increased in India and the current policies are inadequate to deal with the problems?

b. Is poaching a major threat?

3. In absence of strong policy inputs for controlling wildlife crimes and illegal trade wildlife conservation will suffer.

I. Strongly agree
II. Moderately agree
III. Neutral
IV. Disagree
V. Strongly disagree

My answer ( )

4. Policies regarding wildlife conservation including protection and law enforcement require direct and substantial scientific inputs.

I. Strongly agree
II. Moderately agree
III. Neutral
IV. Disagree
V. Strongly disagree

My answer (   )
Additional observation, if any:

5. Scientists are adequately consulted by the policy makers while developing or reviewing conservation policies including those on controlling illegal wildlife trade and poaching.

I. Strongly agree
II. Moderately agree
III. Neutral
IV. Disagree
V. Strongly disagree

My answer (   )
Additional observation, if any:

6. What are the reasons that Indian wildlife policies and laws have not been able to contain poaching and illegal trade in major species?

1.
2.
3.
4.
5.

(Note: numbers do not indicate rank)

7. Indian wildlife laws and policies will become more effective if the scientific and research findings are adequately incorporated in the process of their review and formulations (Please tick mark one or pick one).

1. A strongly relevant argument
2. A relevant argument
3. Neutral, no comments
4. An irrelevant argument
5. A strongly irrelevant argument

My answer (   )
Additional observation, if any:

8. Not enough research is done in India in the area of wildlife law enforcements, illegal trade phenomena and wildlife crimes and therefore policies remain skewed. Do you?

I. Strongly agree
II. Moderately agree
III. Neutral

IV. Disagree
V. Strongly disagree
My answer (   )
Additional observation, if any:

9. On a scale of 1 to 10 how would you rate the success of current policies on wildlife conservation? (1= highest, 10= lowest)

10.a On a scale of 1 to 10 how would you rate the responsiveness of conservation policies to the communities' aspirations in India? (1= highest, 10= lowest)

b. Does this factor affect wildlife poaching in any way?

11. What are the major threats to Indian wildlife conservation?

International Agreements

12.a Are you aware that CITES (Convention of International Trade in Endangered Species of Wildlife Fauna and Flora) makes it mandatory for a member country to appoint one or more scientific authority to advice the government on scientific matters for CITES implementation

1. Yes
2. No

b. Is this system in place in India?

1. Yes
2. No
3. Not aware

13. CITES advocates sustainable use of wildlife for better conservation. Is it practicable in India in wake of overpopulation of certain species vis-à-vis lack of resources?

14. CBD (Convention of Biological Diversity) has strong mandate of sustainable use, access and benefit sharing, research and technology transfer – how the Indian policies are being reoriented? CITES is also looking for greater synergies with CBD, this calls for greater coordination at the national level and at field level. In your view how are these proposed to be achieved in India?

15. On a scale of 1 to 10, how would you rate the efforts made by the Government in last ten years in terms of promoting research and strengthening scientific protocols in wildlife conservation and to control poaching and illegal trade? (1= highest, 10= lowest)

16. On a scale of 1 to 10, how would you rate the responsiveness of conservation policies to changing socio-economic aspirations in present day's India? (1= highest, 10= lowest)
Does this factor affect wildlife poaching and illegal trade?

17. a. Could sustainable harvest of certain species work to create resources for conservation? Why or why not?

b. Could this be a management tool?

c. What would be the likely problems in practicing this as conservation tool in the country?

18. In India wildlife policies reviews are largely based on scientific judgments and field research findings. Do you (Please mark one or pick one of the following)?

I. Strongly agree
II. Moderately agree
III. Neutral
IV. Disagree
V. Strongly disagree

My answer (   )
Additional observation, if any:

19. What are the major species in illegal wildlife trade in India?

1.
2.
3.
4.
5
6.
7.
8.
9.
.

(Note: Numbers do not indicate rank and could be more.)

20. Is sustained economic growth (or socio-economic changes) in the country making a direct or indirect impact on poaching and illegal wildlife trade?

Appendix 5. Reported seizures of sea cucumbers and its derivatives from India 1992-2007.

Year	Quantity (kg)	Date	Place	Legal status	Destination	Source	Year
1992	0	NA	NA	0	NA	NA	1992
1993	0	NA	NA	0	NA	NA	1993
1994	10	07/17/'95	A&N Islands	0	Exmain	MoEF, ND	1994
1995	37	11/10/95	A&N islands	0	Exmain	MoEF, ND	1995
1995	300	NA	Kolkata	0	EXUN	CITES ER	1995
1996	27	7/12/1996	Kolkata	0	EXUN	CITES ER	1996
1996	40	10/3/1997	A&N Islands	0	EXUN	CITES, ER	1996
1997	64	2/10/1998	A&N Islands	0	EXUN	MoEF, ND	1997
1997	47	4/17/1998	A&N Islands	0	EXUN	MoEF, ND	1997
1998	30	2/1/2001	A&N Islands	0	EXUN	MoEF, ND	1998
1998	5	NA	WB	0	EXUN	CITES, ER	1998
2001	271	3/20/2002	Chennai Harbor	1	SNG	CITES, SR	2001
2002	25	2/3/2003	Chennai Airport	1	SNG	CITES, SR	2002
2003	68	3/3/2003	Chennai Port	1	MLY	CITES, SR	2003
2003	70	6/3/2003	Chennai	1	SNG	CITES, SR	2003

Appendix 5. Continued.

Year	Quantity (kg)	Date	Place	Legal status	Destination	Source	Year
2003	30	6/18/2003	Chennai	1	HG	CITES, SR	2003
2003	950	7/27/2003	Chennai	1	SNG	Customs, Chennai	2003
2003	1540	NA	Tuticorin, TN	1	MLY	CITES, SR, India	2003
2003	981	NA	Chennai	1	SNG	CITES, SR, India	2003
2004	0	NA	NA	1	NA	NA	2004
2005	0	NA	NA	1	NA	NA	2005
2006	0	NA	NA	1	NA	NA	2006
2007	250	2/20/2007	Tuticorin, TN	1	SL	TNFD	2007

0 = No protection under the WPA 1972, regulated for export and prohibited in A&N Islands

1 = All trade banned under WPA 1972 and prohibited in A&N islands

NA = Not applicable / not available

A&N Islands = Andaman and Nicobar Islands

Exmain = Export to mainland in India

EXUN = Export to unknown destination

SNG = Singapore

MLY = Malaysia

MoEF = Ministry of Environment and Forests, New Delhi

CITES = Convention of international Trade in Endangered Species of Wild Fauna and Flora

ER = Eastern Region, India

SR = Southern region, India

APPENDIX B. DRAFT MANUSCRIPT TO BE SUBMITTED TO THE JOURNAL OF WILDLIFE MANAGEMENT.

NIRAJ, S. K., P. R. KRAUSMAN, AND V. DAYAL. POACHING AND OTHER THREATS TO 3 PROTECTED AREAS IN INDIA.

30 January 2009
Shekhar K. Niraj
School of Natural Resources
University of Arizona
Tucson, Arizona 85721
(520) 621-7255; Fax (520) 621-8801; Email shekhar.niraj@gmail.com

POACHING AND OTHER THREATS TO 3 PROTECTED AREAS IN INDIA

SHEKHAR K. NIRAJ[1,2], School of Natural Resources, Biological Sciences East Building, University of Arizona, Tucson, AZ 85721, USA

P. R. KRAUSMAN[3], School of Natural Resources, 325, Biological Sciences East Building, University of Arizona, Tucson, AZ 85721, USA

VIKRAM DAYAL, Institute of Economic Growth, University of Delhi Enclave, North Campus, Delhi 110007, India

ABSTRACT Evaluating poaching and illegal trade is important to understand how protected areas (PA) in India can achieve biodiversity conservation. We surveyed 216 randomly selected village households, in 3 different protected areas (PAs) along 2 strata (i.e., enclave and fringe villages) to assess household perceptions on poaching and illegal

---

[1]Correspornding author e-mail: shekhar.niraj@gmail.com

[2]Present address: Indian Forest Service, Conservator of Forests (Tamil Nadu Afforestation Project 1), 8 D, Panagal Building, 1 Jeenis Road, Saidapet, Chennai 600015, India

[3]Wildlife Biology Program, 32 Campus Drive, University of Montana, Missoula, Montana 59812, USA

trade of key wildlife species among other threats in PA. The fringe, located ≤ 5 km from the PA, and enclave villages, located inside the PA boundary, had different legal restrictions imposed by the PA. We used structured questionnaires and interviews to obtain responses of households and compared the perceptional data with data from PA management. Fringe and enclave villages did not have significant attitudinal differences on most issues. Among the fringe and enclave households >93% considered sustainable use of wildlife a potentially useful management and conservation tool. Poaching declined since 1992 in 3 PAs but is still difficult to detect. Threats from urbanization along the fringe could be as serious as illegal use of wildlife. The fringe and enclave households have similar access to PA resources and can cause unmanageable pressures on the PA in future. The need for careful management of PAs has increased due to urbanization and changing socio-economic scenarios.

KEY WORDS community, enclave, fringe, India, poaching, protected area, sustainable harvest

The Journal of Wildlife Management: 00(0): 000-000, 2009

The World Conservation Union (IUCN) defines Protected Area (PA) as "an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means" (IUCN 1996:2). In 2007, the PA network in India constituted 96 national parks (NP), 513 wildlife sanctuaries (WS), 41 conservation reserves, and 4 community reserves, covering an area of > 157,000 km^2 (Government of India 2007-2008). All 4 are categories of PA in India and were established for biodiversity under different sections of the Wildlife Protection Act (WPA) of 1972. A NP has the highest legal protection (e.g., grazing is not permitted) followed by WS where grazing could be permitted. The conservation and community reserves are new initiatives through amendments to the WPA in 2003 to encourage community and individual participation in conservation (WPA 1972).

Since the beginning of Project Tiger (PT) in 1973, 28 tiger reserves (TRs), a specialized management unit focused on tiger conservation, have been established, which are coterminous with the existing NP and WS boundaries, but have designated buffer zones. The size of a NP or a WS can vary from 8 km^2 to > 2,500 km^2, and conform to the IUCN category II and IV, respectively (Weeks and Mehta 2004). India adopted a policy of PA and village coexistence (Wells et al.1992, Rangarajan 2001). However, increasing human pressure has increased demands on PA resources against a constant demand from wildlife (Wells et al. 1992, Rodgers et al. 2002).

The PAs across India faces different levels of pressure from human communities for resources, prompting management in PA to relocate villages outside the PA to free the core areas for exclusive use of the wildlife. Unfortunately, these plans have not been successful (Narayan et al. 2005, Rangarajan and Shahabuddin 2006). However, extensive plans have serious consequences for village communities living in and around a PA (Lustig and Kingsbury 2006). India has debated the relationship between local communities and PA since the 1800s (Weeks and Mehta 2004), however, little quantitative research has been done to understand the relationship (Taneja 2001, Schmidt-Soltau 2004, Lustig and Kingsbury 2006) between changing dependence of human communities on forests and poaching.

Hunting by local communities is a major threat to wildlife in PAs in India (Madhusudan and Karanth 2002). Wildlife is poached for illegal trade in domestic and international markets. The illegal trade in wildlife has increased since the 1990s globally (Bennet and Robinson 2000, Freese and Trauger 2000, Mishra 2003 and 2004), though documentation is poor (Roe et al 2002) and India is considered an important supplier country (Broad et al 2003, Mishra 2004) for illegal trade in wildlife. The relationships between the village communities, PA resources, and poaching have not been assessed in most developing countries. A quantitative analysis of this relationship is important from a policy, economic, and ecological perspective (Shahabuddin and Prasad 2004, Weeks and Mehta 2004, Hegde and Bull 2007).

The relationship between the living standards and resources use patterns with poaching or illegal wildlife trade is poorly understood. Poaching and illegal trade in wildlife could be caused by poverty, decreasing livelihood opportunities and loss of employment opportunities (Mockrin et al. 2000, Roe et al. 2002, Broad et al. 2003). Existing laws in India do not permit many activities inside PAs. In the 1990s, eco-development programs, modeled on integrated conservation and development programs (ICDP), were started in a few PAs to provide alternative means of livelihood (Schmidt-Soltau 20004) to the villagers living in enclave villages. However, there are very few successful models (Hegde and Enters 2000). The objective to link conservation and livelihood issues has not been met and, in some instances, lost to misplaced priorities. In the process, the real issue- reducing poaching and other pressures on PA by providing alternative economic means and raising living standards was minimized.

The current policies on PAs in India are unclear. On one hand rehabilitation from PAs (Narayan et al. 2005, Rangarajan 2005, Rangarajan and Shahabuddin 2006) was considered an important conservation strategy. On the other hand, a new legislation was passed awarding property rights to the people living inside the PA (Narayan et al. 2005). Attempts to involve village communities in both the processes remain discordant. In recent policy changes, forced displacement of villages from the PA has been replaced by a consented relocation, which is in line with a draft United Nations Declaration on the Rights of Indigenous People adopted in 2006 (Lustig and Kingsbury 2006).

The PAs in India can not remain isolated from the development process that India has been witnessing since 1993 (Virmani 2002 and 2004, Pachauri 2006). The pressure, including demographic, on natural resources in a PA, is poised to increase with much of development taking place outside it. The link between these 2 is perceived but not assessed quantitatively. The quantitative assessment and its role in planning for a PA assume importance as the primary objective of creating a PA is to conserve biodiversity (Rodgers et al. 2004).

Households living in the PA will be first to perceive the positive or negative changes that occur in the forests. A household living on the fringe of a PA will be related to a PA primarily for resources. The pressures on PA can come from enclave villages that lie within the PA and fringe villages that are situated in the immediate vicinity ($\leq$ 5 km) of the PA boundary. The enclave and fringe villages are subject to different laws, but exert pressure on the PA in terms of resources extraction. The quantitative analysis of the household use of PA resources is limited, and relationships with other environmental resources are scanty (Hegde and Enters 2000, Dayal 2006, Hegde and Bull 2007).

Household surveys provide a rich source of information at the household level, and its relationship with policy (Deaton 1997, Adams and Darwin 1982, Adhikari et al 2003). We attempted to quantify the relationship between communities and PA and its resources, from the perception that is held by the communities that live within or on the fringe of the PA. We compared these perceptions with data from PA management to analyze the differences, as larger differences create less effective policies on PA. management.

Our objectives included, estimating; (1) changes in living standards of fringe and enclave village communities since 1993 to assess whether such changes meant more pressure on the PA, (2) poaching as threat to wildlife conservation in these PAs, (3) threats to PA from demographic development occurring on the fringe, and, (4) evaluating communities' perceptions of sustainable use of wildlife.

Study Areas and Location

We used a 3 stage sampling design. First, we purposively selected 3 PAs located in different geographic and cultural settings of the country to obtain variability in socio-economic patterns of the villages. Second, we used stratified random sampling to select villages, and finally we randomly sampled households. In selection of the PA, connectivity by rail and road communication, our limited resources, time and money (Singleton et al. 1993) were important considerations.

We selected (1) Achanakmar wildlife sanctuary (Achanakmar WS), an area of 553 km^2 in the state of Chattisgarh (17^{o}46' N to 24^{o}5'N, 80^{o}15' E to 84^{o}20' E), (2) Kanha national park (Kanha NP), an area of 941 km^2 in the state of Madhya Pradesh (17º 47' and 26º 52' N and 74º 02' and 84º 24' E) in central India, and (3) Mudumalai wildlife sanctuary (Mudumalai WS), an area of 321 km^2, in the state of Tamil Nadu (8° 04' and 13° 34' N and

76° 14' and 80° 21' E). Kanha NP is a Project Tiger reserve with the country's largest single tiger population (Narayan et al. 2005), Mudumalai WS, a project elephant reserve and a TR, an existing NP, and a WS. Achanakmar WS is being considered as a TR.

Key Characteristics of the Villages

We randomly sampled 3 fringe villages and 3 enclave villages in Achankmar WS (Fig. 1), Kanha NP (Fig. 2) and Mudumalai WS (Fig. 3). The villages in Kanha NP were located in the most remote areas (Fig. 2). The accessibility to villages is poor due to underdeveloped infrastructure. Most households in these PAs practiced farming for subsistence and would sell the surplus to nearby markets (Table 1). Mudumalai households have greater accessibility to markets, a more developed infrastructure, and are close to tourist towns (i.e., Udhagamandalam and Mysore). The adjoining Karnataka state also offered opportunities to sell agricultural produce. Farming in Kanha NP is mainly for subsistence; Achanakmar WS has subsistence and commercial production. A major state highway divides Achanakmar WS. In Mudumalai WS vegetables are grown for markets in Udhagamandalam and Gudalur (Table 1).

METHODS

We conducted household surveys using pre-structured questionnaires (Grosh and Munoz 1996, Deaton 1997) for the enclave (Appendix1) and fringe (Appendix2) households, from October 2007 to February 2008. We used an identical set of questions (Deaton 1997) in both surveys except we added questions that specifically addressed the conditions faced by the enclave villages. The surveys also asked about the household perception of wildlife harvest as a possible strategy for better conservation. A typical interview time was 45 minutes to 1 hour. The questions were direct. Several studies (Adams and Darwin 1982, Roszkowski and Bean 1990, Dillman et al.1993, Raghunathan and Grizzle 1995) show that surveys with long questionnaires tend to have high non-response rates.

We conducted analysis with Stata 10 statistical package (Deaton 1997). Stata 'survey' commands take into account the survey design while making point estimates, fitting models, and estimating variances (Deaton 1997, StataCorp 2007). These adjustments are made for sample averages and for regression estimates. Auto- correlations between observations belonging to the same cluster are also corrected.. The stages in sampling, sampling weights, and the different units at each stage have to be input into Stata 10. From each village, 12 households were chosen randomly. Using data on the number of PAs, the number of fringe and enclave villages in each PA, and the number of households in each village, we could calculate the sampling weight of each household.

Testing Differences Between Households in Different PAs and in Fringe and Enclave Villages

Each thematic question was a response variable and responses were sub-variables. Most responses from the villagers were binary variables, which helped in easing respondent recall. Taking into account the binary nature of the responses, we opted for logistic regressions to statistically test for differences in variables in different protected areas and villages (Verbeek 2004).

Our specification for the logistic regression was:

$$P\{y_i = 1 \mid x_i\} = F(x_i'\beta) = \frac{e^{x'\beta}}{1+e^{x'\beta}}$$

where, P denotes probability, y is the dependent variable, i denotes the ith observation, x is a vector of independent variables, *F* is the standard logistic distribution function, and β is the vector of regression coefficients. $e^{x'\beta}$ is the exponential function applied to x'β, with e

= 2.718. Our independent variables were dummy variables for 1 of the 3 PA and 1 of the 2 village strata. The statistical significance of the coefficients on the dummy variables is a test for statistical significance of the difference between the PA represented by the dummy (i.e., Achanakmar WS and Kanha NP) and the base PA (i.e., Mudumalai WS), and between the villages represented by the dummy (enclave) and the base village (i.e., fringe). The Change in probability (Δ) is the difference in probability of y = 1 between categories represented by the dummy and the base category, holding other variables at the mean value. Some responses were computed as percentages and multiple responses were permitted for many open ended questions (Madhusudan and Karanth 2002). In such cases also the responses were in binary form (high or low).

We collected data on key socio-economic variables, population estimates of major wildlife species and on poaching and seizures of species from the PA management and compared these with the perceptions of the households.

RESULTS

We had >99% response rate in all PAs. For 230 sub-variables, out of 49,680 possible responses, we recorded 247 non-responses.

Socio-economic Differentiation and Occupation Levels in PA

In Achanakmar WS, Kanha NP, and Mudumalai WS; 79, 80, and 28 % fringe households and 88, 86 and 46 % enclave households, respectively, engaged in agriculture. Employment as labor in agriculture fields, construction, and forest department offered next best opportunity to the villages to earn a livelihood. In Achanakmar, Kanha, and Mudumalai; 17, 5, and 42% fringe houses and 3, 6 and 43% enclave households, respectively, engaged in labor as their primary occupation. However, as a secondary occupation, 54, 63 and 26 % fringe households in Achanakmar WS, Kanha NP, and Mudumalai WS, as against 70, 57 and 29% enclave houses, respectively, engaged in labor. Only 6% of enclave households in Mudumalai WS reported getting work in eco-tourism activities.

The likelihood that a household is engaged in agriculture is similar in Achanakmar WS and Kanha NP, and is significantly higher than in Mudumalai WS (Table 2). An enclave household will more likely associate with agriculture as occupation than a fringe household (Table 2). Apart from agriculture, more households engage in labor as a secondary occupation in Achanakmar WS or Kanha NP than in Mudumalai WS and are statistically significant (Table 2). An Achanakmar household does not have many opportunities for other occupations as compared to households in Mudumalai WS and Kanha NP. An enclave household will also obtain fewer opportunities for occupations in other vocations other than agriculture than a fringe household.

Income Level.—In Achanakmar WS, 43% fringe households and 37% enclave households reported an increase in household income since 1993. In Kanha NP, 49% fringe and 58% enclave households, and in Mudumalai WS 41% fringe and 48% enclave households reported that income has remained at the same level since 1993. Overall, in Achanakmar, Kanha, and Mudumalai 60, 75, and 48% households reported an income of ≤$35.00 (US)/ month, respectively. Among enclave households in all PAs, 76% of households reported income ≤$35.00 (US)/ month.

A Kanha NP household had more likelihood of reporting less income since 1993 than a Mudumalai WS or an Achanakmar WS household. An Achanakmar WS household had higher income than the other PA. An enclave household will likely have lower income than a fringe household.

Both Achanakmar WS and Kanha NP households are more likely to possess ≥1 head of livestock (i.e., cattle) than a Mudumalai household, which could have none. Households had more cattle 10-15 years ago and have gradually reduced their livestock operations. The difference between Kanha NP and Mudumalai WS is statistically significant. There is not much difference between enclave and fringe households in regard of cattle possession, and this has been consistent since 1993.

Household size.—In Achanakmar WS and Kanha NP, 48 and 51% fringe households and 44 and 37% enclave households, respectively, reported an average household size of 6-10 persons. In Mudumalai WS, 35% fringe household and 25% enclave households reported an average household size of 4-6, and 20% fringe households reported >10 persons per household.

Problems and Benefits of Living in or Around a PA

People increasingly find living more difficult in PA because of the rapid development that occurs outside the PA and that is disallowed inside the PA due to legal restrictions and management policies. Since 1985, some PAs attempted relocating villages outside the core area of the PAs to other reserve forest lands.

We examined households' perception of difficulties they face while living within or in the vicinity of PA. Further, we let the communities evaluate the difficulties and benefits that they enjoyed in the PA. Mudumalai WS has most of the households (33% enclave and 31% fringe) that viewed legal restriction as a main problem compared with the households in Achanakmar WS and Kanha NP (Table 3). However, enclave and fringe villages across all PAs view this as a problem of similar magnitude (Table 3). The households in Achanakmar WS and Kanha NP will associate more with crop damage as a major problem than the households in Mudumalai WS (Table 3). The enclave and fringe households viewed crop damage by wild animals a problem of similar magnitude. A Mudumalai WS household will likely state the problem of depredation as a greater problem in the PA than in Achanakmar WS. However, households in Kanha NP regard this problem more serious than the Mudumalai WS households. Enclave households feared attack by wild animals as a marginally less serious problem than the fringe villages (Table 3).

Land is limited in a PA due to legal restrictions on purchase or new acquisition. A large proportion, 40% of the enclave households in Mudumalai WS reported the problem of land as serious. The likelihood of a household reporting land acquisition a serious problem in Achanakmar WS is marginally less than in Mudumalai WS. Enclave and fringe households across all PAs considered land a problem in PAs with similar magnitude. Mudumalai WS households, 36% among enclave and 12% among fringe, reported unemployment and limited growth in infrastructure in and around PA as problems. The fringe households across 3 PAs considered the problem of unemployment and infrastructure less severe than by enclave households (Table 3). An Achanakmar WS household will likely face less firewood problem, than a Mudumalai WS household. On the other hand, an enclave household across all 3 PAs will have fewer problems associated with firewood availability than a fringe household, although the difference is not significant. Few households also considered a ban on hunting as a problem of living in or around PAs. A large number of fringe households, 28%, in Mudumalai WS did not report any problem in living close to PA. A Kanha NP household has a higher probability of reporting problems in living in or around the PA than a Mudumalai WS household (Coefficient = -0.795, P = 0.002). An enclave household has greater probability of reporting ≥1 problem than a fringe household will likely report.

Benefits.—Households across 3 PAs counted fewer benefits than the variety of problems faced living in a PA. Grazing was a main benefit. An Achanakmar WS household will have less likelihood of considering grazing as an important benefit than a household in Kanha NP or a Mudumalai WS (Table 4). The PA boundary does not restrict cattle from entering the PA for grazing as the enclave and the fringe households have similar likelihood of considering grazing as an important benefit from the PA. In Achanakmar, Kanha and Mudumalai; 56, 68 and 55% households reported collecting firewood from PA. An Achanakmar household will have less likelihood of reporting firewood collection from the PA as a benefit than a household in Kanha or in Mudulmalai (Coefficient = -0.321, P = 0.028). An enclave household has a higher probability of reporting firewood collection as an important benefit but not significantly different from a fringe household (Table 4).

Very few households in Mudumalai WS (i.e., 11% fringe and none among enclave) reported benefits of timber from PA. A household in Kanha and Achanakmar will more likely report availability of timber as a benefit from the PA compared with Mudumalai (Table 4). An enclave household has a marginally better access to timber than a fringe household across 3 PAs (Table 4).

In Kanha NP enclave, 56% households regularly collected non-timber forest produces (NTFP) from PA. Mudumalai WS and Kanha NP households have better access to fruits, fiber, medicinal plants etc than in Achanakmar WS. An enclave household has easier access to NTFP than a fringe household but the difference is not significant.

Of the 3 PAs, large proportions of Mudumalai WS households; 39% among fringe and 60% among enclave, regarded environmental satisfaction an important benefit of living in or around a PA (Table 4). Across the 3 PAs, the enclave households and fringe households were similar with regard to environmental satisfaction (Table 4).

Beneficial Factors that Influence PA

Although, 52% enclave households and 66% fringe households across all PAs reported that the number of wildlife has increased in PA, they did not significantly differ on reporting increases in wildlife, forest cover, and increases in protection have contributed to an improvement in PAs.

In Mudumalai WS, Kanha NP, and Achanakmar WS, 80, 63, and 42% households, respectively, reported an increase in wildlife in PAs. A household in Mudumalai WS has greater probability of associating with increase in wildlife population as factor of improvement of the PA than Achanakmar WS (Coefficient = -1.533, P = 0.006, change in probability Δ = -0.360) and Kanha NP (Coefficient = -0.919, P = 0.002, Δ = -0.218). Among the respondents 12 households (0.57%) who considered that the forest quality has improved associated with an increase in wildlife populations (χ^2_2 = 0.0978, P = 0.733), but is statistically insignificant. There is no significant difference in enclave and fringe households in considering that an increase in wildlife improves the PA. The enclave households do not consider this factor as important as the fringe households. The households in Mudumalai considered increase in forest cover as contributing to improvements in PAs than an Achanakmar household (Coefficient = -2.484, P = 0.010, Δ = -0.439) and a Kanha household (Coefficient = -0.962, P = 0.002, Δ = -0.193).

The households in Mudumalai WS reported contribution of PA management an important factor in PA improvement and was more significant than Achanakmar WS (Coefficient = -1.236 P = 0.011, Δ = -0.1114) and Kanha NP (Coefficient = -0.155, P = 0.065, Δ = -0.0156). However, only 23 (11.9 %) households who considered that forest quality has improved associated them with improved PA management since 1993 (χ^2_2 = 26.28, P = 0.021). The fringe and enclave households had no significant difference on this observation

Protection.— Overall, only 34% households across all PAs reported that protection to wildlife or forest has increased**.** In Achanakmar WS, Kanha NP, and Mudumalai WS, 42 (20%) households that reported an improvement in the forest quality in the PA associated with legal protection as a causative factor (χ^2_2 = 65.402, P = 0.33). A Mudumalai WS household has much higher likelihood of reporting better protection as a factor of improvement of the PA than an Achanakmar WS household (Coefficient = -2.902, P = 0.004, Δ = -0.23) but less likely than a Kanha NP household (Coefficient = 1.323, P = 0.001, Δ = 0.1576). The enclave and fringe households had no significant difference on the observation that better protection had contributed to improvement in PA.

With regard to legal protection, a Kanha NP household has greater likelihood of reporting legal protection an important factor for PA improvement (Coefficient = 1.699, P = 0.001, Δ = 0.2185). A fringe household also reported legal protection as an important factor in PA improvement more significantly than an enclave household (Coefficient = -0.895, P = 0.012, Δ = -0.0926).

Destructive Factors that Influence PAs

Households mainly reported illegal tree felling (30%) and extraction of NTFP (23%) from the PA as destructive factors for the PA. In Achanakmar WS, Kanha NP and Mudumalai WS, 43 (20.5%) households that reported the forest has degraded since 1993 associated degradation with illegal harvest of tress as the factor responsible (χ^2_2 = 25.072, P =.0.045). Mudumalai WS households have less probability of reporting illegal harvest of trees than Achanakmar WS households **(**Coefficient = 1.02, P = 0.021, Δ = 1.1594) and Kanha NP households (Coefficient = 2.276, P < 0.001, Δ = 0.3932). Fringe and enclave households did not differ significantly that illegal harvest of trees had degraded the PA.

A Mudumalai WS household also has less likelihood of considering NTFP extraction an important factor for PA deterioration than an Achanakmar WS household (Coefficient = 2.698, P = 0.002, Δ = 0.3008) or Kanha NP households (Coefficient = 3.329, P = 0.001, Δ = 0.4057). A fringe household will more likely report excessive extraction of NTFP leading to destruction of the PA than an enclave household (Coefficient = -0.596, P = 0.038, Δ = -0.0424).

From all the respondents, 46 (21%) households who reported that the human population has considerably increased around the PA associated with illegal harvest of trees as important reason for the PA degradation (χ^2_2 = 83.7943, P = 0.008)

Wildlife Sighting

Overall, 64 % of respondents (n = 216) saw wild animals in ≤15 days, 20 % in ≤ 30 days, and 11 % in ≤ 3 months. Only 4% would see a wild animal once in ≥ 6 months and about

1 % of respondents would never see a wild animal in the PA. This difference in sighting frequency among the PA was insignificant (χ^{2}_{2} = 39.6443, *P* = 0.532).

The likelihood of wildlife sighting is less in Achanakmar WS (Coefficient = -2.242, *P* = 0.007, Δ = -0.4916) and in Kanha NP (Coefficient = -1.390, *P* < 0.001, Δ = -0.3114) than in Mudumalai WS. There is small difference in sighting frequency between the enclave households and fringe households (Coefficient = 0.334, *P* = 0.329, Δ = 0.0714).

A household in Achanakmar WS (Coefficient = -1.533, *P* = 0.006, Δ = -0.3601) or in Kanha NP (Coefficient = -0.919, *P* = 0.002, Δ = 0.002) will less likely report that wildlife population has increased since 1993 than a household in Mudumalai WS. An enclave household has less likelihood of reporting an increase in wildlife population since 1993 than a fringe households across all PAs (Coefficient = -0.320, *P* = 0.201, Δ = -0.747).

Wildlife Poaching and Species Composition

In Mudumalai WS, 18% enclave and 13% fringe households saw poaching of wildlife once in ≤15 days. In Kanha NP and Achanakmar WS, 8 and 5% fringe households, respectively encountered poaching in ≤15 days. Households in Mudumalai WS were more likely to encounter poaching once/15days than in Achanakmar WS (Coefficient = -2.554, *P* = 0.085) and in Kanha NP (Coefficient = -0.784, *P* = 0.005). An enclave household was marginally less likely to encounter poaching than a fringe household (Coefficient = -1.069, *P* = 0.490, Δ = -0.0376).

Tiger (*Panthera tigris*)

In Mudumalai WS, 5% of the households encountered poaching of tigers since 1993. In Kanha NP, 21% of the households reported poaching of tigers≥1 time. The PAs differed in sighting tiger poaching ($\chi^2_2 = 6.4358$, $P < 0.001$). We further examined the differences among the PAs by running logit regressions on the responses. The households between Kanha NP and Mudumalai WS differed significantly on encountering a poached tiger (Coefficient = 1.646, $P = 0.001$, $\Delta = 0.1792$). However, the difference between the enclave and the fringe villages across all PAs was insignificant ($\chi^2_1 = 0.999$, $P = 0.264$).

Leopard (*Panthera pardus*)

Leopard poaching was not reported since 1993 in Achanakmar WS, Kanha NP (0.46%), and Mudumalai WS (3.89%). This was a common observation across 3 PAs ($\chi^2_2 = 3.51$, $P = 0.427$) or between fringe and enclave households across the PAs ($\chi^2_1 = 3.31$, $P = 0.190$). This is in contrast with the reported national trend, which indicates increased leopard poaching since 1998, but is in agreement with the PA data which does not record any leopard poaching in 3 PAs since 1993.

Elephant (*Elephas maximus*)

Wild elephants are found only in Mudumalai WS. About 21 households (29%) reported seeing a poached elephant since 1993. An enclave household has lower probability of encountering poached elephant (Coefficient = -1.005) than a fringe household. The government record stated only 4 poaching cases in 1997 and none in 2006 and in 2007, which contradicted the household perceptions on elephant poaching.

Wild boar (*Sus scrofa*)

Wild boar is a well distributed species and occurs in most of the PAs in India (Prater 1971) and are poached for meat. Tiger and leopard prey upon wild boar (Prater 1971, Karanth and Sanquist 1995). In Achanakmar WS, Kanha NP and Mudumalai WS, respondents from 29(40%), 32 (45%) and 5 (7%) households, respectively reported poaching of wild boar (χ^2_2 = 0.5155, $P < 0.001$). However, the 45 enclave households (44%) and 38 fringe households (38%) reported encounters of poaching of a wild boar since 1993 (χ^2_1= 0.5155, P = 0.2168).

Deer

The households in Mudumalai WS (65%, n = 72) reported more spotted deer (*Axis axis*) poaching than in Achanakmar WS (54%, n = 72) or in Kanha NP (49%, n = 72). The likelihood of poaching in Mudumalai was higher than in Kanha (Coefficient = -0.441, P = 0.005, Δ = -0.1091). The difference between enclave households (58%, N = 108) and fringe households (50%, N = 108) of observing poaching spotted deer was marginal (χ^2_1= 0.7995, P = 0.2473).

Sambar (*Cervus unicolor*) is important prey for tiger in many regions in India (Prater 1971). Poaching of sambar was reported by 36 (50%), 12 (17.32 %) and 16 (18.14%) households respectively in Kanha NP, Achanakmar WS, and Mudumalai WS. The PAs differed in reporting sambar poaching (χ^2_2 = 16.5988, $P < 0.001$). The enclave and fringe households, however, differed marginally in encountering poaching of sambar (χ^2_1 = 2.407, P = 0.378). The logistic regressions on sambar poaching established a significant higher poaching of sambar in Kanha NP than in Mudumalai WS (Coefficient = 1.90, P = 0.001, Δ =.0.3888).

Poaching of barking deer (*Muntiacus muntjak*), hog deer (*Axis porcinus*), four horned antelopes (*Tetracerus quadricornis*) was rarely reported by the PA households, though national level data show the four horned and other antelopes (i.e., black buck [*Antelope cervicapra*]) were poached frequently during 1992-2006. The data from 1992-2007 from the record do not mention seizures of these deer and antelope species in PA so their poaching is largely unrecorded.

Guar (*Bos gaurus*)

Guars are found in all 3 PAs (Prater 1971). Gaur poaching was reported by 5 (6.3%), 7 (9.6%), and 12 (15%) households, respectively, in Achanakmar WS, Kanha NP, and Mudumalai WS as being poached. Poaching gaur differed significantly among the PAs (χ^2_2 = 1.1052, P < 0.001). The fringe households (11.3%) and enclave households (4.4%) differed marginally (χ^2_1 = 1.745, P = 0.238).

Wild dog (*Cuon alpinus*)

Only 2 (1.46%) households in Mudumalai reported poaching wild dogs (*Cuon Alpinus*) and none in the other 2 PAs. No fringe households across 3 PAs and only 1.36% enclave households reported poaching of a wild dog.

Sloth bears (*Melursus ursinus)*

Poaching sloth bears was reported by 6 (4.3%), 4 (3.1%) and 3 (2.1%) of the households in Achanakmar WS, Kanha NP, and Mudumalai WS since 1993. The difference is not significant among the PAs (χ^2_2 = 0.1919, P = 0.168). An Achanakmar WS household has higher likelihood of observing a poached sloth bear than a Mudumalai WS household (Coefficient = 1.19, P = -0.177, Δ = 0.0454). Among fringe and enclave, 3.31% and 2.18% households, respectively, reported poaching of a sloth bear since 1993, and the difference was not significant (χ^2_1 = 0.2408, P = 0.6676).

Other Species

Only, insignificant proportions of the households reported poaching of stripped hyaena (*Hyaena hyaena*), barking deer (*Muntiacus muntjak*), and reptiles in 3 PAs. In Mudumalai WS, only 2 (1.9%) households, in Achanakmar WS 14 (19.1%), and in Kanha NP 11 (16.4%) reported bird poaching.

Across the PAs, 7% of households reported black-naped hare (*Lepus nigricollis*) poaching. In Achanakmar WS, Kanha NP and Mudumalai WS; 14.5, 5.7 and 11.2% households, respectively reported hare poaching (χ^2_1 = 2.921, P = 0.002). Among fringe and enclave households, 6 and 14% reported hare poaching (χ^2_1 = 2.921, P = 0.028).

In Achanakmar WS, Kanha NP and Mudumalai WS respondents from 20 (29 %), 13 (18%) and 12 (18%) households, respectively never encountered poaching of any species since 1993. An Achanakmar WS household will have the highest probability of not encountering poaching of any species (Coefficient = 0.925, P = 0.048, Δ = 0.1626).

Poaching Frequency

In Achanakmar WS, Kanha NP and Mudumalai WS, 22 (12%) households who reported an increase in poaching also reported an increase in wildlife populations since 1993 (χ^2_1 = 3.8626, P = 0.198). Mudumalai households have the highest probability of encountering a poached animal and is significantly different from Kanha NP (Δ = -2.554) and from

Achanakmar WS (Δ = -0.784). Across the PAs, 14 households (7%) who reported seeing a poached animal in <15 days, also reported an increase in wildlife population (χ^2_1 = 8.316, *P* = 0.124). An enclave household has the greater probability of encountering a poached animal in ≤15 days than a fringe households (Coefficient = 0.334, *P* = 0.304, Δ = 0.0724). The households that reported wildlife poaching has increased did not associate significantly with a decease in wildlife populations (χ^2_1 = 5.1258, *P* = 0.174). A Mudumalai WS household has a greater probability of encountering a poached animal in ≤15 days than an Achanakmar WS household (Coefficient = -2.242, *P* = 0.007, Δ = -0.4916) and a Kanha NP household (Coefficient = -0.784, *P* = 0.005, Δ = -0.0241).

Illegal Trade

The households across all PAs reported they rarely found open market trade of wild animals (0-1 time in 6 months). A Mudumalai WS household had a higher probability of seeing open market trade of wildlife than an Achanakmar WS household (Coefficient = 1.244, *P* = 0.009, Δ = 0.0685) or a Kanha NP household (Coefficient = 1.867, *P* = 0 .002, Δ = 0.118). The probability that a household will likely never see an open market sale of wildlife is less in Achanakmar WS and Kanha NP than in Mudumalai WS (Coefficient = -0.323, *P* = 0.001, Δ = -0.1305).

Poaching trend.— We examined the villagers' perception on the poaching trend from 1992 to 2007. The villages are sensitive to poaching and there was no difference in their attitudes or between the attitudes of villagers in fringe and enclave households on poaching. An Achanakmar WS household is more likely to report increasing poaching than a Mudumalai WS household, which, in turn, has a greater probability than a Kanha NP household. On the whole, there was no clear trend about poaching in the responses.

Sustainable Use of Wildlife as a Conservation and Management Strategy

We examined the communities' perception of sustainable harvest of wildlife as a management strategy for improved conservation in the PAs. In Kanha NP, 29 (80.6%) enclave households and 25 (70.2%) in fringe villages, in Mudumalai WS, 31 (86.3%) enclave, and 29 (83%) fringe households reported that sustainable harvest will be a useful policy. In contrast, in Achanakmar WS only 15 (42.5%) fringe households and 15 (42.7%) enclave households considered sustainable harvest to be a useful policy. We further examined this issue among the PA using logit regressions. A Mudumalai WS household is more likely to consider sustainable harvest useful to conservation and significantly more than an Achanakmar WS household (Coefficient = -2.225, P = 0.003, Δ = -0.4885), and than a Kanha NP household (Coefficient = -0.683, P = 0.003, Δ =-0.1514). An enclave household will likely consider wildlife harvest more useful for conservation management more than a fringe household (Coefficient = 0.429, P = 0.104, Δ = 0.0918). In all 3 PAs, respondents from 200 (93%) households reported sustainable harvest will be useful as conservation tool.

Involving Communities in PA Management

Community involvement in PA management has been emphasized since 1992. We examined the communities' perception of PA management efforts by involving them in management. In Achanakmar WS, Kanha NP and Mudumalai WS respondents from 40 (18.5%) households reported that they were involved in the PA management through the village protection committees. An Achanakmar WS household has greater probability of being involved in PA management than a household in Mudumalai WS (Coefficient = 0.524, P = 0.204, Δ = 0.1009). A Kanha NP household has less probability of being involved than a household in Mudumalai WS and is statistically significant (Coefficient = -0.302, P = 0.027, Δ = 0.0542). In all 3 PAs, respondents from 117 (54%) households reported that in the local village bodies such as the ‘gram panchayat’(i.e., a village administrative body consisting of elected village community members) collective village and ‘gram sabhas’ (i.e., meetings of village communities to take decisions), wildlife and conservation issues never appeared in their meetings (χ^2_2 = 46.979, P = 0.436).

Involvement in policies affecting communities and PA.—We examined the issue of relocation in context of the recently enacted Tribal (Recognition of Forest Rights) Bill 2005 (Rangarajan and Shahabuddin 2006) in relation to involvement of PA communities in policy processes. In Achanakmar WS, Kanha NP, and Mudumalai WS respondents from 60 (43.3%), 11 (7.9%) and 22 (15.9%) households, respectively, were aware of the Tribal Bill, which would affect all forest dwellers (χ^2_2 = 35.635, P < 0.001). In enclave villages across all PA, only 11 (12.3%) households and in fringe villages, 29 (31.6%) households were aware of this legislation.

The likelihood of an Achanakmar WS household (Coefficient = 0.529, P = 0.021, Δ = 0.1113) and a Kanha NP household (Coefficient = 0.608, P = 0.003, Δ = 0.1285) favoring relocation out of the PA is significantly higher than a household in Mudumalai WS. However, respondents from 60 (64.6%, n = 108) households in the enclave villages favored living inside the PA despite the limitations.

The perceptions of major issues between the fringe and the enclave villages did not differ significantly across all 3 PAs. However, the PAs differed significantly on growth in household income, problems the households faced in the PA, and on the perception of the benefits such as collection of construction timber from the PA. Only Mudumalai WS households considered environmental satisfaction as an important benefit from the PA. Mudumalai WS households also associated with the increase in wildlife populations and forest cover as factors of PA improvement. Kanha NP and Achanakmar WS households were more concerned with illegal harvest of trees and NTFP than the Mudumalai households. Achanakmar WS households had significantly less sighting of wildlife animals than Kanha NP and Mudumalai WS households. Mudumalai WS households had a higher probability of encountering poaching than the other PAs. Both Kanha NP and Mudumalai WS households considered sustainable use of wildlife a potentially useful policy more than the Achanakmar WS households. However, the majority of the households across all PAs regarded sustainable harvest useful as conservation and management tool. .

DISCUSSION

The livelihood earning opportunities for the enclave village households is lower than for a fringe household in Kanha NP, and indicates increasing restrictions on land and access to other resources in the PA. Because Achanakmar WS is close to major towns (Appendix 3), the enclave and fringe households have more opportunities of work outside the PA. Kanha NP also had a well developed tourism program that attracted domestic and international tourists (Nayak and Shukla 2007). Kanha NP had the highest growth in tourist visitations in 2007 since 2002 (Appendix 4). Mudumalai WS was located at the tri-junction of 3 southern states of India (Fig. 3) and this has provided further opportunities for employment by dispersion. Both Kanha NP and Mudumalai WS are popular wildlife tourist destinations (Appendix 4). The benefits of growing tourism (Appendix 4) and related activities have, however, not made much contribution to increasing living standards of households in the PA. In contrast, in neighboring Nepal, where social and economic programs in the PA have benefited the households, attitudes towards conservation have improved (Baral and Heinen 2007). In 3 PAs, 70% of households earn ≤$35.00 (US)/ month while supporting an average family of 5-7. The enclave village households have fewer opportunities of employment other than agriculture and labor compared to the fringe villages.

The fringe and enclave households have similar access to the PA resources for grazing, firewood, and timber for house construction. These are prohibited activities in the PA (WPA 1972), but the stringent legal provisions are not effective to shield the PA from demand increasing due to human population (Hegde and Bull 2007). The households in Kanha NP and Achanakmar WS extracted more timber from the PAs than in Mudumalai WS. In Mudumalai WS grazing has been permitted in the reserve forests surrounding the sanctuary at nominal fees (Hegde and Enters 2000). However, the fringe and enclave villages preferred to use the open-access resources (Chopra and Dasgupta 2008) of the PA. Apart from grazing, the PA communities depend on wild sources of proteins, fibers, and food in many developing countries (Bennett and Robinson 2000). The enclave households depended more on the PA for non-wood forest produces than the fringe households.

The rate of increase of cattle was highest in Kanha NP. Achanakmar WS and Mudumalai WS showed a gradual decline in the cattle population during 2002-2007 (Fig.4). Kanha NP also had a rising trend of household increase from 2002 to 2007, but Mudumalai and Achanakmar had a declining trend in 1992 to 2007 (Fig. 5) indicating a possible dispersion of the local population. The PA resources will be subject to further pressures with the rising human populations in 3 PAs since 1993 (Appendix 4, Fig.6).

Whereas, employment opportunities have decreased over the years, particularly with the forest department, human population has increased by 83% between 1992 and 2007 in Achanakmar, 25% in Kanha, and 15% in Mudumalai WS over the same period. The growth in human population has the steepest increase in Kanha from 2002-2007, but a declining trend in Achanakmar in 1992-2007 and a small increasing trend in Mudumalai (Fig.6). The growth in the number of tourists showed an increase in Kanha NP and Achanakmar WS, but a smaller increase in Mudumalai WS from 1992 to 2007 (Fig. 7). The volume of tourists is high in Mudumalai, which could be due to its location close to the popular Udhagamandalam-Mudumalai-Bandipore tourist tract. In Mudumalai and Kanha there has been a consistent growth in tourist visitations since 1992 against a sharp but fluctuating trend in Achanakmar (Fig. 7). On the whole, the demographic pressure is building up fastest in Kanha and more moderately in Mudumalai. These growths translate into increased demand on PA resources.

There is no direct evidence that these developments have caused an increase in illegal harvest of wild fauna. The income of households has remained low since 1993, at the same time the households in all 3 PAs reported a downward trend in poaching. The PA data showed fluctuations in poaching in all 3 PAs from 1992-2007 (Fig. 8). The government poaching data are unreliable and often discredited (Reeve 2002). This is a reason for concern. Even minor subsistence poaching occurring in small parks can lead to local extinction of large species (Nelson 1995). In North America, commercial markets based on wildlife and other values are large, growing, and diversifying (Freese and Trauger 2000). The commercial values of many species (e.g., Canadian fishes, commercial fisheries) have increased manifold during the last 3 decades in Canada and the United

States. Although, commercial markets are also viewed as important for providing economic incentives to conserve wildlife and biodiversity (Freese and Trauger 2000)

Households in Kanha reported tiger poaching significantly more than Mudumalai or Achanakmar. Although, tiger poaching is a serious national and international concern (Kenney et al. 1995, Karanth and Madhusudan 1997, Thapar 2003, Damania 2008), tiger poaching was not a commonly reported phenomenon in these PAs. Similarly, leopard poaching increased all over India since 1998, and has been related to declining tiger populations (Niraj et al. 2009), the evidence for leopard poaching was non-existent in the PA responses indicating the likelihood of more hidden poaching and trade. The illegal trade demands have remained unchanged or increased (Oldfield 2003, Broad et al. 2003, Damania 2008). Mudumalai WS households have greater likelihood of sighting leopard poaching, though the official statistics do not mention any leopard poaching in since 1993 (Appendix 5). These gaps in information are common and could affect the protection strategies adversely. Mudumalai reported substantial elephant poaching, contradicting the observation that elephant poaching is not a very critical issue now as compared with poaching in the 1970s or 1980s (Sukumar et al. 1998).

Deer poaching, particularly spotted deer was more frequently reported by the households in Mudumalai. The enclave and the fringe households did not differ significantly in reporting spotting deer poaching. This implies that it is randomly distributed in a PA and accessible to poachers across the PAs. However, Mudumalai WS there was no deer poaching in 2007, and only 1 case each in 2002 and 1997 (Appendix 5). The PA record on deer population establishes a >400% increase in the population of spotted deer in 2007 from its 2002 level (Appendix 6). Kanha also showed a consistent increase in spotted deer from 1992 until 2007 against declining poaching from 1992 to 2007 (Appendix 5). In contrast, Kanha NP households reported frequent poaching of sambar, which is significantly greater than in Mudumalai and in Achanakmar. Sambar generally, have a body mass >60 kg, and contributes significantly to prey of tigers. Spotted deer and sambar are poached for meat and antlers (Hanfee 1998, Menon and Kumar 1998). Deer are poached for domestic and international markets (Menon and Kumar 1998). Deer and gaur are important prey for tigers, leopards and wild dogs. Research, using stochastic modeling, has established relationship between the depletion in ungulates and declining populations of carnivores (Karanth and Stith 1999).

Poaching of sloth bears, barking deer, wild dogs, hare, and reptiles was not reported significantly by the households from 1992 to 2007, although, the national figures for reptiles and birds seizures indicated extensive poaching from 1992-2007 (Niraj et al. 2009). Achanakmar reported more sloth bear poaching than Kanha and Mudumalai, and this is consistent with national data. Bird trade was voluminous from 1960 to1997 in North India (Ahmad 1997). There are large seizures of reptiles from all parts of India from 1992 to 2006 (Niraj et al. 2009). The lack of evidence of poaching of these common species indicated an organized and hidden trade. This was further confirmed by a lack of evidence on the market sale of poached species, in the responses of the households in all 3 PAs, despite the presence of popular tourist markets in the vicinity of at least 2 of the 3 PAs. The sighting frequency of a poaching incidence in $\leq$ 1 month or even in $\leq$ 3 months is low. In contrast, in their study in 2 PAs in southern India, Madhusudan and Karanth (2002) reported hunting of all major species in the PAs.

The change in probability of reported poaching further substantiates our argument that poaching is not incidental or subsistent but could be part of a commercial trade that is hidden and organized. This could have more serious implications as the profit of illegal trade almost entirely goes to the unscrupulous elements (Stiles 2004), who have no legal or moral stake in conservation. Proximity of south Asia to traditional consumer regions such as East Asia (China and Japan, in particular), the Middle East, and Europe has also ensured the continuation of the legal and illegal supplies of wildlife items from this region (Mishra 2004). For some wildlife species and products, however, a significant segment of products traded are ultimately designed for foreign markets (Roe et al. 2002).This process is facilitated by a good infrastructure near the resource points.

The low poverty levels and lack of sufficient employment opportunities in the PA are apparently not associated with poaching. However, increasing pressures of demands for firewood, trees, and NTFP collections were indicated by the households in the PA. The excessive tree felling and NTFP extraction in Kanha correlated well with the increasing demographic pressure discussed earlier. This would affect the enclave households more intensely than the fringe households.

The buffer resources (i.e., found in the immediate vicinity of the protected area) are also used by many wildlife species, which result in conflicts (Wells et al.1992, Kumar and Shahabuddin 2005). There are arguments that historically the PA resources have been open access and legal restrictions in the form of protected areas came much later with the advent of conservation laws. Both common property resources (CPR) and open access resources have been managed by PA communities since ancient time. Gordon (1954) discussed those resources where access is open are overused, in that it is in the common interest to restrict their use by collective management. His reasoning was simple; given that resources are finite in size, they have positive social worth. But an open access resource is free to all who use it (Adhikari et al. 2003, Chopra and Dasgupta 2008). This is linked to the changing values of a PA and needs to be monitored closely with a perspective planning process. Since, we argued that there is no significant difference in access to PA resources between the enclave and fringe villages, the rise in population and process of rapid urbanization along the fringes could be a major concern (Wells et al. 1992). The households reported increasing population pressures and associated demands on the PA resources as being detrimental to the PA quality. There about 3.7 million people (740,000 families) who live within the NP and WS (Narayan et al. 2005). In the larger scenario, 56% of the NPs and 72% of WSs in India reported human populations living within them (Kothari et al.1989). Impact of human population and human activities and associated technological factors could influence wildlife and these factors tend to act simultaneously (Wells et al. 1992, Hall et al. 2000).

In view of this it is critical to note that wildlife sightings by households have come down in these PAs since 1993, even when poaching is reported to be down, and PA data demonstrated increase in populations of all major species except for a marginal decrease in the tiger population in Kanha NP and a decrease in Achanakmar WS during 1997-2007 (Appendix 6).

Relocation of households from the PA to non-PA forest areas appears to be an effective solution. The households listed more problems than the benefits that they enjoyed living within or in the vicinity of the PA. However, this is a complicated process and a strong communication between the PA management and the villagers is needed.

Only a few households in the PAs reported that they are involved in the PA management, contrary to the emphasis laid down on community involvement in government policies. Lack of effective collaboration could also create management problems in view of the recent legislations such as the Tribal Bill (Recognition of Forest Rights) 2005. The necessity of building long-term partnerships between local residents and management or for the redistribution of economic benefits from the reserve to local villages, are topics that do not receive the attention of management any more than they had in the past (Rangarajan and Shahabuddin 2006).

The households considered sustainable harvest of wildlife, though currently prohibited under the Indian laws (WPA 1972), a viable opportunity for creating alternative livelihood means (Nelson 2000) that could also provide an effective conservation tool. This could also increase long term partnership with the PA management and could deal with the pest species in certain PAs and thus improve the management. In Africa sustainable harvest (Stills 2004) has been used to achieve a long term conservation goals (Schmidt-Soltau 2004). In India a ban on export of snake skins under the WPA 1972 had a major negative impact on the Irula tribe (Roe et al. 2002). A ban on trade of species benefits the smugglers, unscrupulous traders and middlemen, while the species is harvested illegally (Stiles 2004).However, Bennet and Robinson (2000) have argued that hunting is largely additive to natural mortality and reduces population densities of hunted species. There are also induced risks of creating perverse incentives (Fresse and Trauger 2000).

Given an increasing scenario of habitat limitations and lack of resources, and increasing demographic pressures (Nelson 2000), the potential of sustainable use as a conservation and management tool could be scientifically investigated in India. The CITES and CBD have increasingly recognized sustainable use of wildlife as useful strategy to achieve goals of biodiversity (Sinclair-Brown 2003). To begin with, the species that are considered pests could be a starting point with careful considerations on the adequacy of their life history characteristics.

MANAGEMENT IMPLICATIONS

Human and wildlife coexistence is not easy to manage as human demography is a highly dynamic process. The policy of wildlife and human coexistence in PAs could become unstable in the long run as the demographic structure keeps changing along the fringes of the PA. Programs for rehabilitation of the villages from the core and other ecologically sensitive habitats of the PA, to reduce the pressure from within, need to be facilitated. Indian policy discourages forced rehabilitation. Programs must be initiated for consensual rehabilitation in the TRs and other PAs by first assessing all sensitive habitats. The households will come forward more convincingly, and to mutual benefit, if the quality of the rehabilitation program is good and implementation reassuring. Setting up a few good models followed by regular monitoring will help the process. Some recent initiatives have been taken up in the PT programs. This will help in ensuring effective corridors and quality buffer areas that are important for a long term development of wildlife and conservation (Newmark 1995).

The study provides evidence that poaching is facilitated by better infrastructure and is influenced from the outside (e.g., ivory poaching in Mudumalai WS and tiger poaching in Kanha NP). Therefore, the local level trade remains invisible and can be deceptively represented in the official records. Anti-poaching strategies to combat illegal extraction of wildlife, which is the most hidden pressure on PAs, will not be effective without a well organized intelligence network involving motivated individuals from among the households. This is possible with a system of incentives and rewards.

Controlling poaching of sambar, spotted deer and other prey species needs to be given equal priority along with the protection of tigers, leopards, and other predators to ensure a healthy prey-predator relationship (Karanth and Stith 1999).

ACKNOWLEDGEMENTS

We thank W. W. Shaw, R. R. Gimblett, and J. L. Koprowski for their valuable comments on earlier drafts. We thank A. N. Prasad for his suggestions on the questionnaires. We thank H. S. Pabla, S. Sen, A. Sahu, R. K. Dogra, and many other senior officials in the state governments in India for their help in facilitating the field work and in collecting PA level data. We thank M. Gupta of Wildlife Trust of India, New Delhi, M. Shakthivel, and S. Barnaiah of Indian Institute of Science, Bangalore for their help in field surveys in different PAs in India. The Ministry of Environment and Forests, Government of India, New Delhi, India; and the Arizona Agricultural Experiment Station, and the School of Natural Resources, University of Arizona, Tucson, USA sponsored this research.

LITERATURE CITED

Adams, L. M, and G. Darwin. 1982. Solving the quandary between questionnaire length and response rate in educational research. Research in Higher Education 17:231-240.

Adhikari, B., S. D. Falco, and J. C. Lovett. 2003. Household characteristics and forest dependency: evidence from common property forest management in Nepal. Ecological Economics 38:245-257.

Ahmad, A. 1997. Live bird trade in northern India. TRAFFIC and WWF- India, New Delhi, India.

Baral, N., and J. T. Heinen. 2007. Resources use, conservation attitudes, management intervention and park-people relations in the Western Terai landscape of Nepal. Environmental Conservation 34:64-72.

Bennett, L. E., and G. J. Robinson. 2000. Hunting of wildlife in tropical forests: Implications for biodiversity and forest peoples. Biodiversity series –Impact studies. World Bank, Washington, D.C., USA.

Broad, S., T. Mulliken, and D. Roe. 2003. The nature and extent of legal and illegal trade in wildlife. Pages 3-22 in Sara Oldfield, editor. The trade in wildlife: regulation for conservation. Earth Scan, London, United Kingdom.

Chopra, K., and P. Dasgupta. 2008. The nature of household dependence on common pool resources: An econometric study for India. Economic and Political Weekly 43(8).

Damania, R., J. Seidensticker, T. Whitten, G. Sethi, K. Mackinnon, A. Kiss, and A Kushlin. 2008. A future for wild tigers. The World Bank and Smithsonian National Zoological Park, Washington, D.C.

Dayal, V. 2006. A micro econometric analysis of household extraction of forest biomass goods in Ranthambore national park, India. Journal of Forest Economics 12:145-163.

Deaton, A. 1997. The analysis of household surveys: a micro econometric approach to development policy. The Johns Hopkins University Press, Baltimore, USA.

Dillman, D. A., M. D. Sinclair, and J. R. Clark. 1993. Effects of questionnaire length, respondent-friendly design, and a difficult question on response rates for occupant-addressed census mail surveys. Public Opinion Quarterly 57:289-304.

Freese, H. C., and D. L.Trauger. 2002. Wildlife markets and biodiversity conservation in North America. Wildlife Society Bulletin 28:42-51.

Gordon, H. S. 1954. The Economic Theory of Common-Property Resources. Journal of Political Economy 62:124-42.

Grosh, M. E., and J. Munoz. 1996. A Manual for Planning and Implementing the LSMS Survey. Living Standards Measurement Study, Working Paper No. 126, World Bank, Washington, D.C.

Hall, A. S. C., W. P. Jones, T. M. Donavan, and J. P. Gibbs. 2000. The implications of mainstream economics for wildlife conservation. Wildlife Society Bulletin 28:16-25.

Hanfee, F. 1998. Wildlife trade: a handbook for enforcement staff. TRAFFIC and WWF-India. New Delhi.

Hegde, R., and T. Enters. 2000. Forest products and household economy: A case study from Mudumalai Wildlife sanctuary, Southern India. Environmental Conservation 27:1-10.

_____, and G. Q. Bull. 2007. Economic shocks and Miombo woodland resource use: A household level study in Mozambique. Center for International Forest Research, Bogor, Indonesia.

International Union for Conservation of Nature. 2006. CNPPA in Action: safeguarding life on Earth. IUCN Gland, Switzerland.

Karanth, K. U., and M. D. Madhusudan. 1997. Avoiding paper tiger and saving real tigers: response to Saberwal. Conservation Biology 11:818-820.

_____, and B. M. Stith. 1999. Prey species depletion as a critical determinant of tiger population viability. Pages 100-113 in riding the tiger: tiger conservation in human dominated landscapes, Seidensticker, J., S.Christie and P. Jackson, editors. Cambridge Univ. Press, Cambridge, United Kingdom.

_____, and M. E. Sunquist. 1995. Prey selection by tiger, leopard and dhole in tropical forests. Journal of Animal Ecology 64:439-450.

Kenney, J. S, J. L. D.Smith, A. M. Starfield, and C.W. McDougal. 1995. The long term effect of tiger poaching on population viability. Conservation Biology 9:1127-1133.

Kothari, A., P. Pande, S. Singh, and D. Variava. 1989. Management of national parks and sanctuaries in India - A Status Report. Environmental Studies Division, Indian Institute of Public Administration, New Delhi, India.

Kumar, R., and G. Shahabuddin. 2005. Effects of biomass extraction on vegetation structure, diversity and composition of an Indian tropical dry forest. Environmental Conservation 32:1-12.

Lustig, D., and B. Kingsbury. 2006. Displacement and Relocation from Protected Areas: International Law Perspectives on Rights, Risks and Resistance. Conservation and Society 4:404-418.

Mashusudan, M. D., and K. U. Karanth. 2002. Local hunting and the conservation of large mammals in India. Ambio 31:49-54.

Menon, V. 2002. Tusker: the story of the Asian elephants. Penguin, Wildlife Trust of India and International Fund for Animal Welfare, New Delhi, India.

_____, and A. Kumar. 1998. Wildlife crime: an enforcement guide. Wildlife Protection Society of India, Natraj, Dehradun, India.

Ministry of Environment and Forests. 2008. The annual report 2007-08. Government of India, New Delhi, India.

Mishra, M. 2003. Evolution, impact, and effectiveness of domestic wildlife trade ban in India. Pages 78-88 in Sara Oldfield, editor. The trade in wildlife: regulation for conservation. Earth Scan, London, United Kingdom.

_____. 2004. Research report on wildlife trade on wildlife trade regulations CITES and law enforcement in south Asia. TRAFFIC, WWF and IUCN.

Mockrin, M. H., E. L. Bennett, and D. L. Labaruna. 2005. Wildlife farming: a viable alternative to hunting in tropical forests? WCS Working Paper 23. Wildlife Conservation Society, New York, New York, USA.

Narayan, S., S. Singh, H. S. Pawar, and M. Gadgil. 2005. Joining the dots: the report of the tiger task force. Ministry of Environment and Forests, Government of India, New Delhi, India.

Nayak, K., and R. Shukla. 2005. Kanha: glimpses of a tiger reserve. Center of Environmental Education, Ahmedabad, India.

Nelson, F. 2000. Sustainable development and wildlife conservation in Tanzania's Maasailand. Environment Development and Sustainability 2:107-117.

Newmark, W.D. 1995. Insularization of Tanzanian parks and the local extinction of large mammals. Conservation Biology 10:1549-1556.

Niraj, S. K., P. R. Krausman, and V. Dayal. 2009. Temporal and spatial analysis of wildlife poaching in India from 1992 to 2006. Dissertation, University of Arizona, Tucson, USA.

Oldfield, S., editor. 2003. The trade in wildlife: regulation for conservation. Fauna and Flora International, Resource Africa and TRAFFIC International. Earthscan, London, United Kingdom.

Pachauri, R. K. 2006. India empowerment to me is: we start restoring the natural resources that we have destroyed. The Indian Express, 20 October 2005:1.

Prater, S. H. 1971. The book of Indian animals. Bombay Natural History Society. Oxford University Press, Bombay, India.

Raghunathan, T. E., and J. E. Grizzle. 1995. A split questionnaire survey design. Journal of the American Statistical Association 90:54-63.

Rangarajan, M. 2001. India's wildlife history. Permanent Black and Ranthambore Foundation, New Delhi, India.

_____. 2005. Fire in the forest. Economic and Political Weekly. November 19.

_____, and G. Shahabuddin. 2006. Displacement and relocation from protected areas: towards a biological and historical synthesis. Conservation and Society 4:359-378.

Reeve, R. 2002. Policing international trade in endangered species: the CITES treaty and compliance. The Royal Institute of International Affairs, London, United Kingdom.

Rodgers, W. A., H. S. Pawar, and V. B. Mathur. 2002. Wildlife protected area network in India: a review. Wildlife Institute of India, Dehradun, India.

Roe, D., T. Mulliken., S. Milledge, J. Mremi, S. Mosha, and M.Grieg-Gran. 2002. Making a killing or making a living? Wildlife trade, trade controls and rural livelihoods. Biodiversity and Livelihoods Issues: 6. TRAFFIC and IIED, United Kingdom.

Roszkowski, M. J., and A. G. Bean. 1990. Believe it or not: longer questionnaires have lower response rates. Journal of Business and Psychology 4:495-509

Shahabuddin, G., and S. Prasad. 2004. Assessing ecological sustainability of non-timber forest produce extraction: the Indian scenario. Conservation and Society 2:235-250.

Schmidt- Soltau, K. 2004. The costs of rainforest conservation: local responses towards integrated conservation and development projects in Cameroon. Journal of Contemporary African Studies 22:94-116.

Statacorp. 2007. Stata Survey Data Reference Manual: Release 10. College Station, Stata Press, Texas, USA.

Stiles, D. 2004. The Ivory trade and elephant conservation. Environmental Conservation 31:309-321.

Sukumar, R., U. Ramakrishnan, and J. A. Santosh. 1998. Impact of poaching on an Asian elephant population in Periyar, southern India: a model of demography and tusk harvest. Animal Conservation 1:281-291.

Taneja, B. 2001. Biodiversity planning support program: integrating biodiversity into the forestry sector, India case study. International workshop on Integration of biodiversity in national forestry planning program, Bogor, Indonesia, 13-16 August 2001.

Thapar, V. 2003. Battling for survival: India's wilderness over two centuries. Oxford University Press, New Delhi, India.

Verbeek, M. 2004. A guide to modern econometrics. John Wiley and Sons. Singapore.

Weeks, P., and S. Mehta. 2004. Managing people and landscapes: IUCN protected areas categories. Journal of Human Ecology 16:253-263.

Virmani, A. 2002. Star performers of the 20th (21st) century: Asian tigers, dragons or elephants. Occasional paper, China, September 1999.

______, 2004. Economic performance, Power, potential and global governance: towards a new international order; ICRIER working paper 150, December 2005.

Wells, M., K. Brandon, and L. Hannah. 1992. People and parks. The World Bank, the World Wildlife Fund, the U.S. Agency for International Development, Washington, D.C., USA.

Table 1. Selected characteristics of fringe and enclave villages that were surveyed in Achanakmar Wildlife Sanctuary (WS), Kanha National Park (NP), and Mudumalai Wildlife Sanctuary (WS), India, 2007-2008.

	Distance to main tar road (km)	Farming	Access to market	No. households	Households sampled
Achanakmar WS					
Enclave					
Ataria	<1	S[a]	Poor	60	12
Lamnahi	6	S	Poor	105	12
Jahkarbandh	10	S	Poor	75	12
Fringe					
Ataria	<1	S,C[b]	Medium	95	12
Jamani	12	S,C	Medium	120	12
Sarasdol	15	S,C	Poor	55	12
Kanha NP					
Enclave					
Jami	12	S	Very poor	201	12
Patua	20	S,C	Fair	150	12
Dhaniajhor	30	S	Very poor	50	12
Fringe					
Batwar	16	S,C	Poor	112	12
Dhanwar	25	S,C	Poor	162	12

Table 1. Cont.

	Distance to main tar road (km)	Farming	Access to market	No. households	Households sampled
Mana	30	S,C	Very poor	114	12
Mudumalai WS					
Enclave					
Anaikatti	20	S,C	Poor	163	12
Chokkanahhli	6	S,C	Fair	35	12
Boothnathan	<1	S,C	Fair	47	12
Fringe					
Valaithottam	<1	S,C	Fair	150	12
Moyar	<1	S,C	Fair	400	12
Mavanallah	4	S,C	Fair	213	12

[a]Subsistence

[b]Commercial

Table 2. Logit regressions on the responses of 216 village households in enclave and fringe villages in Achanakmar Wildlife Sanctuary (WS), Kanha National Park (NP), and Mudumalai Wildlife Sanctuary (WS), India, 2007-2008, on occupation, income, and growth in households income since 1992.

Variable	Logit parameters	Achanakmar WS	Kanha NP	Enclave	Constant
Agriculture	Coefficient	2.29	2.269	0.581	-0.904
	P-value	0.001	<0.001	0.037	0.002
	Change in probability	0.3836	0.3809	0.1186	
Labor	Coefficient	1.665	1.555	-0.0872	-1.035
	P-value	0.007	<0.001	0.700	0.002
	Change in probability	0.3877	0.3651	-0.0218	
Other occupations	Coefficient	-0.440	0.549	-0.0817	-1.537
	P-value	0.182	0.003	0.816	0.001
	Change in probability	-0.061	0.0845	-0.0119	
Low income	Coefficient	-0.376	1.313	1.219	-0.294
	P-value	0.407	0.002	0.134	0.062
	Change in probability	-0.0867	0.2707	0.2705	
Have no Cattle	Coefficient	-2.043	-2.157	-0.149	0.332
	P-value	0.026	0.001	0.792	0.077
	Change in probability	-0.311	-0.3253	-0.0273	

Table 2. Cont.

Variable	Logit parameters	Achanakmar WS	Kanha NP	Enclave	Constant
Had no Cattle 10-15 Years ago	Coefficient	-1.401	-2.147	0.396	-0.294
	P-value	0.064	0.001	0.522	0.098
	Change in probability	-0.2089	-0.300	0.0674	
Income growth Since 1993	Coefficient	0.215	0.00202	0.0567	-0.746
	P-value	0.063	0.969	0.465	0.002
	Change in probability	0.0489	0.0005	0.0128	

Table3. Logit regressions on responses of 216 households in enclave and fringe villages in Achanakmar Wildlife Sanctuary (WS), Kanha National Park (NP), and Mudumalai Wildlife Sanctuary (WS) in India, 2007-2008, on the problems they faced in living in the protected area.

Variable	Logit parameters	Achanakmar WS	Kanha NP	Enclave	Constant
Legal restrictions	Coefficient	-0.429	-0.146	0.166	-0.818
	P-value	0.013	0.028	0.104	<0.001
	Change in probability	-0.0843	-0.0294	0.0337	
Damage by Wildlife	Coefficient	1.578	2.244	0.580	-0.986
	P-value	0.025	0.001	0.277	0.007
	Change in probability	0.3231	0.4307	0.1328	
Cattle killing by wild Animals	Coefficient	-0.700	0.724	0.252	-1.449
	P-value	0.050	0.004	0.378	0.001
	Change in probability	-0.1091	0.129	0.042	
Attack by wild animal	Coefficient	-0.884	0.308	-0.0423	-0.767
	P-value	0.007	0.017	0.727	0.002
	Change in probability	-0.1627	0.0624	-0.0084	
Limitation on land	Coefficient	-1.367	-0.335	0.439	-1.288
	P-value	0.013	0.009	0.179	0.001
	Change in probability	-0.1623	-0.044	0.0599	

Table 3. Cont.

Variable	Logit parameters	Achanakmar WS	Kanha NP	Enclave	Constant
Infrastructure limitation	Coefficient	-0.360	-0.313	-0.318	-0.985
	P-value	0.029	0.008	0.065	0.001
	Change in probability	-0.0562	-0.049	-0.0514	
Limitation on Employment	Coefficient	-0.184	-0.793	0.298	-1.682
	P-value	0.705	0.004	0.673	0.006
	Change in probability	-0.021	-0.0847	0.0349	
Firewood Restriction	Coefficient	-1.939	-0.0561	-0.735	-0.965
	P-value	0.093	0.487	0.523	0.015
	Change in probability	-0.1695	-0.0059	-0.0782	
fear of law	Coefficient	-0.814	-0.254	0.383	-1.085
	P-value	0.039	0.024	0.242	0.002
	Change in probability	-0.1305	-0.0429	0.0662	
ban on Hunting	Coefficient	-1.384	-0.771	1.170	-2.681
	P-value	0.069	0.013	0.119	0.002
	Change in probability	-0.0636	-0.0373	0.0649	
None	Coefficient	-0.279	-0.795	-0.629	-0.984
	P-value	0.243	0.002	0.119	0.002
	Change in probability	-0.0363	-0.0982	-0.0849	

Table 4. Logit regressions on responses of 216 households in enclave and fringe villages in Achanakmar Wildlife Sanctuary (WS), Kanha National Park (NP), and Mudumalai Wildlife Sanctuary (WS) in India, 2007-2008, on the benefits they enjoyed in living in the protected area.

Variable	Logit parameters	Achanakmar WS	Kanha NP	Enclave	Constant
Grazing	Coefficient	-0.141	-2.39	0.897	-3.518
	P-value	0.909	0.008	0.665	0.027
	Change in probability	-0.0027	-0.0384	0.0177	
Firewood	Coefficient	-1.295	-0.321	1.926	-0.0032
	P-value	0.266	0.028	0.205	0.976
	Change in probability	-0.31	-0.0776	0.432	
Timber	Coefficient	1.053	1.769	0.896	-2.536
	P-value	0.082	0.004	0.225	0.004
	Change in probability	0.2087	0.3596	0.1642	
Non-timber Forest Produce (NTFP)	Coefficient	-1.535	0.00405	2.109	-2.513
	P-value	0.107	0.980	0.168	0.027
	Change in probability	-0.1411	0.0004	0.2396	
Environmental Satisfaction	Coefficient	-1.510	-1.483	-0.541	-0.218
	P-value	0.159	0.004	0.654	0.320

Table 4. Cont.

Variable	Logit parameters	Achanakmar WS	Kanha NP	Enclave	Constant
	Change in probability	-0.196	-0.1929	-0.0815	

LIST OF FIGURES

between each 5 year period was calculated by taking first year of the 5- year period as base = 100.

7. The percentage differences in number of visitors in consecutive 5 year periods between 1992-2007 in Achanakmar Wildlife Sanctuary (WS), Kanha National Park (NP) and Mudumalai Wildlife Sanctuary (WS) in India. The percentage difference between each 5 year period was calculated by taking first year of the 5- year period as base = 100.

8. Trend in wildlife offences in Achanakmar Wildlife Sanctuary (WS), Kanha National Park (NP) and Mudumalai Wildlife Sanctuary (WS) from 1992-2007 based on the Protected Area (PA) data.

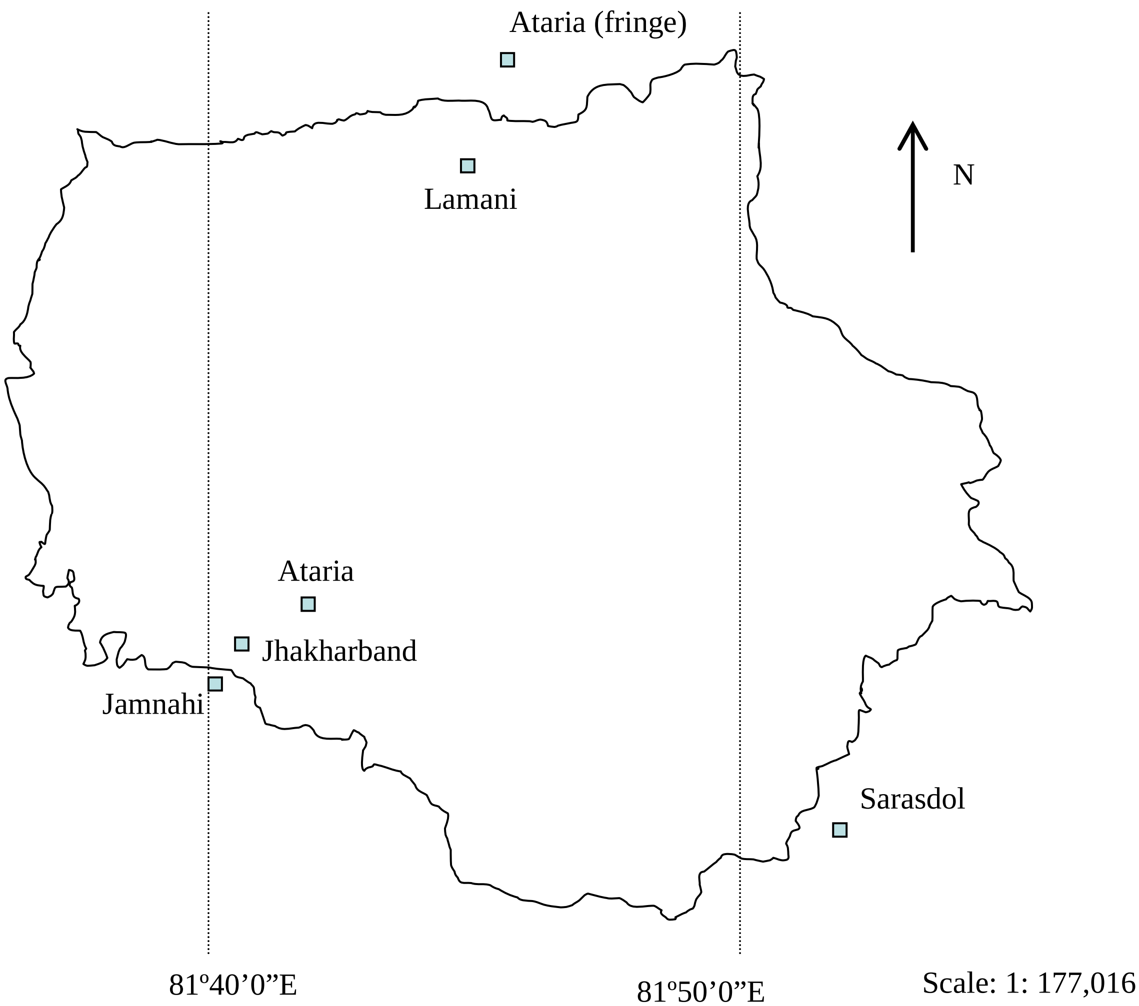


Figure 1.The 6 study villages Ataria-enclave, Jamnahi, Jhakharband, Sarasdol, Lamani and Ataria-fringe in Achanakmar Wildlife Sanctuary (WS) in Chattisgarh state of India

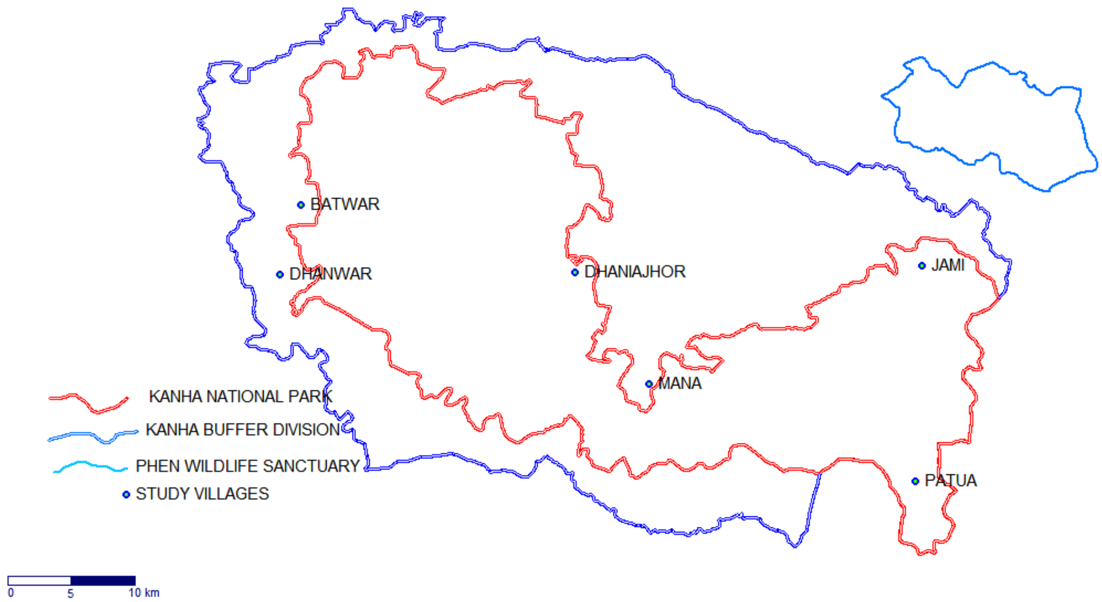


Figure 3. The 6 fringe and enclave study villages Batwar, Dhanwar, Dhaniajhor, Jami, Patua and Mana in Kanha National Park (NP) in Madhya Pradesh state in central India.

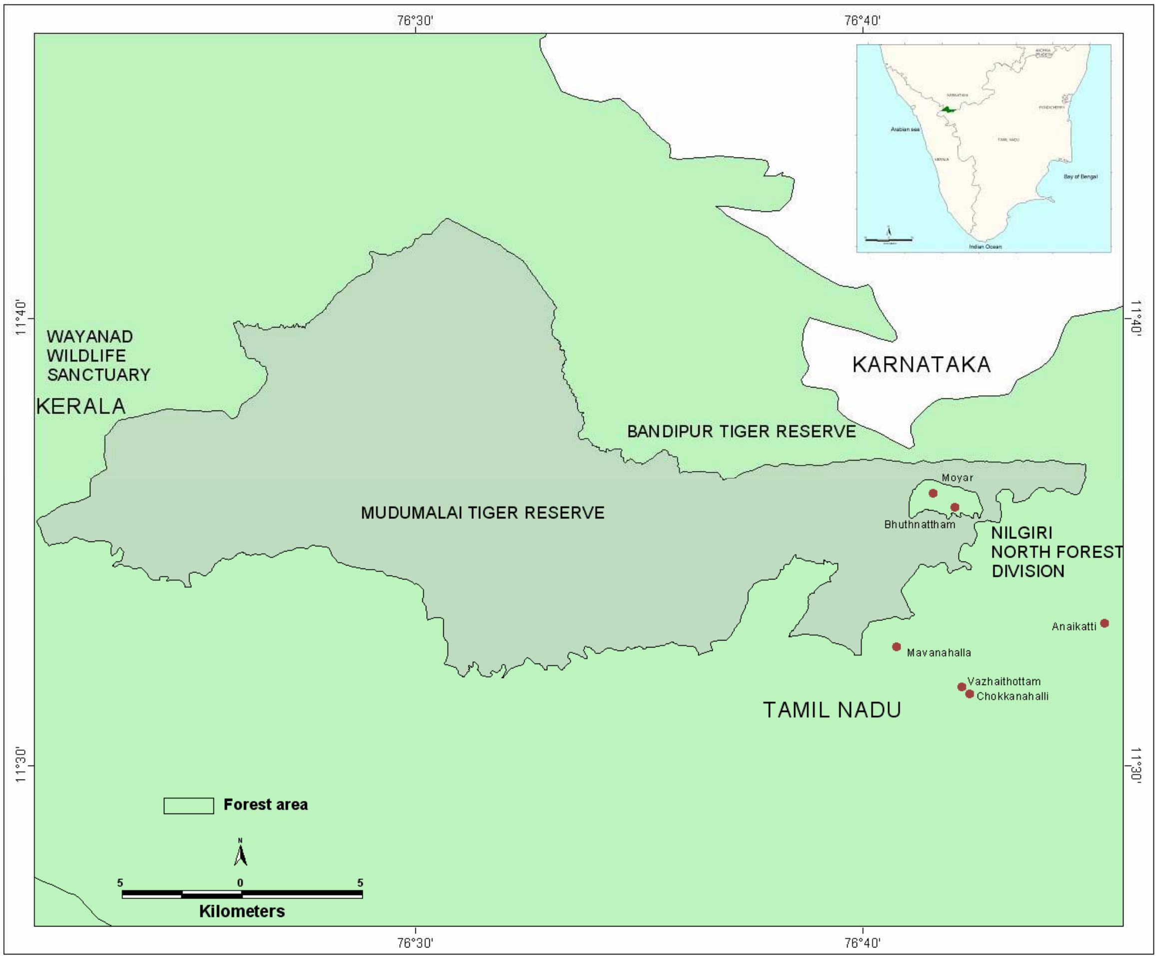


Figure 3. The 6 fringe and enclave study villages Moyar, Bhuthanathan, Anaikatti, Mavanallah, Vlaithottam and Chokkanali in Mudumalai Wildlife Sanctuary (WS) in Tamil Nadu state of India.

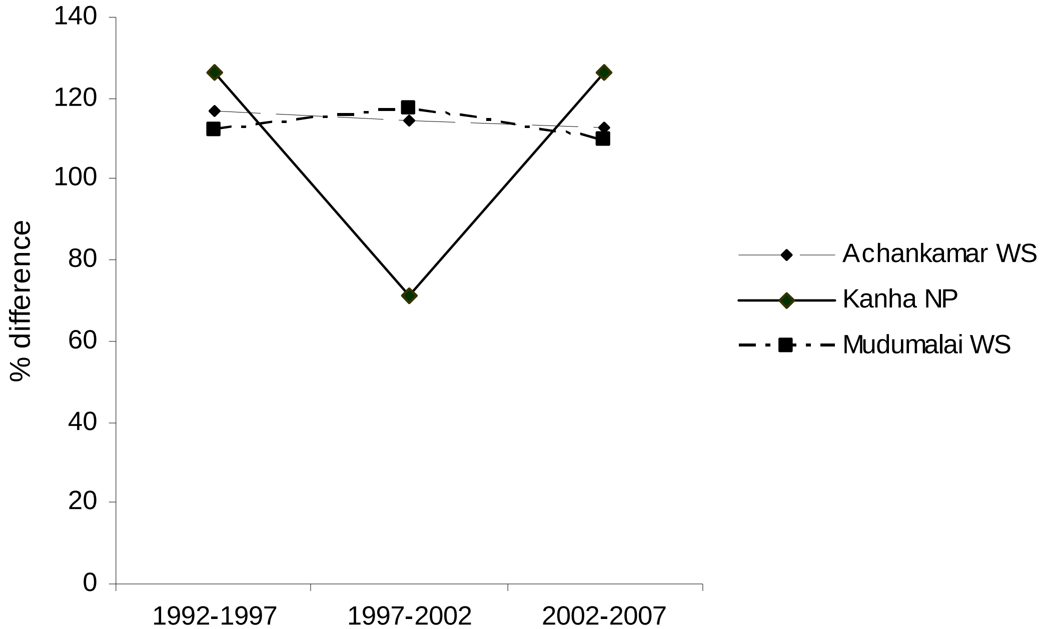


Figure 4. The percentage differences in number of cattle in consecutive 5-year periods between 1992-2007 in Achanakmar Wildlife Sanctuary (WS), Kanha National Park (NP), and Mudumalai Wildlife Sanctuary (WS) in India. The percentage difference between each 5-year period was calculated by taking the first year of the 5-year period as base = 100.

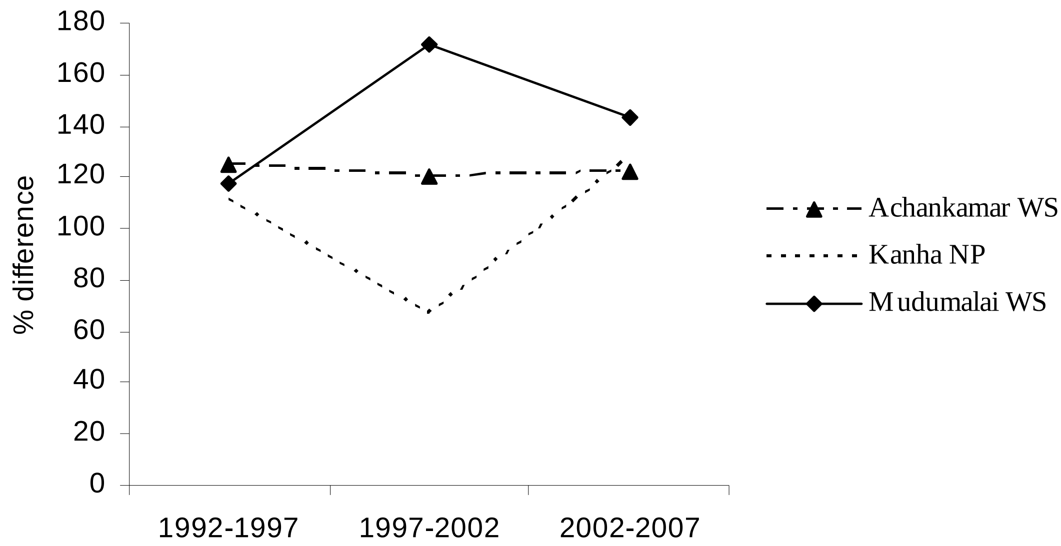


Figure 5. The Percentage differences in number of households in the consecutive 5-year periods between 1992 -2007 in Achanakmar Wildlife Sanctuary (WS), Kanha National Park (NP), and Mudumalai Wildlife Sanctuary (WS) in India. The percentage difference between each 5 year period was calculated by taking the first year of the 5-year period as base = 100.

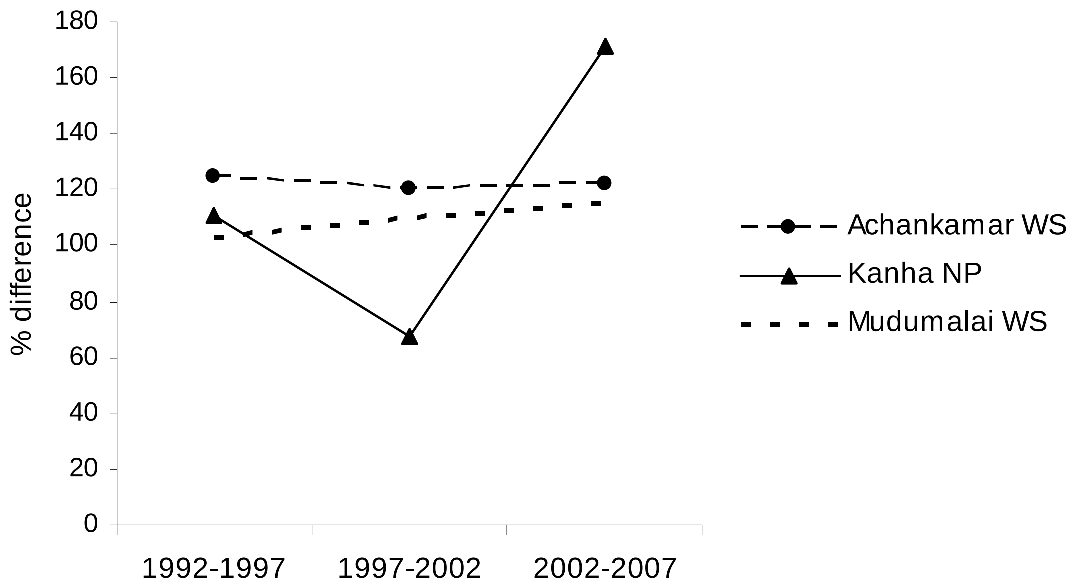


Figure 6. The percentage differences in human population in the consecutive 5-year periods between 1992-2007 in Achanakmar Wildlife Sanctuary (WS), Kanha National Park (NP), and Mudumalai Wildlife Sanctuary (WS) in India. The percentage difference between each 5 year period was calculated by taking first year of the 5-year period as base = 100.

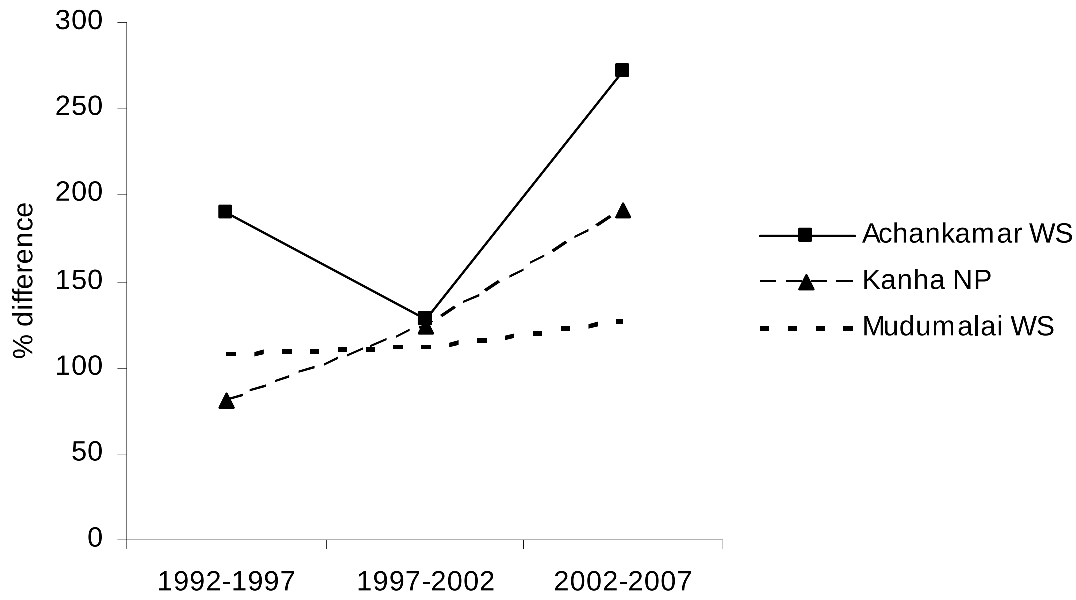


Figure 7. The percentage differences in number of visitors in consecutive 5-year periods between 1992-2007 in Achanakmar Wildlife Sanctuary (WS), Kanha National Park (NP), and Mudumalai Wildlife Sanctuary (WS) in India. The percentage difference between each 5 year period was calculated by taking first year of the 5-year period as base = 100.

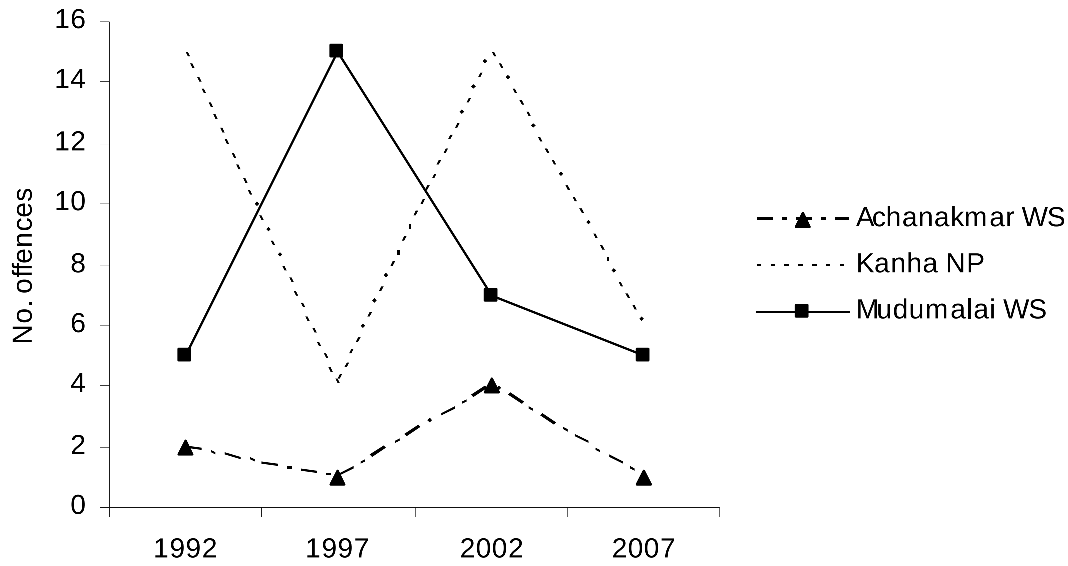


Figure 8. Trend in wildlife offences in Achanakmar Wildlife Sanctuary (WS), Kanha National Park (NP) and Mudumalai Wildlife Sanctuary (WS) from 1992-2007, based on the Protected Area (PA) data.

APPENDIX1

SURVEY OF VILLAGES AROUND PROTECTED AREA

ENCLAVE-VILLAGE QUESTIONNAIRE

NAME OF THE PROTECTED AREA:

VILLAGE SERIAL NUMBER:

NAME OF THE INVESTIGATOR:

DATE OF SURVEY:

BRIEF DESCRIPTION OF THE VILLAGE:

Name of the Village ______________________________

Name of the state: ______________________________

Name of the District: ______________________________

Name of the Taluka / subdivision: ______________________________

Number of households in the village: [ ]

Year of the estimate: [ ]

PART A

Household Number_______________________ Household code_________________

1. What is your primary occupation?

Agriculture-----------1
Labour----------------2
Masonry--------------3
Forest Department-4
Ecotourism---------- 5
Business--------------6
Others ----------------7
No work-------------- 8

Ist 2nd

2. What is the average monthly income of your household?

< $15 (Rs. 500) ----------------------- 1
$15- $25(Rs. 500- Rs. 750) --------2
$25- $35 (Rs. 750- Rs. 1400) ------3
$35- $45 (Rs 1400- Rs 1800) ------4
>$45 (> Rs. 1800) ------------------ --5

1st 2nd

3. How many persons live in your household?

<2------------------------------1
2-4-----------------------------2
4-6-----------------------------3
6-10---------------------------4
>10----------------------------5

4. How many cattle heads do you have in your household?

None-------------------------1
1-2---------------------------2
2-4---------------------------3
>4----------------------------4

5. How many cattle heads did you have 10-15 years ago?

None-------------------------1
1-2---------------------------2
2-4---------------------------3
>4----------------------------4

6. Has your monthly income increased, decreased or remained the same in last 10-15 years?

Increased------------------1
Remained the same ---2
Decreased----------------3

7. What are the main problems you face living inside a protected area?

a. ____

b. ____

c. ____

d. ____

e. ____

8. What are the main benefits you get living inside a protected area?

a. ____

b. ____

c. ____

d. ____

e. ____

9. How often you come across wild animals in this protected area?

Once in <15 days-----------------------1
Once in 30 days-------------------------2
Once in 3 months-----------------------3
Once in 6 months-----------------------4
Never see it-------------------------------5

10. Has the number of wild animals in this WS/NP increased deceased or remained the same in last 10-15 years?

Increased----------1
Decreased--------2
Remained the same---------------3

11. In your opinion has this forest or the area become better or worse for the wildlife in last 10-15 years?

Has become better---------------------1
Has become worse---------------------2
No change--------------------------------3

12. If it is better, what could be the reasons for it?

1.____
2.____
3.____

13. If worse, what could be the reasons for it?

1.____
2.____
3.____

PART B

14. How often do you come across any killed or poached wildlife in this protected area?

Once in <15 days-----------------------1
Once in 30 days-------------------------2
Once in 3 months-----------------------3
Once in 6 months-----------------------4
Never see it-------------------------------5

15. What species have you seen poached or killed more in last 10-15 years?

1____________________________
2____________________________
3.____________________________
4____________________________

16. Has poaching of wildlife increased, decreased or remained the same in this protected area in last 10-15 years?

Increased----------1
Decreased--------2
Remained the same---------------3

17. What are the main species that are poached or killed in this protected area?

1. _____________________________
2. _____________________________
3._______________________________
4. _____________________________
5._______________________________
6._______________________________
7._______________________________

18. How often do you see a wild animal or its part being sold by someone?

Once in <15 days-----------------------1
Once in 30 days-------------------------2
Once in 3 months-----------------------3
Once in 6 months-----------------------4
Never see it-------------------------------5

19. Do you think that protection given by the government to wildlife has increased, decreased or remained the same in last 15 years?

Yes-------------------1
No--------------------2
No change---------3

20. Do people in this village collect firewood from the forests?

Yes----------------------1
No---------------------- 2

(If No, skip to 24)

21. Where do people collect firewood from?

From the buffer area----------------1
From the NP/WLS area------------2

From community land--------------3
From private lands------------------4
Other----------------------------------5

22. Has the average time taken to collect a load of firewood has increased, decreased or remained the same?

Increased enormously--------------1
Increased somewhat----------------2
Remained the same-----------------3
Decreased somewhat---------------4
Decreased enormously-------------5

PART C

23. Are you aware that government has passed theTribal bill recently that would permit the tribal, living inside the reserve forest (RF) to own land inside that RF?

I am aware---------------------1
I am not aware----------------2

24. Would you like to live inside a protected area or shift outside to a suitable place, if government provides you enough facilities?

Live inside as we do------------1
Shift outside to a suitable land---------------------------------2
Don't know-----------------------3

25. In last 10-15 years population of wild animals has increased, decreased or remained the same?

Increased-----------------------1
Remained the same---------2
Decreased---------------------3

26. Which species has increased?

a.____________________
b.____________________
c.____________________
d.____________________
e.____________________

27. Which species has decreased?

a.____________________
b.____________________
c.____________________
d.____________________
e.____________________

28. How often does the village panchayat discuss about protection and conservation of wildlife and forests here?

Once in 15 days-------------1
Once in a month------------2
Once in 3 months-----------3
Never discusses------------4
There is no panchayat-----5

29. Do the villagers have a say in the management of this protected area?

Yes----------------------------1
No-----------------------------2

30. How often do you meet senior WS / NP officials?

Once a week----------------------1
Once in 15 days------------------2
Once in a month-----------------3
Once in 3 months----------------4
Never meet them----------------5

31. Do you see many Non-governmental organizations working in this WS/NP for wildlife protection?

Yes------------------------1
No-------------------------2

32. In your opinion do they help in protecting these forests and wildlife in any way?

Yes------------------------1
No-------------------------2
Do not know------------3

33. Do you see many people doing research works in these forests now?

Yes, I do-----------------1
No, I see very few-----2
None---------------------3

34. Do you think that 10-15 years ago more or fewer people were doing research on wild animals and forests here?

Yes, there were more------1
No, only a few----------------2
None, ever--------------------3

35. How do you like the idea of wild animals bred and harvested to give you direct benefits and better conservation?

This is a useful idea, I support---------1
This is a non-workable idea------------2
This will not lead to better conservation------------------------------3
No comments----------------------------4

APPENDIX 2

SURVEY OF VILLAGES AROUND PROTECTED AREA

FRINGE-VILLAGE QUESTIONNAIRE

NAME OF THE PROTECTED AREA:

VILLAGE SERIAL NUMBER:

NAME OF THE INVESTIGATOR:

DATE OF SURVEY:

BRIEF DESCRIPTION OF THE VILLAGE:

Name of the Village ____________________________

Name of the state: ____________________________

Name of the District: ____________________________

Name of the Taluka / subdivision: ____________________________

Number of households in the village: [ ]

Year of the estimate: [ ]

PART A

Household Number______________________ Household code________________

1. What is your primary occupation?

Agriculture-----------1
Labour----------------2
Masonry--------------3
Forest Department-4
Ecotourism---------- 5
Business--------------6
Others ----------------7
No work-------------- 8

Ist 2nd

2. What is the average monthly income of your household?

< $15 (Rs. 500) ----------------------- 1
$15- $25(Rs. 500- Rs. 750) --------2
$25- $35 (Rs. 750- Rs. 1400) ------3
$35- $45 (Rs 1400- Rs 1800) ------4
>$45 (> Rs. 1800) ------------------ --5

1st 2nd

3. How many persons live in your household?

<2------------------------------1
2-4-----------------------------2
4-6-----------------------------3
6-10---------------------------4
>10----------------------------5

4. How many cattle heads do you have in your household?

None-------------------------1
1-2---------------------------2
2-4---------------------------3
>4----------------------------4

5. How many cattle heads did you have 10-15 years ago?

None-------------------------1
1-2---------------------------2
2-4---------------------------3
>4----------------------------4

6. Has your monthly income increased, decreased or remained the same in last 10-15 years?

Increased------------------1
Remained the same ---2
Decreased----------------3

7. What are the main problems you face living in the vicinity of a protected area?

a. ____

b. ____

c. ____

d. ____

e. ____

8. What are the main benefits you get living in the vicinity of a protected area?

a. ____

b. ____

c. ____

d. ____

e. ____

9. How often do you come across wild animals (not including birds) in this protected area?

Once in <15 days----------------------1
Once in 30 days------------------------2
Once in 3 months----------------------3
Once in 6 months----------------------4
Never see it------------------------------5

10. Has the number of wild animals in this WS/NP, increased, deceased or remained the same in last 10-15 years?

Increased----------1
Decreased--------2
Remained the
same---------------3

11. In your opinion has this forest or the area become better or worse for the wildlife in last 10-15 years?

Has become better---------------------1
Has become worse---------------------2
No change--------------------------------3

12. If it is better, what could be the reasons for it?

1.____
2.____
3.____

13. If worse, what could be the reasons for it?

1.____
2.____
3.____

PART B

14. How often do you come across any killed or poached wildlife in this protected area?

Once in <15 days----------------------1
Once in 30 days------------------------2
Once in 3 months----------------------3
Once in 6 months----------------------4

Never see it-------------------------------5

15. What species have you seen poached or killed more in last 10-15 years?

1____________________________
2____________________________
3.____________________________
4____________________________

16. Has poaching of wildlife increased or decreased or remained the same in this protected area in last 10-15 years?

Increased----------1
Decreased--------2
Remained the same---------------3

17. What are the main species that are poached or killed in this protected area?

1. _____________________________
2. _____________________________
3.______________________________
4. _____________________________
5.______________________________
6.______________________________
7.______________________________

18. How often do you see a wild animal or its part being sold by someone?

Once in <15 days-----------------------1
Once in 30 days-------------------------2
Once in 3 months-----------------------3
Once in 6 months-----------------------4
Never see it-------------------------------5

19. Do you think that protection given by the government to wildlife has increased, decreased or remained the same in last 15 years?

Yes-------------------1
No--------------------2
No change---------3

2o. Do people in this village collect firewood from the forests?

Yes----------------------1
No---------------------- 2

(If No, skip to 24)

21. Where do people collect firewood from?

From the buffer area----------------1
From the NP/WLS area------------2
From community land--------------3

From private lands------------------4
Other----------------------------------5

22. Has the average time taken to collect a load of firewood has increased, decreased or remained the same?

Increased enormously--------------1
Increased somewhat----------------2
Remained the same-----------------3
Decreased somewhat---------------4
Decreased enormously-------------5

PART C

23. Are you aware that government has passed theTribal bill recently that would permit the tribal, living inside a Reserved Forest (RF) area, to own land inside RF?

I am aware---------------------1
I am not aware----------------2

24. In last 10-15 years, has the population of wild animals increased, decreased or remained the same?

Increased-----------------------1
Remained the same---------2
Decreased---------------------3

25. Which species has increased?

a.____________________
b.____________________
c.____________________
d.____________________
e.____________________

26. Which species has decreased?

a.____________________
b.____________________
c.____________________
d.____________________
e.____________________

27. How often does the village panchayat discuss about protection to and conservation of wildlife and forests?

Once in 15 days-------------1
Once in a month------------2
Once in 3 months-----------3
Never discusses------------4
There is no panchayat-----5

28. Are the villagers involved in the management of this WS/NP area in any way?

Yes----------------------------1
No-----------------------------2

Please explain:

29. Do you see many Non-governmental organizations working in this WS/NP for wildlife protection?

Yes------------------------1
No-------------------------2

30. In your opinion do they help in protecting these forests and wildlife in any way?

Yes------------------------1
No-------------------------2
Do not know------------3

31. Do you see many people doing research works in these forests now?

Yes, I do-----------------1
No, I see very few-----2
None---------------------3

32. Do you think that 10-15 years ago more or fewer people were doing research on wild animals and forests here?

Yes, there were more------1
No, only a few----------------2
None, ever--------------------3

33. How do you like the idea of wild animals bred and harvested to give you direct benefits and better conservation?

This is a useful idea, I support---------1
This is a non-workable idea------------2
This will not lead to better conservation------------------------------3
No comments----------------------------4

APPENDIX 3. Distance to major towns, interstate border, major highways, and number fringe and enclave villages in Achanakmar Wildlife Sanctuary (WS), Kanha National Park (NP), and Mudumalai Wildlife Sanctuary (WS), India, 2008.

	Achanakmar WS	Kanha NP	Mudumalai WS
Distance to major town (km)	65	160	100
Distance to international border	1000	1180	200
Distance to inter-state boundary	120	120	0
Distance to major highway	0	100	0
Distance to major tourist hub	50	150	35
No. enclave Villages	22	18	21
No. fringe Villages	8	150	30
Special protection Status	Proposed Tiger Reserve	Tiger reserve	Project elephant Tiger reserve, and Biosphere reserve

APPENDIX 4. State of urbanization and growth in human and cattle population in Achanakmar Wildlife Sanctuary (WS), Kanha National Park (NP), and Mudumalai Wildlife Sanctuary (WS), India, 2008.

	Achanakmar WS				Kanha NP				Mudumalai WS			
	1992	1997	2002	2007	1992	1997	2002	2007	1992	1997	2002	2007
No. vehicles	8,000	10,000	11,000	12,000	6,823	9,094	12,874	21,990	NA	NA	18,377	21,540
No. tourists	534	1,010	1,288	3,495	55,958	44,977	55,475	106,297	84,514	91,418	102,293	129,621
No. buildings	1,300	1,580	1,890	2,280	NA	386	429	526	170	184	205	215
No. households	1,200	1,500	1,800	2,200	6,586	7,294	4,900	8,396	205	262	334	407
Human population	6,000	7,500	9,000	11,000	6,586	7,294	4,900	8,396	1,360	1,403	1,538	1,768
Cattle population	6,000	7,000	8,000	9,000	6,897	8,704	6,215	7,843	2,668	2,988	3,507	3,852
Road network (km)	323	323	323	323	30	30	30	30	35	35	35	35
[a]State GDP	NA	NA	7	11	14	15	17	20	17	26	29	52
[b]Per capita GDP	NA	NA	243	415	66	56	222	305	347	395	403	632

[a]In billion dollars (U.S.)

[b]In dollars (U.S.)

APPENDIX 5. Reported number of poached wild animals every 4 years from 1992-2007 in Achanakmar Wildlife Sanctuary (WS), Kanha National Park (NP), and Mudumalai Wildlife Sanctuary (WS).

	Achanakmar WS				Kanha NP				Mudumalai WS			
Species	1992	1997	2002	2007	1992	1997	2002	2007	1992	1997	2002	2007
Tiger	0	0	0	0	3	0	1	1	0	0	0	0
Leopard	0	0	1	0	7	3	1	1	0	0	0	0
Spotted deer	2	0	3	1	4	2	2	1	0	1	1	0
Sambar	0	0	0	0	2	1	3	3	0	0	0	0
Gaur	0	0	0	1	0	0	0	0	0	0	0	0
Elephant	NA[a]	NA	NA	NA	NA	NA	NA	NA	1	4	0	0
Wild boar	0	1	1	0	0	0	0	0	0	0	0	0

[a]Not applicable. Wild elephants are not found in Achanakmar Wildlife Sanctuary (WS), and Kanha National Park (NP).

APPENDIX 6. Estimated population of species reported every 4 years from 1992-2007 in Achanakmar Wildlife Sanctuary (WS), Kanha National Park (NP), and Mudumalai Wildlife Sanctuary (WS), India, 2008.

	Achanakmar WS				Kanha NP				Mudumalai WS			
Species	1992	1997	2002	2007	1992	1997	2002	2007	1992	1997	2002	2007
Tiger	NE[a]	21	26	18-22	101	114	111	73-105	21	NE	25	31-37
Leopard	NE	NE	47	35-45	60	86	75	60-85	25	NE	NE	15-25
Spotted Deer	NE	NE	1686	NE	19825	20162	20804	20999	1585	5902	2671	11877
Sambar	NE	NE	NE	NE	2632	3538	3604	3351	1614	1593	989	963
Gaur	NE	NE	NE	NE	875	1113	1288	1605	364	962	988	1284
Elephant	0	0	308	0	0	779	0	0	703	0	0	995

[a]Not estimated by the protected area management.

APPENDIX C. DRAFT MANUSCRIPT TO BE SUBMITTED TO THE JOURNAL OF WILDLIFE MANAGEMENT.

NIRAJ, S. K., P. R. KRAUSMAN, AND V. DAYAL. TEMPORAL AND SPATIAL ANALYSIS OF WILDLIFE POACHING IN INDIA FROM 1992 TO 2006.

30 January 2009
Shekhar K. Niraj
School of Natural Resources
University of Arizona
Tucson, Arizona 85721
(520) 621-7255; Fax (520) 621-8801; Email shekhar.niraj@gmail.com

RH: Niraj et al.• Wildlife poaching in India

TEMPORAL AND SPATIAL ANALYSIS OF WILDLIFE POACHING IN INDIA FROM 1992 TO 2006

SHEKHAR K. NIRAJ,[1] School of Natural Resources, Biological Sciences East Building, University of Arizona, Tucson, AZ 85721, USA

P. R. KRAUSMAN[3], School of Natural Resources, 325, Biological Sciences East Building, University of Arizona, Tucson, AZ 85721, USA

VIKRAM DAYAL, Institute of Economic Growth, University of Delhi Enclave, North Campus, Delhi 110007, India

ABSTRACT Although poaching is a major threat to wildlife it has not been analyzed quantitatively, because of a lack of data. We studied temporal and spatial patterns in poaching and seizures of 18 legally protected or regulated wildlife species or categories: 15 of animal and 3 of plants or tree species in India. We also developed a causal loop

---

[1]Correspornding author e-mail: shekhar.niraj@gmail.com

[2]Present address: Indian Forest Service, Conservator of Forests (Tamil Nadu Afforestation Project 1), 8 D, Panagal Building, 1 Jeenis Road, Saidapet, Chennai 600015, India

[3]Wildlife Biology Program, 32 Campus Drive, University of Montana, Missoula, Montana 59812, USA

diagram of poaching and seizures. We found that some species experience regular poaching on a quarterly basis. For these species, (e.g., tiger [*Panthera tigris*], leopard [*P. pardus*], Asian elephant [*Elephas maximus*], Indian rhinoceros [*Rhinoceros unicornis*], deer, and antelopes, we conducted tests for the presence of stochastic trends and structural breaks. The presence of a stochastic trend was not rejected for elephants. However, the timing of the structural breaks and their intensity vary in these species. Among these, although overall trends vary, all species (i.e., tiger, leopard, elephant, rhino, deer, and antelopes) experienced declining poaching trends towards 2006. Local indicators of spatial association (LISA) and Moran's I statistics indicated significant spatial clustering of tiger and leopards seizures near northern borders. Seizures in red sander (*Pterocarpus santalinus*), shells, and leopards increased significantly in 2000-2006.The strategies to combat poaching and illegal trade must consider all possible factors, some of which could be extraneous but could have significant impacts. Enhanced resources and field level enforcement is required to match the magnitude of enhanced threats to wildlife due to illegal trade and poaching.

KEY WORDS illegal trade, India, leopard, poaching, rhinoceros, spatial, temporal, tiger, wildlife seizures

The Journal of Wildlife Management: 00(0): 000-000, 2009

Wildlife poaching and illegal trade vary over time and space. They vary temporally when regulations, the economy, and policies change. They vary in space as poaching and illegal wildlife trade, which involves illegal harvest, move parts of animals through different geographical regions of the world.

Globally, the wildlife trade is estimated to be worth 11 to $15 billion (US) annually (Iqbal 1993, Menon and Kumar 1998, Hillstrom and Hillstrom 2002, Oldfield 2003); ≥ 30 % could be illegal (Menon and Kumar 2002, Reeve 2002). The scientific communities have only recently studied wildlife trade that could be one of the major causes for the decline of wild fauna and flora worldwide.

India, Indonesia, Malaysia, Thailand and Brazil are major countries involved in illegal wildlife trade (Broad et al. 2003). Illegal trade involves movement of species from the developing countries to the developed countries. In India, wildlife was exploited for domestic use and export until the early 1970s (Thapar 2003) when noticeable population declines led to establishing the stringent Wildlife Protection Act (WPA) in 1972. This act regulated the use and exploitation of wildlife, and banned hunting of many species (Thapar 2003). From 1970 to 1990, regulations and controls succeeded in reducing exploitation, which led to many species recovering (Thapar 2003). From the 1990s to 2000s, sudden and rapid increases in poaching and illegal trade were observed for tiger (Kenney et al. 1995) and many other species, which were economically important to a new market (Fresse and Trauger 2000, Virmani 1999a, b; 2004); a result of the economic liberalization, where improved per capita income creates new and greater demands (FAO 2001). This led to commercialization in many wildlife products (Fresse and Trauger 2000).

Poaching reduces genetic variability, alters sex ratio (Sukumar et al. 1998, Kenney et al. 2005), and could lead to local and global extinctions (Newmark 1995, Bennett and Robinson 2000). In India, there is an understanding of the poaching of tigers, Asian elephant, and Indian rhino but other species have not been examined as illegal trade. Adequate studies are limited by the absence of data (Sukumar et al. 1998, Reeve 2002).

There are some studies on individual species, but systematic time series analysis of groups of species affected by illegal harvest for trade have not been conducted. The tiger is one of the most sought after economic species in illegal trade (Kenney et al. 1995, Damania 2008). The tiger population decreased sharply in 2000-2002, and thus is less available for trade. In the same period there was a rapid increase in seizures in leopard and its derivatives and in poaching cases. In many seizures, tiger parts have been seized along with leopard parts indicating an overlapping trade demand or substitution of leopard for tiger.

Analysis of spatial clustering of wildlife seizures could give evidence for their association in trade related movements. Clusters may be regarded as classes of observations that represent potentially useful categories in further research (O'Sullivan and Unwin 2003). Cluster analysis can help identify potential classification and may be an important first step in understanding poaching. The clusters that lead to spatial heterogeneity may be influenced by the nearness of international borders, markets, or other factors that could facilitate the movement of harvest towards the trade points. Porous international borders could be a potential path for illegal harvests. Large scale seizures of skins and bones of tiger, leopard, and otters (*Aonyx cinerea*, *Lutra lutra*, and *L. perspicillata*) in 2000-2004 along the border of India, Tibet, Nepal, Bhutan, and Myanmar support this argument (Mishra 2004).

With the focus on poaching of tiger, elephant, or rhino, many other species are overlooked. Possibly, some of these species may be subjected to large scale poaching. In 1992-2006, seizures were reported involving otters, mongooses, reptiles, star tortoise (*Geochelone elegans*), and among the wild flora, red sanders Agarwood (*Aquilaria* *malaccensis*) and Kuth root (*Saussurea costus*). We examined 18 species or categories, 15 of protected wild fauna and 3 of protected or regulated wild flora, to understand the trend in their illegal harvest during 1992-2006.

Our objectives were to: (1) analyze the temporal trend of poaching and seizures in 18 protected or regulated species (including their parts and derivatives) of India from 1992-2006, (2) analyze the spatial patterns in poaching and seizures of species in trade at the scale of states in India to determine if there were geographical relationships in clusters, (3) develop a causal loop diagram to explore the relationship among elements that affect poaching, and (4) analyze the correlations between poaching trends in tigers and leopards as a factor of substitution to examine whether leopards were being substituted for tigers in illegal trade.

STUDY AREA

We obtained seizures and poaching data from all 28 states and 7 union territories of India (6°44' and 35°30' N and 68°7' and 97°25' E). India (Fig.1) borders Pakistan to the west; the People's Republic of China, Nepal, and Bhutan to the north-east; Bangladesh and Myanmar to the east; and Sri Lanka immediately to the south in the Indian Ocean. On 3 sides it is surrounded by sea and on the north by the Himalayas. To protect species India created a network of protected areas (PA), and by 2007 had established 513 wildlife sanctuaries (WS) and 96 national parks (NP) covering > 157,000 km^2 (Ministry of Environment and Forests 2008), to protect wild fauna and flora. A NP has the highest legal protection (e.g., grazing is not permitted) followed by WS where grazing could be permitted (WPA 1972).

METHODS

Compiling and Aggregating Seizures Data

We collected data on seizures and poaching from files maintained at the Ministry of Environment and Forests of the Indian government. The ministry maintained the data received from the state governments and the regional Convention of International Trade in Endangered Species of Wild Fauna and Wild Flora (CITES) management agencies from 4 CITES regions of the country. We also obtained data from the Wildlife Trust of India (WTI) and Wildlife Protection Society of India (WPSI), which have compiled databases on wildlife seizures and poaching since 1998. We cross verified individual entries from their sources and with reports from state governments in India. We collected data between July 2005 and December 2007. We also included seizures made at the export points in India by other government enforcement agencies. Most of these data related to seizures. We used several approximations for converting the seizures into number equivalents (animal equivalent) of tiger, leopard, bears, chiru (*Pantholops hodgsonii*), bird feather, peacock (*Pavo cristatus*) tail feathers, mongoose (*Herpestes avanicus, H. vitticollis*, and *H. edwardsii*), spotted deer (*Axis axis*), musk deer (*Moschus moschiferus*), and sambar (*Cervus unicolour*; Appendix 1). Our approximations were based on the measurements carried out by Kanha NP and Bilaspur Zoological Park field stations, and information from published literature (Appendix 1).

When teeth, bone, and skin seizures of tiger and leopard were reported together or within 3 days and from the same place, we considered them coming from the same tiger or leopard. Elephant seizures presented greater challenges. Ivory was seized in form of raw tusks, worked tusks, finished ivory, and ivory artifacts (Menon and Kumar 1998, Menon 2002). There is a loss of minimum of 10% ivory when it is worked (Menon 2002).

Shell seizures were also recorded by weight and by count. We did not convert shells into one unit, because species from different regions will vary considerably in size and weight due to the influence of local environmental factors (Apte 1998).

Basic Species Information

We compiled information on species, geographical distribution, habitat, trade use, destination markets, prices in illegal international markets, and legal protection, from the field enforcement units, published literature and the electronic resources available on the website of the World Conservation Union (IUCN) and CITES (Appendices 2-4).

Trend Analysis

We arranged data on seizures by quarter (i.e., q) from 1992 to 2006. The first quarter (q1) is January to March, q2 is April to June, q3 is July to September, and q4 is October to December. For several species, seizures did not occur frequently, and the number of seizures in many quarters was zero. Species for which the frequency of seizures was low were arranged by year from 1992 to 2006. For all species, we plotted line graphs of seizures against time or tabulated the seizures versus time.

For species with a high frequency of seizures, we carried out detailed trend analysis, by dividing time (1992 to 2006) into 3 equal periods (e.g., 1992-1996, 1997-2001, and 2002-2006) and plotting box plots for each time period, plotting loess scatterplot smoothers of seizures against time, and conducting tests of whether the seizures had deterministic or stochastic trends and structural breaks.

Box plots.—A box plot consists of a box in the centre and whiskers that project from the box. The outer lines of the box represent the 0.25 and 0.75 quantiles of the distribution. The height of this box represents the interquartile range. The middle line in the box represents the 0.5 quantile, or the median. The whiskers represent adjacent values that are the lowest and highest values that lie within the lower and upper inner fences. The lower and upper inner fences are the 0.25 quantile minus the interquantile range and the 0.75 quantile plus the interquantile range (Jacoby 1997).

Loess smoother.—The purpose of loess (i.e., locally weighted regression), a non-parametric scatterplot smoother, is to fit a curve to the data without specifying the functional relationship between 2 variables, and by passing through areas where the density of data are high. Loess involves 3 steps: (1) running a series of regressions at different points along the X axis using a proportion of the total values and larger weights for closer observations, (2) generating a fitted value for each regression, and (3) plotting a line connecting each of the fitted values (Jacoby 1997).

Trends and structural breaks.—Since 1990, several econometric tests of deterministic versus stochastic trends, and structural breaks have been developed. A trend is a persistent long-term movement of a variable over time. Modern econometrics distinguishes between stochastic and deterministic trends. A deterministic trend is a nonrandom function of time (e.g., a visible growing at 5%/year). A stochastic trend is random and varies over time (Stock and Watson 2003). In addition to a stochastic or a deterministic trend, a time series variable may have a structural break. A structural break is a change in the parameters of a model characterizing the variable (e.g., slope or level). The distinction between a stochastic and a deterministic trend break is based on how frequent the shocks to the trend are (Hansen 2001). In a stochastic trend, shocks occur frequently while in the case of a deterministic trend with a break shocks occur at the break. The statistical tests for a stochastic trend are sensitive to the presence of structural breaks. Hence, both stochastic trends and breaks should be tested.

Lee and Strazicich (2004) devised a test to examine whether a time series has a stochastic trend or deterministic trend, and to find the most likely location of a structural break. Lee et al. (2006) examine whether non-renewable prices have stochastic or deterministic trends. After using the Lee and Strazicich (2004) test, we ran a regression of the following form to examine the nature of the break:

$$y_t = \mu + \beta t + \theta DU_t + \gamma DT_t + \varepsilon_t$$

where y is the seizure of a species, t denotes time, μ denotes the intercept, β denotes the slope in the regression of species versus time, θ denotes the change in intercept at the break point, γ denotes the change in slope at the break point, and ε denotes the disturbance term. The dummy variables (e.g., DU and DT) are created to capture breaks in the level and intercept, respectively. DU and DT are given by:

$DU_t = 1$ *if* $t > T_B$, *0 otherwise, and* $DT_t = t - T_B$ *if* $t > T_B$, *0 otherwise*, *w*here T_B is the break point determined by the Lee and Strazicich (2004) test.

Spatial Analysis

To examine the impact of international borders that separate India from its neighboring countries on wildlife seizures we classified the states as border and non-border states (Fig. 2). Because Haryana and Delhi became nested we included them in the border category. We used a repeated measures Analysis of Variance (ANOVA) model to examine the impact of the border, from 1992-1996, 1997-2001, 2002-2006, and an interaction of border and time on wildlife seizures as dependent variables. We used the following model in Stata 10

ANOVA (seizure) border / state | border time time*border, repeated (time).

To examine the effects of different time periods on the spatial pattern of seizures we computed t statistics on the spatial mean difference at the state scale using Arc map (ArcGIS 9.3). When data were not normally distributed we normalized data by taking a linear transformation and then a log of the value using tools in Arc Map. We also reported the state mean seizure of species in 3 time periods with the t statistics.

The above approach provided an overall pattern of spatial and temporal variation and aided the methods we used in our time series analysis. For the spatial distribution of the seizures and poaching, at the state scale, we look at the spatial data and map visualizations, which is an effective tool (Le Gallo and Ertur 2003). To explore the clustering pattern we used exploratory spatial data analysis (ESDA; Le Galo and Ertur 2003).

Exploratory spatial data analysis (ESDA) is a set of techniques to describe and visualize spatial distributions; to identify atypical localizations or spatial outliers; to detect patterns of spatial association, clusters or hot spots; and to suggest spatial regimes or other forms of spatial heterogeneity (Anselin 1995, Le Galo and Ertur 2003). Four types of hot spots are identified and are described as high value associated with other high values in the neighborhood (HH), high value associated with other low values in the neighborhood (HL), low value associated with other high values in the neighborhood (LH), and low value associated with other low values in the neighborhood (LL). We looked at the clustering pattern globally and locally (O'Sullivan and Unwin 2003). Whereas the global autocorrelation will suggest the overall pattern of clustering of seizures and indicate if there is a spatial dependence on poaching of species, the local effects will be able to locate where in the space the cluster lies. The measurement of global spatial autocorrelation is based on Moran's *I* statistic (Le Gallo and Ertur 2003).

The value of *I* ranges between 0-1, where 0 indicates no autocorrelation and 1 indicates very high autocorrelation. Moran's *I* is the global statistic and does not allow locating them in space. For assessing regional structures we looked at the local indicators of spatial association (LISA) and the Moran's scatter plots. In one of the simplest measures, LISA uses G function (Getis and Ord 1992).

The Gi (d) statistics for each region i and year t is expressed as:

$$G_{i,t} = \sum_{j \neq i} w_{ij}(d)\, x_{j,t} \,/ \sum_{j \neq i} x_{j,t}$$

Where, w_{ij} (d) is an element in an adjacency within a distance d or weights matrix for a region i and equal to zero for all other regions, x_j is the seizure value for the adjacent state. For the weighting we selected Euclidian distances with k-nearest neighbors, and specified 3 nearest neighbors. The choice of 3 neighbors followed the judgment as some of the states (e.g., Jammu and Kashmir) had only 2 nearest neighbors and Sikkim had just 1. The variable x (i.e., seizure) has a natural origin and is positive. Once standardized, a positive value of G_i (d) indicates a spatial cluster of high value and a negative value indicates clustering of low values around the region i.

The local form of the Moran's I is a product of the zone's z score and the average z-score in the surrounding zones:

$$I_i = z_i \sum_{j \neq i} w_{ij} z_j$$

These statistics enabled us to analyze the spatial effect of international land borders on seizures of species. In the case of star tortoise (*Geochelone elegans*), which is traded live, we also analyzed the impact of closeness of international airports.

We excluded Andaman and Nicobar and Lakshadweep islands from the computations of Moran's *I* and LISA statistics due to their geographical isolation (Le Gallo and Ertur 2003). Each test of significance was conducted at ≥ 999 simulations.

Causal loop Diagram for Poaching and Seizures

We examined poaching and seizures data. Poaching activity, because of its criminal nature, is more difficult to record. Poaching is sometimes based on indirect evidences (e.g., if an animal is lying dead with its parts missing it is recorded as poaching or a seizure without the offender). The causal loop diagram distinguishes between seizures and poaching.

Causal loop diagrams are useful tools of the discipline of system dynamics. They help show the structure of systems and the relationship between variables (Sterman 2000). "A system is usually defined as a combination of two or more elements that are interconnected for some purpose. A bicycle, a car, and a bus are all systems for transportation. And at a larger scale, the collection of freeways, surface streets, and vehicles in an urban area is a system. The distinguishing feature of a system is the impression that the whole is more than the sum of the parts (Ford 1999: 12)." In a causal loop diagram, different variables are connected by arrows showing the direction of influence from one variable to another. Each arrow shows a causal link. For example, x → y, implies that x is one of the determinants of y. If the arrow is shown with a positive sign it shows that if the cause increases, the effect increases above what it would otherwise have been (Sterman 2000).

Morecroft (2007) provides an example (Fig. 3) of a simple causal loop diagram of food intake. The relationship between hunger and amount eaten is shown with 2 links. In the top link more hunger leads to more food consumed. The bottom link depicts that more consumption of food leads to less hunger.

One of the hypotheses in the causal loop diagram is that the abundance of Y will affect the poaching effort devoted to X. Poaching of Y, in turn, will depend on a number of factors. Since tigers and leopard have a somewhat similar market, some overlap in habitat (Appendix 2), we examined the relationship between their seizures using a simple distributed lag regression model.

$$\ln(\text{Tiger seizure}_t) = \beta_1 + \beta_2 \ln(\text{Leopard seizure}_t) + \beta_3 \ln(\text{Leopard seizure}_{t-1}) + \beta_4 \ln(\text{Leopard seizure}_{t-2}) + \beta_5 \ln(\text{Leopard seizure}_{t-3}) + \beta_6 \ln(\text{Leopard seizure}_{t-4}) + \varepsilon_t$$

and

$$\ln(\text{Leopard seizure}_t) = \beta_1 + \beta_2 \ln(\text{Tiger seizure}_t) + \beta_3 \ln(\text{Tiger seizure}_{t-1}) + \beta_4 \ln(\text{Tiger seizure}_{t-2}) + \beta_5 \ln(\text{Tiger seizure}_{t-3}) + \beta_6 \ln(\text{Tiger seizure}_{t-4}) + \varepsilon_t$$

where, t denotes time, the βs are the regression coefficients, and ε represents the disturbance term.

Time series regressions can yield spurious results if the variables have stochastic trends. We tested for the presence of stochastic trends in the tiger and leopard seizure series by using the Dickey Fuller and Phillip Perron tests (Stock and Watson 2003). For the Dickey Fuller tests, we chose lags consistent with no autocorrelation in the variables (Hill et al. 2008).

RESULTS

Trend analysis

The number of quarters when poaching seizures are zero is an indicator of the frequency of seizures. Tigers, leopards, elephants and birds had seizures in every quarter from 1992 to 2006. Rhinoceros, deer, antelope, snake, and shells had >0 and <10 zeros. Reptile, bear, mongoose, and star tortoise had >10 and <20 zeros.

Tiger seizures increased in the third quarter of 1993, in the second quarter of 1999, the second quarter of 2000, and 2001. Tiger seizures next increased in the third quarter of 2004 (Fig. 4a). Deer and antelope seizures increased in 2000q1, in 2000q4, in 2002q1 and 2003q1 (Fig. 4b). So, the period from 2000 to 2003 saw a much higher level of seizures of deer and antelopes. The level of seizures of elephants fluctuated randomly, with little pattern, reaching a peak in 2001q4. The leopard data showed 5 distinct spikes. However, 1 huge outlier was not plotted, a seizure of 1,115 in the first quarter of 2000. For rhinos seizures peaked in 1993q1 and 1994q1 (Fig. 4a). Thereafter, there were some fluctuations, but no notable spikes. Snakes were characterized by 3 distinct spikes (i.e., 1993q4, 2002q3, and 2005q4).

The box plots (Fig. 5) and loess curves (Fig. 6) show temporal patterns of seizures of species with high frequency of seizures. The Lee and Strazicich test rejects the null hypothesis of stochastic trends for all the species except elephant (Table 1). Tigers, elephants, leopards, deer, and antelope witnessed a change in slope at the break point that had a *P*-value <10% (Table 2). Tigers and rhinoceros experienced a change in intercept at the break point that had a *P*-value <5% (Table 2). The line graphs of annual seizures of chiru, mongoose, and mountain leopards spiked in a few years (Fig. 7).

Spatial Analysis

The repeated measures ANOVA do not establish a significant border effect on seizures except in the case of elephant ivory (Appendix 5; Fig. 8, 9). The results produced significant F statistics for the effect of time on poaching of tiger skin seizure ($F_{2, 66} = 3.31$, $P = 0.04$; Fig. 10, Fig. 11), and tiger bone seizures ($F_{2, 66} = 3.31$, $P = 0.04$; Fig. 10, Fig. 11), leopard ($F_{2, 66} = 7.18$, $P < 0.01$; Fig. 12 and Fig. 13), elephant ($F_{2, 66} = 12.73$, $P < 0.001$), elephant tusk seizures ($F_{2, 66} = 7.48$, $P = <0.01$). For the red sander there was a significant time and border interactive influence ($F_{2, 66} = 3.53$, $P = 0.04$) on the seizures. The model is significant in all cases except for elephant tusks (Appendix 5).

We further explored the border effects across the 3 time periods using t tests. Leopard skin seizures have near significant differences between border and non-border states in 1992-2006 and 1997-2001, whereas bone seizure increases near significantly in border states than the non-border states in 2002-2006 (Appendix 6). Overall, leopard seizures have higher state mean seizures among border states than the non-border states and recorded near significance in time periods 1992-1996 and 2002-2006. The border state mean seizure of tiger bone is higher than the non-border states and records near significance in 1997-2001. Elephant ivory seizure is more significant for the non-border states than the border states (Appendix 6) in 1997-2001 and 2002-2006. Deer follows a similar pattern to that of elephant and had significant seizures in non-border states than the border states in 1997-2001 and 2002-2006 Deer poaching was spread throughout the country except Gujarat and Punjab (Fig. 14, 15).

For snake skin and snake poaching, the non-border states had reported higher state mean seizures in 1992-1996, but the trends reversed in 1997-2001 and 2002-2006 and recorded nearly significant difference of means (Fig. 16 17). Bird seizures followed a pattern like that of snake and the border state mean seizure recorded more significant results in 2002-2006 than the non-border states. For star tortoise the border state had a much higher mean seizure in 1992-1996 and then the trend reversed in 1997-2001 and 2002-2006 (Fig. 18, 19). Since the species is traded live we changed the classification of border states to include the states with major international airports in case of star tortoise. The results showed a statistical or near statistical significant result in all 3 time periods (Appendix 7). For the red sander seizures in non-border states were higher than the border states in all 3 time periods (Appendix 6; Fig. 20, 21).

We further examined the differences in mean seizures between 3 time periods over all states. Leopard and its derivative seizures record significant results for 2002-2006 than in 1992-1996. Tiger bone seizures increased significantly in 2002-2006 (Appendix 7). Elephant tusk seizures also increased significantly in 2002-2006 than in 1992-1996. Similarly, deer antlers and its overall poaching mean are significantly higher in 2002-2006 than in 1992-1996. Snake skin seizures remained similar in all 3 periods and supported the results we obtained in the time series analysis. Star tortoise also recorded significantly higher seizures in 2002-2006 from the level of 1992-1996. The red sanders seizures recorded a decline in 2002-2006 compared with 1992-2006, which is statistically significant. However, there were also higher mean seizures in 2002-2006 than the preceding period of 1997-2001. The mean state seizure in 1992-1996 is boosted by 2 abnormally large seizures in 1996 and 1997 in the state of Andhra Pradesh (Fig. 20)

Spatial association and cluster analysis

The LISA and local Moran *I* statistics provided insights into locating the clusters of poaching and seizures at the scale of states. In the case of elephant, we did not find significant clustering along the border (Fig. 9). This situation was similar in birds. The spatial clusters of seizures in the case of tiger skin and tiger bone produced statistically significant seizures along the northern border (Moran $I = 0.25$, $P < 0.01$; Fig. 11). For leopard, 10.90 % of the border states produced HH spatial clustering, and is highly significant along the northern border (Fig. 13). For tiger bone, leopard skin, and leopard bone the clusters remained significant even at the 0.01 level along the northern border. In the case of deer skins and antler seizures 6.90% of states along the northern land border produced HH clustering (Moran's $I = 0.23$, $P = 0.01$ and $I = 0.14$, $P = 0.7$; Appendix 8, Fig. 15). The overall deer poaching remained spatially significant with respect to these states. For snakes, clustering is nearly significant (Moran's $I = 0.12$, $P = 0.09$), but not along the border. For red sanders and star tortoise, the spatial associations are reported significant but not along the border (Appendix 8, Fig. 21).

Causal loop diagram of poaching seizures

We identify 1 reinforcing (R) and 3 balancing (B) feedback loops (Fig. 22). In the first reinforcing loop (R1), labeled DEMAND, an increase in poaching reduces abundance that increases demand for species X. Demand increases the price, which leads to greater poaching of X. This loop pushes up the poaching of X. In the first balancing loop (B1), labeled SUPPLY, greater poaching leads to a higher supply that depresses price and poaching effort. This loop will prevent the poaching of X growing exponentially, as do 2 other feedback loops. Greater poaching makes it easier for seizures, which in turn reduces poaching (B2, labeled as SEIZURES). What leads to greater action in terms of seizures is concern on the part of the public, non-governmental organizations (NGOs), and the government (B3, labeled as CONCERN). Three variables are exogenous, or outside, the feedback loops: habitat that affects abundance positively, alternative country supply that affects supply positively, and abundance of another species Y that affects poaching effort spent on X negatively.

Tiger-leopard relationship

We hypothesized that tiger and leopard seizures were related because of overlapping geographical distribution (i.e., leopard occurs on the fringes of tiger habitat), and both were in demand. Poachers may have ‘economies of scope’. A visual examination of the loess curves of the tiger and leopard also seems to confirm this impression (Fig. 6). In studying the relationship, our caveat is that it is an associative, rather than a causal relationship; several common factors could affect both variables (e.g., overlapping habitat, common market) as shown in the system dynamics feedback loop diagram (Fig. 22).

Both the Dickey Fuller and Perron tests rejected the presence of stochastic trends in tiger and leopard seizures. Because tiger seizures do not cause leopard seizures, we could either regress tiger seizures on leopard seizures, or vice versa. For that reason, we regressed tiger poaching on leopard poaching and lags of leopard poaching, and leopard poaching on tiger poaching and lags of tiger poaching. In each case we included ≤4 lags.

The standard errors are robust to autocorrelation and heteroskedasticity (Stock and Watson 2003). In the regression of tiger poaching on leopard poaching, the test of the joint significance of the first to fourth lags of natural log of leopard showed that these were not statistically different from zero. The contemporaneous relationship is substantively and statistically strong, indicating an elasticity of 0.39; a 10% increase in leopard poaching detection or seizures is associated with a 3.9% increase in tiger poaching detection or seizures (Table 7). We have a similar picture in the case of the regression log of leopard on current and lagged log of tiger poaching. The contemporaneous elasticity estimate in this case was 0.89. A 10% increase in leopard poaching was associated with an 8.9% increase in tiger poaching detection or seizures.

DISCUSSION

We found that only some species experience regular poaching on a quarterly basis. For these species (e.g., tiger, leopard, elephant, rhino, deer, and antelope) we carried out tests for the presence of stochastic trends and structural breaks. Only in the case of the elephant is the presence of a stochastic trend not rejected. However, the timing of the structural breaks and their intensity vary in these species. Among these, although overall trends vary, all the species (e.g., tiger, leopard, elephant, rhino, deer, and antelope) experience declining trends towards 2006 indicating a period of change in poaching. The snake seizures remain flat during this period barring very large seizure of >50,000 in 2005. This indicated the years preceding 2005 were spent in collection and stockpiling. Chiru, mongoose, red sanders, otters, snow leopard (*Panthera uncia*), clouded leopard (*Neofelis nebulosa*), star tortoise, and bears also have either flat lines or declining trends during this period. However, star tortoise, snow leopard, and clouded leopard seizures show immediate spikes following this period. Snow leopard and clouded leopards are extensively traded internationally, but there are other resource areas known for their supply to international trade. They inhabit difficult areas (Appendix 2) and low detection of poaching could be misleading.

The reported primary markets for these species occur in East Asia (Appendix 3). Tiger seizures go up then comes down, while rhino seizures have decreased continuously since 1992. Leopard has a trend similar to tiger. It appears that the same poaching network supplies both and so when tigers are seized, so are leopards. Their similarities of habitats, products, and destination lead us to the conclusion that they are related (Fig. 10, 12). Our regression analysis using a distributed lag model shows that they are highly positively and contemporaneously correlated. However, rhino presents a situation in contrast to that of tiger and leopard. This is in further contrast of the poaching situation in neighboring Nepal (Poudyal and Knowler 2005). The population of rhino has been increasing in the 1990s and 2000s and has been recovered from a low of about 10 in 1910 to the present level (Prater 1998). The result posed a paradox: if rhinos are increasing (Appendix 2), why are seizures falling?

The rhino is less vulnerable in India (despite commanding the highest price internationally) for 2 possible reasons. First, the biggest demand is from Yemen (in terms of valuation), which is located far from India, and thus has no border effect, second protection is given high priority in the state policy of Assam (Appendix 4), the primary habitat for Indian rhino. In Assam, much of its habitat is under the influence of state borne militancy where access to poachers is less likely unless supported by the militancy (Poudyal and Knowler 2005). Since, rhino is concentrated in fewer areas, surveillance is easier.

Leopard appears to be more vulnerable to poaching than tiger as it is more widely distributed, has an edge character (Daniel 1996), requires less effort to poach, and is cheaper in the market (Appendix 3), unlike the tiger, which requires a very specialized effort for poaching and for disposing. This agrees well with our observations of larger quantities of leopard parts in seizures in comparison to that of tiger. Although, demand will always be high for tiger parts due to its special place in Oriental medicines (Appendix 3; Mills 1993), leopard and other similar species could still be passed off as tigers.

The number of tigers decreased from 3,836 in 1997 to 3,646 in 2002 and then to about 1,400 in the estimates made in 2006 and 2007. The impact of poaching on tiger will, therefore, assume greater genetic significance (Kenney et al.1995) than in rhinos or leopard. However, in a consistently affected species even a small increase in poaching can increase the possibility of extinction (Kenney et al. 1995). The tiger provides an example that leopards could follow, if the threats remain unmitigated. Tiger and leopard poaching are positively correlated.

Elephant seizures, temporally and spatially, present a conflict to the observations made in the case of tiger and leopard (i.e., there is no significant HH or HL clustering in any region of the country). A plausible argument for spatial variation is that major markets for elephant products lie in different regions of the world including India (Menon et al. 1997), and not necessarily in East Asia. Ivory is used as artifacts, mementoes and, importantly, for making bangles to be used in weddings in Gujarat (Menon et al. 1997, Menon 2002). Large scale seizures of this form of ivory from Rajasthan in 2001, which has no natural elephant habitat, testify to this fact (Fig. 12). It is possible that when the demands in international markets subside there could still be a profitable market within the country (Stiles 2004). Though, results confirm the decline in poaching, they also record a population decline from 29,010 in 1997 to 28,274 in 2001.

Seizures of tail feathers of Indian peafowl (*Pavo cristatus*) and jungle fowls (*Gallus Sonnerati* and *Gallus gallus*) have increased in 2006 (Table 5), indicating the cyclic nature of the trade. Bird seizures present evidence of a more periodic pattern of poaching indicating that there are factors different than above that could be influencing its trade. There is a large demand of birds within India for pets and for food (Ahmad 1997, Appendix 3). Many could be poached. During transportation mortality is high and various estimates suggest that the original catch is depleted by > 50% before exports and a further ~ 19-25 % after the import (Inskipp 1975).

In certain species, seizures also appear to be linked to seasonality. For mongoose there was evidence of more seizures after the annual rains. However, the trade in hair, for paint brushes, does not give evidence of such trends. We assumed that the traders and manufacturers accumulate hair and skins at all times of the year and that the manufacturing cycles would be based on other factors (e.g., availability of labor, finance, market demands), and possibly on legal and enforcement factors. Therefore, the seizures may be independent of the poaching intensity.

Seizures of shells have a constantly rising trend in the 2000s, which appears to be influenced by the change in legal policies on them (Wildlife Protection Act Amendments, 2002). However, the diversity of species in trade has increased in recent years. Shells have diverse markets in the world (Devraj 1996; Appendix 3), and it is obvious that the pattern in their seizures is not influenced by the Asian markets alone. Most of the seizures of shells are located around the major port (sea or dry) cities, (e.g., Mumbai, Chennai, Kolkata, or Delhi or around a major tourist centers [e.g., Goa or Diu in Gujarat]), whereas their resource locations are far off, indicating the influence of trading points on the resources. Red sanders trends (Fig. 20, 21) follow similar pattern to that of the shells. The seizures in 1995, 1996, and 1997 were on the mainland, but were meant for illegal export. The seizures from 2001-2006 were made at the export points or offshore, indicating they were meant for international trade. In India, the species occurs only in Andhra Pradesh and Tamil Nadu (Appendix 2). Legally, the species is not protected under the WPA and figures only in Appendix 2 of CITES (Appendix 4), indicating lack of robust legal measures for protection of plants. Similarly, the seizures of star tortoise show a distinct upward curve since 2000, and >98% seizures have been made at airports. The species has weak legal protection (Appendix 4).

Seizures in deer and antelopes and their products (e.g., antlers, skins, musk) have trends similar to leopard and tigers in 2000-2003 with a big seizure of 49 musk pods (i.e., from musk deer) in 2006. Musk is an expensive wildlife product and is in demand internationally (Khan et al. 2006; Appendix 3). Increasing seizures of pods from musk deer indicate the species is increasingly catering to illegal economic demands. The price of musk in 2006 is reported as US $275– 310 per musk pod of 25 g average weight (Khan et al. 2006).

Large seizures of meat of spotted deer and sambar in 1998-2006 indicated that the species were also harvested for domestic consumption for bush meat. There are no specific conservation schemes meant for the ungulate species (Appendix 4), although their importance as prey for major predator species is researched (Karanth and Sanquist 1995, Karanth and Stith 1999).

The spatial trends in seizures of tiger and leopard agree with the observations that the species are sold to international markets in East Asia. Leopard and tiger seizures gravitate towards India's northern and northeastern borders, which also connect it to mainland China via Nepal, Tibet, and Bhutan. A robust clustering of tiger and leopard seizures along the northern borders confirms their demand originating in China and neighboring countries (Appendix 3). However, this is not replicated in elephants, snakes, deer, and red sanders, which suggest the presence of other influencing factors (e.g., international airports, sea ports or major urban markets), and of markets other than those located in China. The presence of large clusters of star tortoise seizures within the theoretical impact zones of the international borders and international air and sea ports indicate that these spatial features have significant influence on its trade related movements (Appendix 8, Fig. 18). Thus, these factors account for a more deterministic than stochastic influence and support our findings in time series analysis. However, if a precise distance of the theoretical zone of influence from the border could be measured, it will help in determining the extent of influence the borders exert on poaching of tiger, leopard, and similar species.

Among the flora, red sander seizures demonstrate significant clustering in states with major international cargo ports (Fig. 21). Agarwood seizures demonstrate sharp rises in 1999 and 2000, which is similar to trends that some animal species follow. Kuth root seizures follow a more random trend over 1992-2006. Plants are legally ignored (e.g., Wildlife Protection Act 1972), but many of them are highly threatened due to trade (Oldfield et al. 1998, Persoon 2007).

Poaching for illegal trade can affect conservation in 2 ways: it can adversely affect the sex ratio, as recorded for elephants (e.g., male to female ratio of 1:110) in south India (Sukumar et al. 1998), or it can grossly undermine any special conservation efforts of the species in any country, as it will supply the product in the market at a much cheaper price (Jenkins and Broad 1994). In an extreme situation of uncontrolled exploitation of a species, its population could fall under the viability level (Rodgers et al. 2002) and recovery would be very difficult if other factors (e.g., habitat loss and increasing human population) in protected areas remain unmitigated threats.

MANAGEMENT IMPLICATIONS

Analysis of trends in poaching, poaching correlations among species, and their spatial associations could be vital in improving policy and field level capabilities to cope with increasing threats from poaching wildlife. Scientifically analyzed information will also provide the basis for a more objective approach in reviewing legal protection accorded to the species. It will therefore be important to use analytical protocols that we have used in this research for a continuous and long term monitoring of poaching and the imminent factors that impact it significantly. The legal protection alone has not helped conservation in India, as we have seen in the case of tiger and leopard, which have been listed in CITES since 1975 and in the WPA since 1972.

An effective strategy to conserve biodiversity can not overlook imminent threats to other less known species and substitution among species to feed the illegal trade markets.

Poaching should be scientifically monitored. We demonstrated that all poaching and seizures need to be well documented at a fine spatial and temporal scale, which will improve the quality of analysis and reliability and confidence in results. We will be able to accurately determine the factors that influence poaching and illegal movements of wildlife. This will, in turn, help in reprioritizing resources for conservation. An optimal anti-poaching strategy will need to include these protocols for greater effectiveness in controlling them. The best strategy, of course, will be to protect the species within their habitat.

The reduction of the tiger population and special protection measures may have implications on leopard poaching. The species also faces human-leopard conflicts in many parts of India (Niraj et al. 2004). Poaching can not be seen in isolation from other critical factors (e.g., habitat loss, loss of corridors, loss of prey; Karanth and Sunquist 1995, Karanth and Stith 1999, and the impact of policy changes; Narayan et al. 2005). The combined effect of these can be too large to determine. The precautionary principle will work here more effectively and will be needed to extend to many other species, which are not so well known but perishing at similar or higher rates than better known species.

ACKNOWLEDGEMENTS

W. W. Shaw, R. R. Gimblett, and J. L. Koprowski reviewed the earlier versions of this paper. A. N. Prasad assisted with data collection and offered valuable comments. S. Sen helped with the wildlife conversion protocols that he developed in Kanha for our research. A. Kumar has been helpful with similar protocols for different species. D. P. Guertin, M. Reed, and M. Borgstrom provided suggestions in spatial analysis. The officials of the regional CITES enforcement authorities in India were helpful with the data and interpretation. The Department of Personnel and Training, Government of India, New Delhi provided funding assistance in the initial phase of the research. The Ministry of Environment and Forests, New Delhi, India; School of Natural Resources, University of Arizona, Arizona Agricultural Experiment Station, University of Arizona, Tucson, and the Boone and Crockett Program in Wildlife Conservation, University of Montana, USA sponsored this research.

LITERATURE CITED

Ahmad, A. 1997. Live bird trade in northern India. TRAFFIC and WWF, New Delhi, India.

Ali, S. 1996. The book of Indian birds. Oxford University Press, Mumbai, India.

Anselin, L. 1995. Local indicators of spatial association-LISA. Geographic analysis 27:93-115.

Apte, D. 1998. The book of Indian shells. Bombay Natural History Society. Oxford University Press, Mumbai, India.

Barden, A. N. A. Anak, T. Mulliken, and M. Song. 2000. Heart of the matter. Agarwood use and trade and CITES implementation for Aquilaria Malaccensis. TRAFFIC International, Cambridge, United Kingdom.

Bennett, L. E., and G. J. Robinson. 2000. Hunting of wildlife in tropical forests: Implications for biodiversity and forest peoples. Biodiversity series –Impact studies. World Bank, Washington, D.C., USA.

Broad, S., T. Mulliken, and D. Roe. 2002. The nature and extent of legal and illegal trade in wildlife. Pages 3-22 in Sara Oldfield, editor. The trade in wildlife: regulation for conservation. Earth Scan, London, United Kingdom.

Chakrabarty, K., A. Kumar, and V. Menon. 1994. Trade in Agarwood. TRAFFIC and WWF, New Delhi, India.

Choudhury, B. C., S. Bhupathy, and F. Hanfee. 2000. Status information on the tortoises and freshwater turtles of India. Pages 86-94 *in* P. P. Van Dijk, B. L. Stuart, and A. G. J. Rhodin, editors. Asian Turtle Trade: Proceedings of a Workshop on Conservation and

Trade of Freshwater Turtles and Tortoises in Asia, Phnom Penh, Cambodia, 1-4 December 1999. Chelonian Research Monographs 2.

_____, and S. Bhupathy. 1993. Turtle trade in India: a study of tortoises and freshwater turtles. TRAFFIC and WWF, New Delhi, India.

Damania, R., J. Seidensticker, T. Whitten, G Sethi, K Mackinnon, A. Kiss, and A. Kushlin. 2008. A future for wild tigers. The World Bank, Washington, D.C, USA.

Daniel, J.C. 1996. The leopard in India- a natural history. Natraj, Dehradun, India.

Devaraj, M. 1996. Sea-farming and conservation of molluscan resources of India. Pages 71-78 *in* J. Hylleberg, and K. Ayyakkannu, editors. Proceedings of the sixth Workshop of the Tropical Marine Mollusc Program, Annamalai University, India, 12–20 June 1995.

Food and Agriculture Organization. 2001. Economic corridors: transport and energy infrastructure transforming the Greater Mekong Sub region (GMS).

Ford, A. 1999. Modeling the Environment. Island Press, Covelo, California.

Foster-Turley, P., and C. Santiapillai. 1990. Action plan for Asian otters. Pages 52-63 *in* P. Foster-Turley, S, Macdonald and C. Mason, editors. Otters: an action plan for their conservation. IUCN/SSC Otter Specisialist Group.

Fox, J. C. Nurubu, and R. Chudawat. 1991. The mountain ungulates of Laddakh. India. Biological Conservation 58:167-190.

Freese, H. C., and D. L. Trauger. 2000. Wildlife markets and biodiversity conservation in North America. Wildlife Society Bulletin 28: 42-51.

Foundation for Rehabilitation of Local Health Traditions. 1995. Plants under threat - new list forged. Amruth 5:2-3.

Getis, A., and J. K. Ord. 1992. The analysis of spatial association by use of distance statistics. Geographical Analysis 24:189-206.

Hansen, B. E. 2001. The new econometrics of structural change: dating breaks in US labor productivity. Journal of Economic Perspectives 15:117-128.

Hill, R. C., E. W. Griffiths, and G. C. Lim. 2008. Principles of Econometrics. John Wiley and Sons, New York, New York, USA.

Hillstrom, K., and L. C. Hillstrom. 2003. Asia: a continental overview of environmental issues. ABC-CLIO, City California, USA.

Hussain, S. A. 1999. Otter Conservation in India. ENVIS Bulletin - Wildlife and Protected Areas 2:92-97.

Inskipp, T. P. 1975. All heavens in rage. Society for Protection of Birds. Sandy, United Kingdom.

Iqbal, M. 1993. International trade in non-wood forest products: an overview, FAO: Misc/93/11 Working Paper, Food and Agricultural Organization, Rome, Italy.

Jacoby, W. G. 1997. Statistical Graphics for Univariate and Bivariate Data. Sage, New Delhi, India.

Jekkins, M, and S. Broad, compilers and editors. 1994. International trade in reptile skins: a review and analysis of the main consumer markets, 1983-91. TARFFIC International, Cambridge, United Kingdom.

Johnsingh, A. J. T., and S. P. Goyal. 2005. Tiger Conservation in India, past, present and future. Indian Forester October: 1279-1296.

Karanath, K. U., and B. M. Stith. 1999. Prey species depletion as a critical determinant of tiger population viability. Pages 100-113 *in* J. Seidensticker, S. Christie, and P.

Jackson, editors. Riding the tiger: tiger conservation in human dominated landscapes. Cambridge University Press, Cambridge, United Kingdom.

_____, and M. E. Sunquist. 1995. Prey selection by tiger, leopard and dholes in tropical forests. Journal of Animal Ecology 64:439-450.

Kenney, J. S, J. L. D. Smith, A. M. Starfield, and C.W. Mcdougal. 1995. The long-term effect of tiger poaching on population viability. Conservation Biology 9:1127-1133.

Khan, A. A, Quershi, B., and M. S. Awan. 2006. Impact of musk trade on the decline in Himalayan musk deer Moschus chrysogaster population in Neelum Valley, Pakistan. Current Science 91:696-699.

Kuniyal, C.P., Y.S. Rawat, S.S. Oinam, J.C. Kuniyal, and S.C.R Vishvakarma. 2005. Kuth (*Saussurea lappa*), cultivation in the cold desert environment of the Lahul Valley, northwestern Himalayas, India: arising threats and need to revive socio-economic values. Biodiversity and Conservation 14:1035-45.

Lee J., M. C. Strazicich. 2004. Minimum LM Unit Root test with One Structural Break, Working Paper, Department of Economics, Appalachian State University, North Carolina, USA.

Lee, J., J. A. List, and M. C. Strazicich. 2006. Non-renewable resources prices: deterministic or stochastic trend? Journal of Environmental Economics and Management 51:354-320.

Le Gallo, J., and C. Ertur. 2003. Exploratory spatial data analysis of the distribution of regional per capita GDP in Europe, 1980-1995. Papers Regional Science 82:175-201.

Martin, E. B. 1996. The importance of park budgets, intelligence networks and competent man-agreement for successful conservation of the greater one-horned rhinoceros. Pachyderm 22:10-17.

Mills, J. A., editor. 1997. Rhinoceros horn and tiger bone in China: an investigation of trade since the 1993 ban. TRAFFIC International, Cambridge, United Kingdom.

Menon, V., and A. Kumar. 1998. Signed and sealed: the fate of the Asian elephants. Asian Elephant Conservation Center and Wildlife Protection Society of India, New Delhi, India.

_____, and A. Kumar. 1998. Wildlife crime: an enforcement guide. Wildlife Protection Society of India, New Delhi, India.

_____. 2002. Tusker: the story of the Asian elephants. Penguin Enterprise with WTI and IFAW, New Delhi, India.

_____, R. Sukumar, and A. Kumar. 1997. A God in distress: threats of poaching and the ivory trade to the Asian elephants in India. Asian Elephant Conservation Center and Wildlife Protection Society of India New Delhi, India.

Manjunatha, B. K. 2006. Antibacterial activity of Pterocarpus santalinus. Indian Journal of Pharmaceuticals Sciences 68:115-116.

Ministry of Environment and Forests 1972. Wildlife Protection Act 1972. Government of India, New Delhi, India.

Ministry of Environment and Forests. 2008. The annual report 2007-08. Government of India, New Delhi, India.

Mishra, M. 2004. Research report on wildlife trade on wildlife trade regulations CITES and law enforcement in south Asia. TRAFFIC, WWF and IUCN, New Delhi, India.

Molur, S., editor. 1995. Conservation assessment and management plan (CAMP) for selected species of medicinal plants of southern India.

Morecroft, J. 2007. Strategic Modeling and Business Dynamics. John Wiley & Sons, Singapore.

Narayan, S., S. Singh, H. S. Pawar, and M. Gadgil. 2005. Joining the dots: the report of the tiger task force. Ministry of Environment and Forests, Government of India, New Delhi, India.

Nash, V. S., editor. 1997. Still in Business: the ivory trade in Asia, seven years after the CITES ban. TRAFFIC Network report, Cambridge, United Kingdom.

Newmark, W. D. 1995. Insularization of Tanzanian parks and the local extinction of large mammals. Conservation Biology 10:1549-1556.

Niraj, S. K., J. Sharma, N. P. S.Chauhan, and M. K. S. Pasha. 2004. Assessment of human-leopard conflict and strategic planning for problematic areas in Maharashtra. Field Investigation Report submitted to Indian Government.

Nowell, K. 2000. Far from a cure: the tiger trade revisited. Traffic International, Washington, D.C., USA.

Molur, S., and S. Walker, editors. 1998. Report on selected medicinal plants of Northern, Northeastern and Central India resulting from a Conservation Assessment and Management Plan (CAMP) workshop, held in the Forest Department of Uttar Pradesh, Lucknow 21-25 January 1997. Zoo Outreach Organization. Zoos' Print 13(6).

Oldfield, S., C. Lusty, and A. Mackinven, compilers. 1998. The World list of threatened trees. World Conservation Press, Cambridge, United Kingdom.

_____, editor. 2003. The trade in wildlife: regulation for conservation. Fauna and Flora International, Resource Africa and TRAFFIC International. Earthscan, London, United Kingdom.

O'sullivan, and D. J. Unwin. 2003. Geographic information analysis. John Wily and Sons, New Jersey, USA.

Persoon, G. A. 2007. Agarwood: the life of a wounded tree. International Institute of Asian Studies, Newsletter Issue 45.

Poudyal, M., and D. Knowler. 2005. Economic incentives and poaching of the one-horned Indian rhinoceros in the Chitwan Valley, Nepal – A retrospective econometric analysis. Poverty Reduction and Environmental Management, Working Paper 05/07.

Prater, S. H. 1971. The book of Indian animals. Bombay Natural History Society. Oxford University Press, Bombay, India.

Prater, S. H. 1998. The book of Indian animals. Bombay Natural History Society. Oxford University Press, Mumbai, India.

Rahmani, A. R. 2001. Pages 178-187 *in* D.P. Mallon and S.C. Kingswood, compilers. Antelopes. Part 4: North Africa, the Middle East, and Asia. Global Survey and Regional Action Plans, IUCN, Gland, Switzerland.

Reeve, R. 2002. Policing international trade in endangered species: the CITES treaty and compliance. The Royal Institute of International Affairs, London, United Kingdom.

Rodgers, W. A., H. S. Pawar, and V. B. Mathur. 2002. Wildlife protected area network in India: a review. Wildlife Institute of India, Dehradun, India.

Santiapillai, C., M. De Silva, S. Dissanayake. 2000. The status of mongooses (family: Herpestidae) in Ruhuna National Park, Sri Lanka. The Journal of the Bombay Natural History Society 97:208-214.

Shaller, G. B. 1998. Wildlife of the Tibetan Steppe. The University of Chicago Press, Chicago, Illinois, USA.

Shepherd, C. R., E. A. Burgess, and M. Loo. 2004. Demand driven: the trade of Indian star tortoises *Geochelone elegans* in Peninsular Malaysia. TRAFFIC South East Asia, Malaysia.

Sterman, J. D. 2000. Business dynamics: systems thinking and modeling for a complex world. McGraw Hill, Boston, Massachusetts, USA.

Stiles, D. 2004. The ivory trade and elephant conservation. Environmental Conservation 31:309-321.

Stock, J. H., and M. W. Watson. 2003. Introduction to Econometrics, Pearson Education, Delhi, India.

Sukumar, R., U. Ramakrishnan, and J. A. Santosh. 1998. Impact of poaching on an Asian elephant population in Periyar, southern India: a model of demography and tusk harvest. Animal Conservation 1:281-291.

Thapar, V. 2003. Battling for survival: India's wilderness over two centuries. Oxford University Press, New Delhi, India.

Theile, S. 2003. Fading footprints: the killing and trade of snow leopard. TRAFFIC International, Cambridge, United Kingdom.

Van Djik, P. P., B. L. Stuart, and A. G. L. Rhodin, editors. 2000. Asian turtle trade. Proceedings of a workshop on conservation and trade of freshwater turtles and tortoises in Asia, Phnom Penh, Cambodia, 1-4 December 1999. Chelonian Research Monographs 2.

Virmani, A. 1999a. Star performers of the 20th (21st) century: Asian tigers, dragons or elephants. Occasional paper, Chintan, China, September 2000.

_____. 1999b. Potential growth stars of the 21st century: India, China and the Asian century. Occasional Paper, Chintan, China, October 2000.

_____. 2004. Economic performance, power, potential and global governance: towards a new international order. Indian Council for Research on International Economic Relations. Working paper 150. December 2005.

Wikramanayake, E., M. Mckinight, E. Dinerstein, A. Joshi, B. Gurung, and D. Smith 2004. Designing a conservation landscape for tigers in human-dominated environments. Conservation Biology 18:839-844.

Wildlife Protection Society of India. 1997. Fashioned for extinction. New Delhi, India.

World Conservation Union. 2008. IUCN Red List of Threatened Species. www.iucnredlist.org. Downloaded on 29 October 2008.

Yonzon, P. 2005. Mongoose trade in Nepal. Tiger Paper. Regional Quarterly Bulletin on Wildlife and National Parks Management 32:2.

Table 1. Test of break date and stochastic trend for seizures of different species from India, 1992-2006.

Species	Break date	LM unit-root statistic[a]
Tiger	2001q3[b]	-6.87[c]
Leopard	1999q3	-6.96[c]
Elephant	1998q1	-3.96
Rhino	1994q4	-6.39[c]
Deer Antlers	1998q4	-7.45[c]

[a]Lagrange Multiplier unit-root statistic; if the value of this statistic is high then the hypothesis of unit-root or stochastic trend is rejected.

[b]q = quarter for the year (e.g., q1 = first yearly quarter).

[c]Significant at 5% level

Table 2. Regressions with dependent variables seizures (by species) against time and break dummies for tiger, leopard, elephant, deer and antelope, and rhinoceros in India, 1992-2006.

Dependent variables / Species	Statistic	Change in slope at break point	Slope (seizure versus time)	Change in intercept at break	Intercept	*N*
Tiger	Coefficient	-0.981	0.642	-13.86	5.645	60
	P-value	(0.000)	(0.000)	(0.001)	(0.153)	
Leopard	Coefficient	-2.384	1.310	2.852	8.651	59
	P-value	(0.070)	(0.049)	(0.903)	(0.559)	
Elephant	Coefficient	-2.262	0.269	20.11	21.35	60
	P-value	(0.008)	(0.248)	(0.115)	(0.001)	
Deer and antelope	Coefficient	-48.99	10.31	326.1	-69.56	60
	P-value	(0.063)	(0.116)	(0.442)	(0.418)	
Rhinoceros	Coefficient	0.0543	-0.332	5.599	16.75	60
	P-value	(0.762)	(0.001)	(0.041)	(0.000)	

Table 3. Seizures of shells by number or mass (kg) from India during 1992-2006.

	Shells	
Year	No.	Mass
1992	1	1,084
1993	4,153	940
1994	2,960	235
1995	7,986	412
1996	31,782	8
1997	582	6,169
1998	1,386	5,550
1999	25,526	45
2000	6,222	849
2001	15,370	52,206
2002	318,476	16,871
2003	1,020	688
2004	9,743	10,216
2005	70,938	481
2006	1,892	10

Table 4. Seizures of different species of birds and feathers of Indian pea fowl and Jungle fowls from India during 1992-2006.

		Feathers		
Year	Birds	No.	Kg	Birds
1992	8,959	17,000	0.0	85
1993	15,009	420,500	600.0	2,103
1994	4,220	0	21.1	53
1995	443	600	11.4	33
1996	2,640	1,010	15.0	6
1997	6,361	1,400	40.0	107
1998	6,617	73,730	0.0	368
1999	1,676	139,907	19.5	658
2000	13,788	5,000	3.9	35
2001	9,461	46,620	36.7	137
2002	5,646	89	365.4	803
2003	3,070	195	718.3	1,807
2004	1,905	860	144.9	384
2005	1,660	6	7.5	28
2006	6,420	555,245	10.8	2,804

Table 5. Seizures of agarwood and its derivatives from India during 1992-2006

	Agarwood		
		Oil	
Year	Kg	Kg	Ml
1992	4	0	0
1993	0	0	0
1994	46,707	0	0
1995	39	0	0
1996	1	0	0
1997	0	0	0
1998	690	0	87,000
1999	20,321	0	0
2000	8,840	0	10,000
2001	650	2	0
2002	713	19	500
2003	2,029	1	600
2004	202	0	7,500
2005	51	0	65,730
2006	126	0	0

Table 6. Seizures of kuth and its derivatives from India during 1992-2006.

Year	No.	Kg	Ml
1992	0	72,002.7	0
1993	0	18,800.0	0
1994	97	0.0	0
1995	0	8.5	0
1996	50	0.0	0
1997	600	0.0	0
1998	1	32.4	2,000
1999	0	560.7	0
2000	1,380	14.4	3,470
2001	1,207	1.3	0
2002	14	25.0	64,500
2003	222	12.0	6,800
2004	0	28,672.9	31,000
2005	0	21,500.0	0
2006	0	0.0	0

Table 7. Regression results for dependent variables logarithm of tiger and logarithm of leopard in India, 1992-2006

	$\ln(tiger_t)$		$\ln(tiger_t)$		$\ln(leopard_t)$		$\ln(leopard_t)$	
	(1)		(2)		(3)		(4)	
Independent variables	coefficient	*p*-value	coefficient	*p*-value	coefficient	*p*-value	coefficient	*p*-value
$\ln(leopard_t)$	0.31	-0.011	0.389	0				
$\ln(leopard_{t-1})$	-0.0327	-0.798						
$\ln(leopard_{t-2})$	-0.0897	-0.276						
$\ln(leopard_{t-3})$	0.0466	-0.654						
$\ln(leopard_{t-4})$	-0.0916	-0.387						
$\ln(tiger_t)$					0.758	-0.001	0.889	0
$\ln(tiger_{t-1})$					0.344	-0.102		
$\ln(tiger_{t-2})$					0.147	-0.491		
$\ln(tiger_{t-3})$					0.134	-0.523		
$\ln(tiger_{t-4})$					-0.216	-0.318		
Constant	2.116	0	1.333	0	0.0894	-0.908	0.823	-0.023
N	51		59		55		59	

LIST OF FIGURES

FIGURE

10. Spatial distribution of tiger poaching and seizures of its parts and derivatives from India during 1992-2006. Equivalent units (Eq. units) were computed based on measurements of body parts or derivatives as would be derived from 1 animal.
11. The percentile and local indicators of spatial association (LISA) cluster and significance map of tiger poaching and seizures from India during 1992-2006. Madhya Pradesh and Uttar Pradesh states have High-high (HH) clusters and Uttaranchal has a High-low (HL) cluster reported at the 5% significance level.
12. The spatial distribution of leopard poaching and leopard skin, bone and claw seizures from India during 1992-2006. The distribution has a wide range covering nearly all the states in India except the islands and few states in the north-east. Equivalent units (Eq. units) were computed based on measurements of body parts or derivatives as would be derived from 1 animal.
13. The percentile and local indicators of spatial association (LISA) cluster and significance maps of leopard poaching in India from 1992-2006. Uttar Pradesh and Madhya Pradesh show High-high (HH) cluster, West Bengal has a High-low (HL) cluster and Assam, Tripura, and Mizoram have a Low-low (LL) clusters at the 5% significance level.
14. Spatial distribution of poaching and seizures of deer and antelopes, their parts and derivatives converted into equivalent units (Eq.units) from India during 1992-2006. The distribution covers nearly all the states in India. Equivalent units were computed based on measurements of body parts or derivatives as would be derived from 1 animal.

15. The percentile and local indicators of spatial association (LISA) cluster and significance map of deer and antelope poaching in India from 1992-2006. Uttar Pradesh and Madhya Pradesh have High-high (HH) cluster, Gujarat has a Low-low (LH) cluster and Jammu and Kashmir, Punjab, and Himachal Pradesh have Low-low (LL) clusters reported at the 5% significance level.
16. Spatial distribution of snake poaching, seizures of skins, articles and snake equivalent units from India in 1992-2006. The snake poaching also covers a wide region over 1992-2006. Equivalent units (Eq. units) were computed based on measurements of body parts or derivatives as would be derived from 1 animal.
17. The percentile and local indicators of spatial association (LISA) cluster and significance maps of snake poaching and seizures in India from 1992-2006. Maharashtra, West Bengal, Andhra Pradesh and Kerala have significant clustering at 5% significance levels.
18. The spatial distribution of star tortoise seizures from India in different time periods between 1992 and 2006. The spread of seizure areas increases between 1992 and 2006.
19. The percentile and local indicators of spatial association (LISA) cluster and significance map of star tortoise seizures in India from 1992-2006. West Bengal and Haryana show High-low (HL) clusters whereas Goa and Pondicherry have Low-high (LH) clusters reported at 1% significance level.
20. The spatial distribution of red sander seizures from India in different time periods between 1992 and 2006. The spread of seizure areas increases between 1992 and 2006.

21. The percentile and local indicators of spatial association (LISA) cluster and significance map of red sander seizures in India from 1992-2006. West Bengal has an H-L cluster, whereas Chattisgarh and Karnataka have Low-high (LH) clusters at 5% significance level.

22. Causal loop diagram of poaching. We identify one reinforcing (R) and three balancing (B) feedback loops, labeled DEMAND, SUPPLY, SEIZURES, and CONCERN.

Figure 1. India with its immediate neighboring countries that share land borders with it. The northern boundary is considered sensitive from consideration of wildlife trafficking.

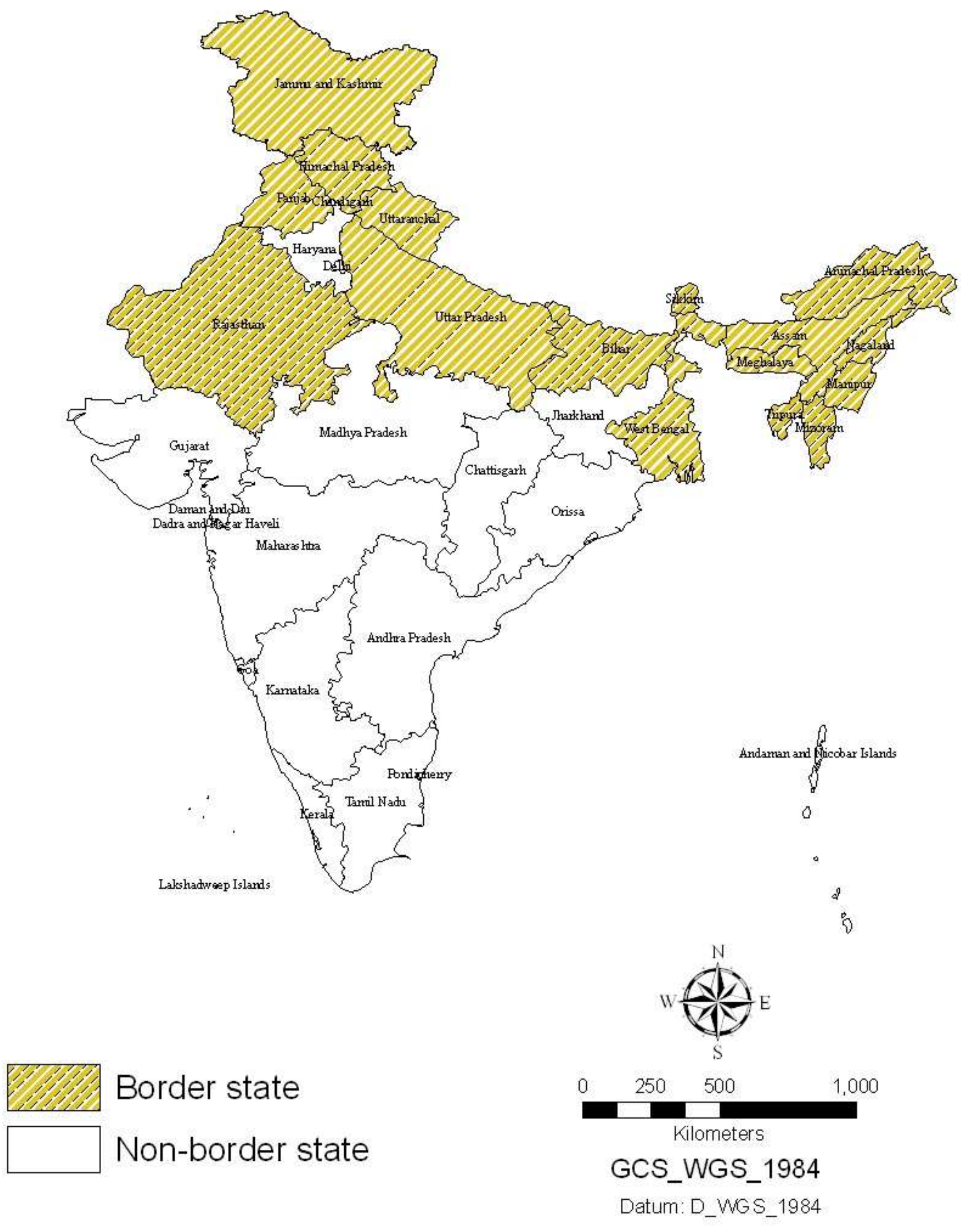


Figure 2. The Indian states classified as border (sharing land border) and non-border states. The nested states of Haryana and Delhi are surrounded by border states on all sides.

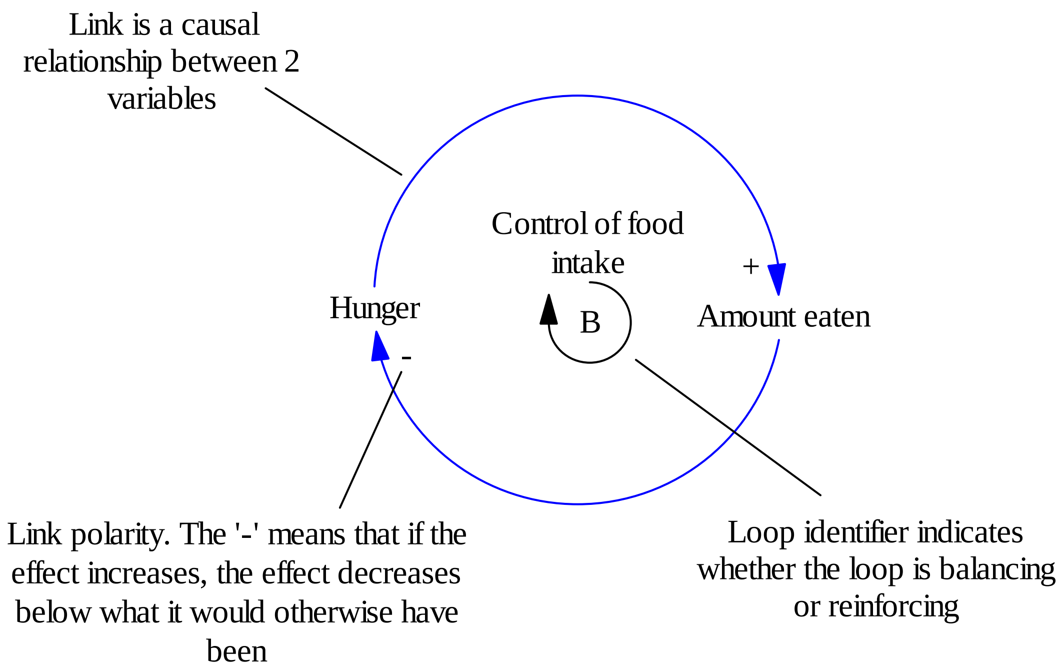


Figure 3. Simple causal loop diagram of food intake (Morecroft 2007: 39)

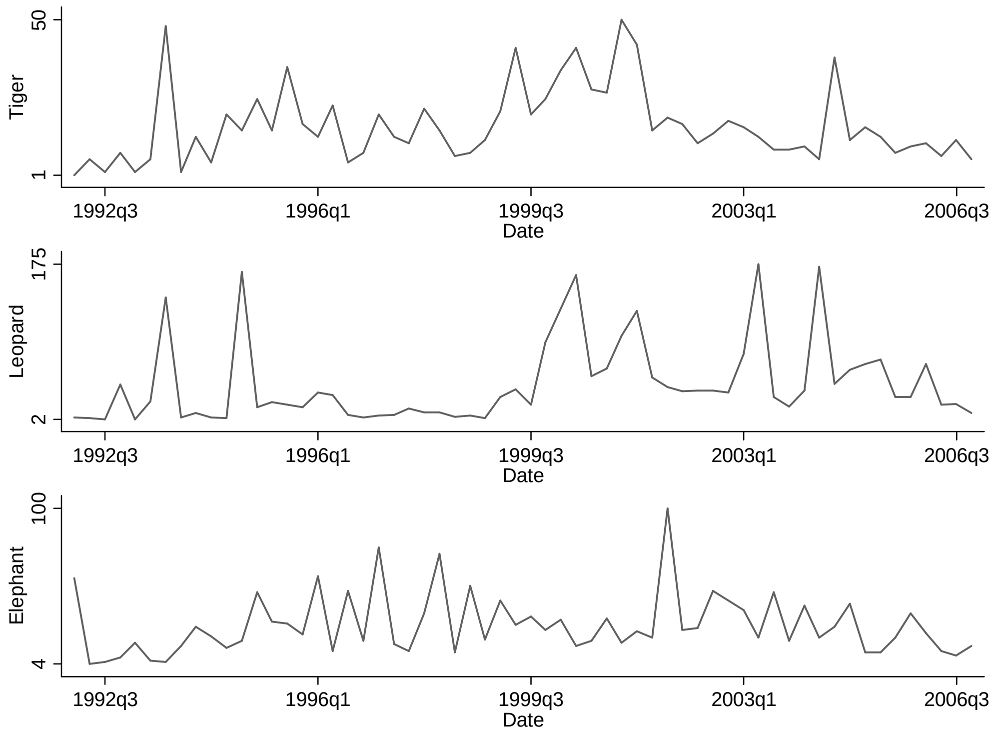


Figure 4a. Graphs of seizures of different species versus time (year and quarter [q]) from 1992q1 to 2006q4.

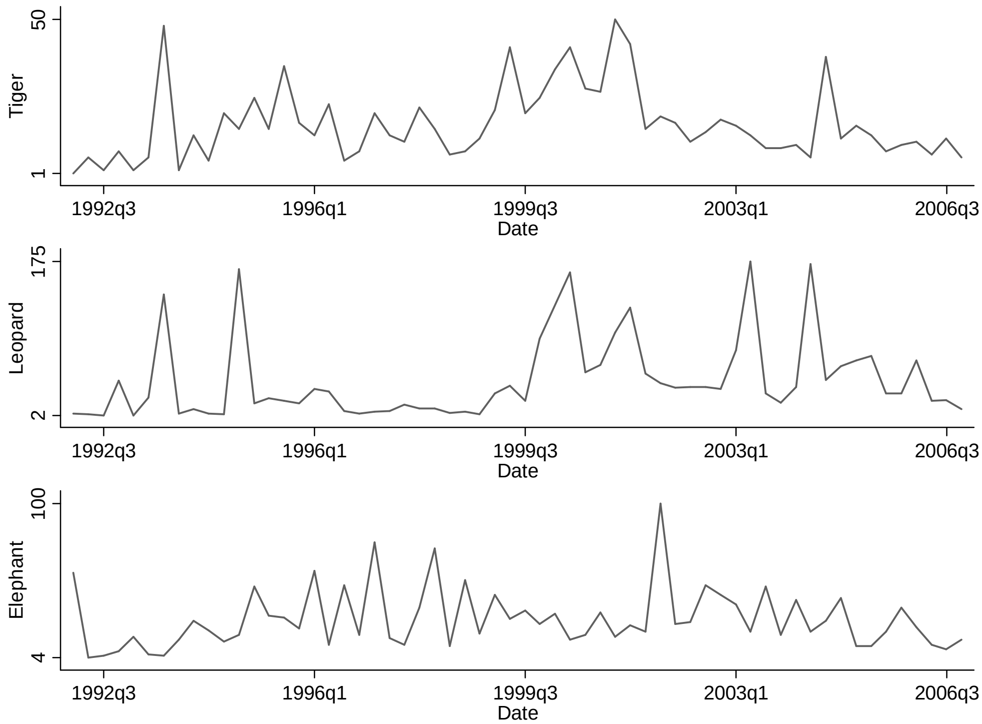


Figure 4a. Graphs of seizures of different species versus time (year and quarter [q]) from 1992q1 to 2006q4.

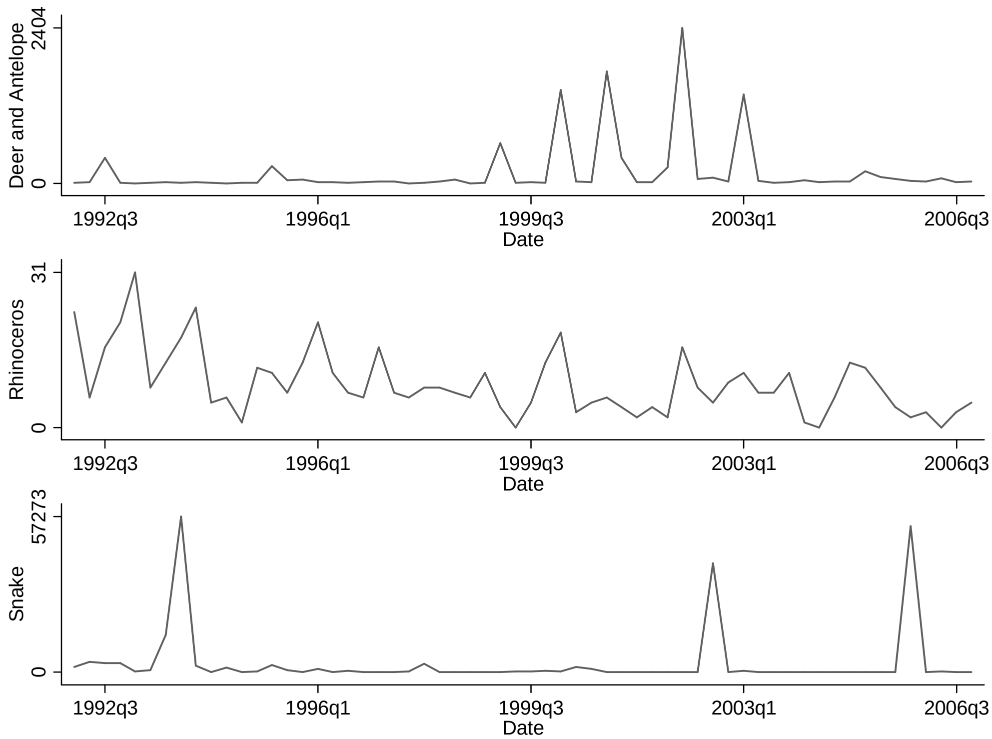


Figure 4b. Graphs of seizures of different species in India versus time (year and quarter [q]) from 1992q1 to 2006q4.

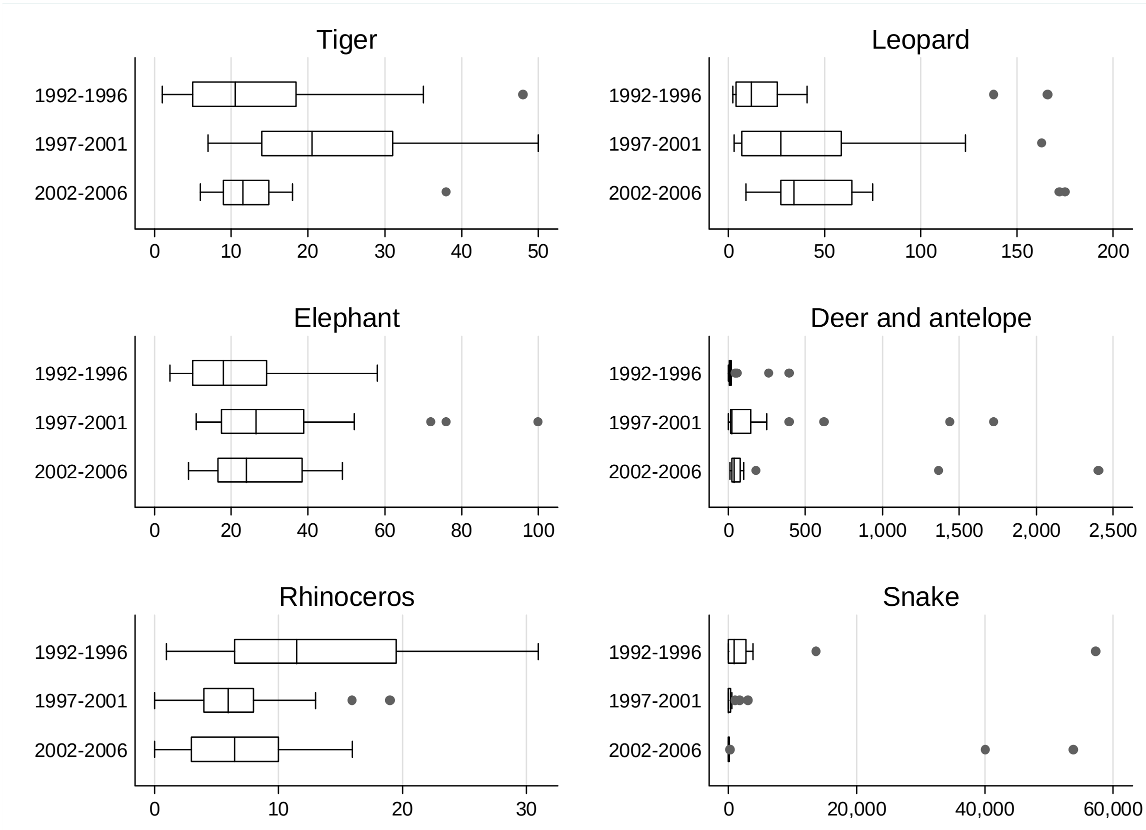


Figure 5. Box plots of seizures of different species in India by three different time periods: 1992 to 1996, 1997 to 2001, and 2002 to 2006.

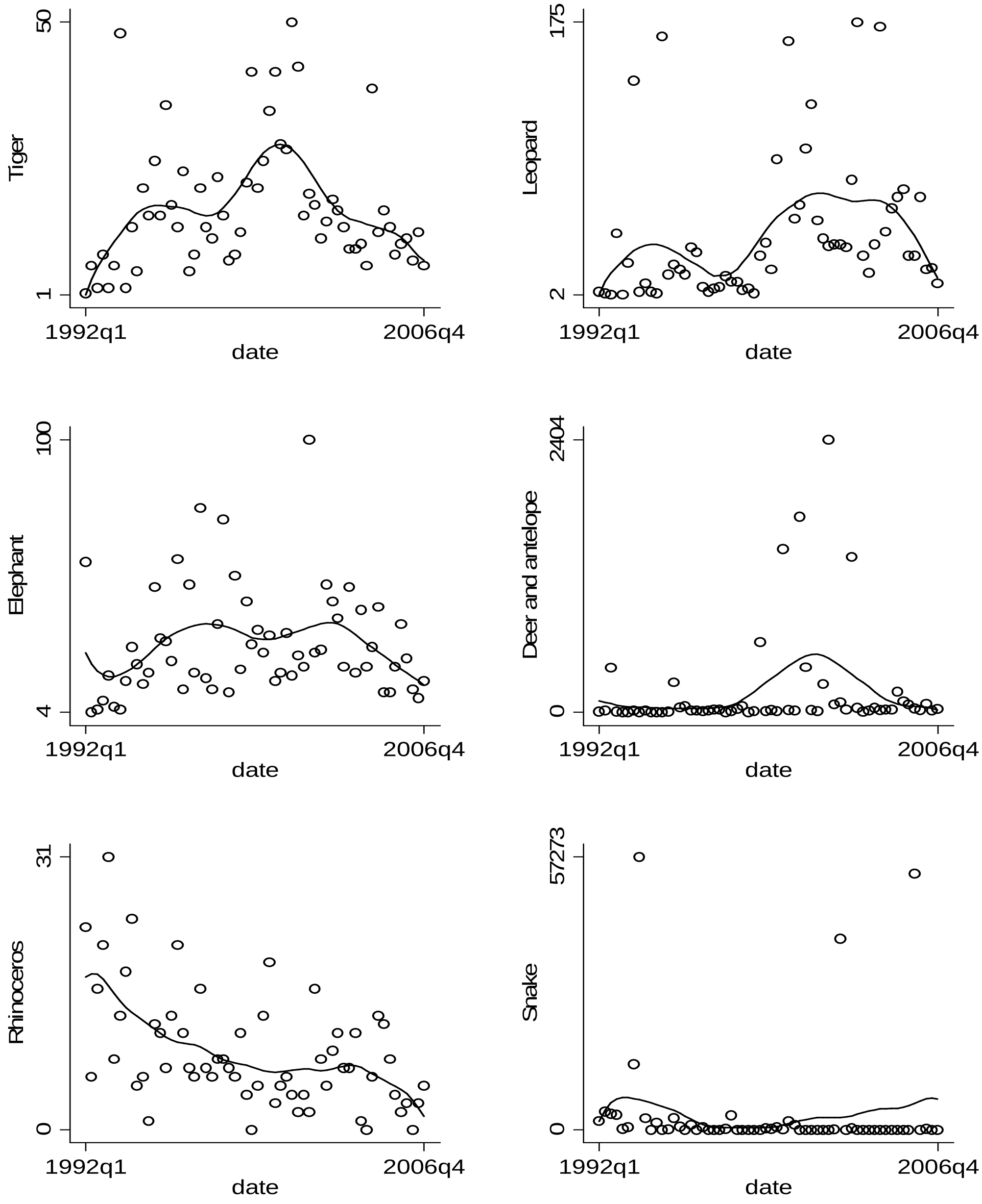


Figure 6. Loess curves of seizures of species in India against time (year and quarter [q]) from 1992q1 to 2006q4

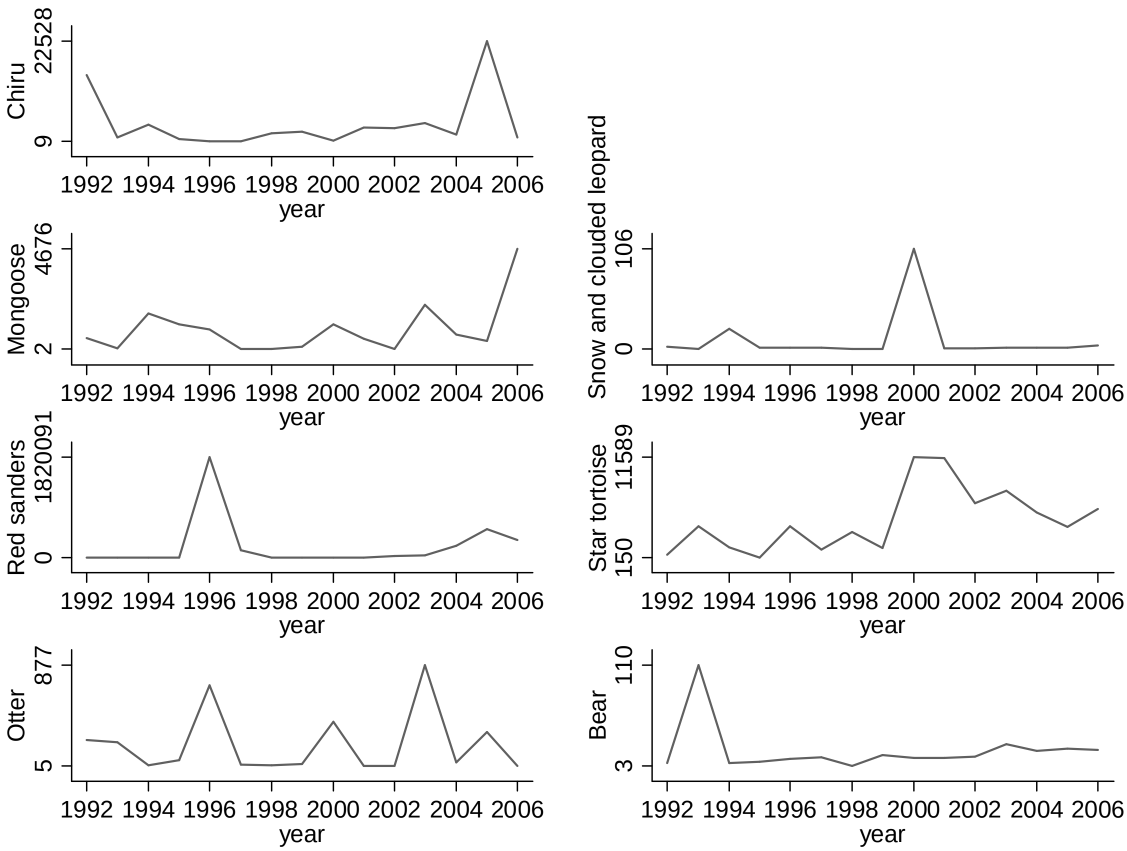


Figure 7. Annual seizures by species in India, from 1992 to 2006.

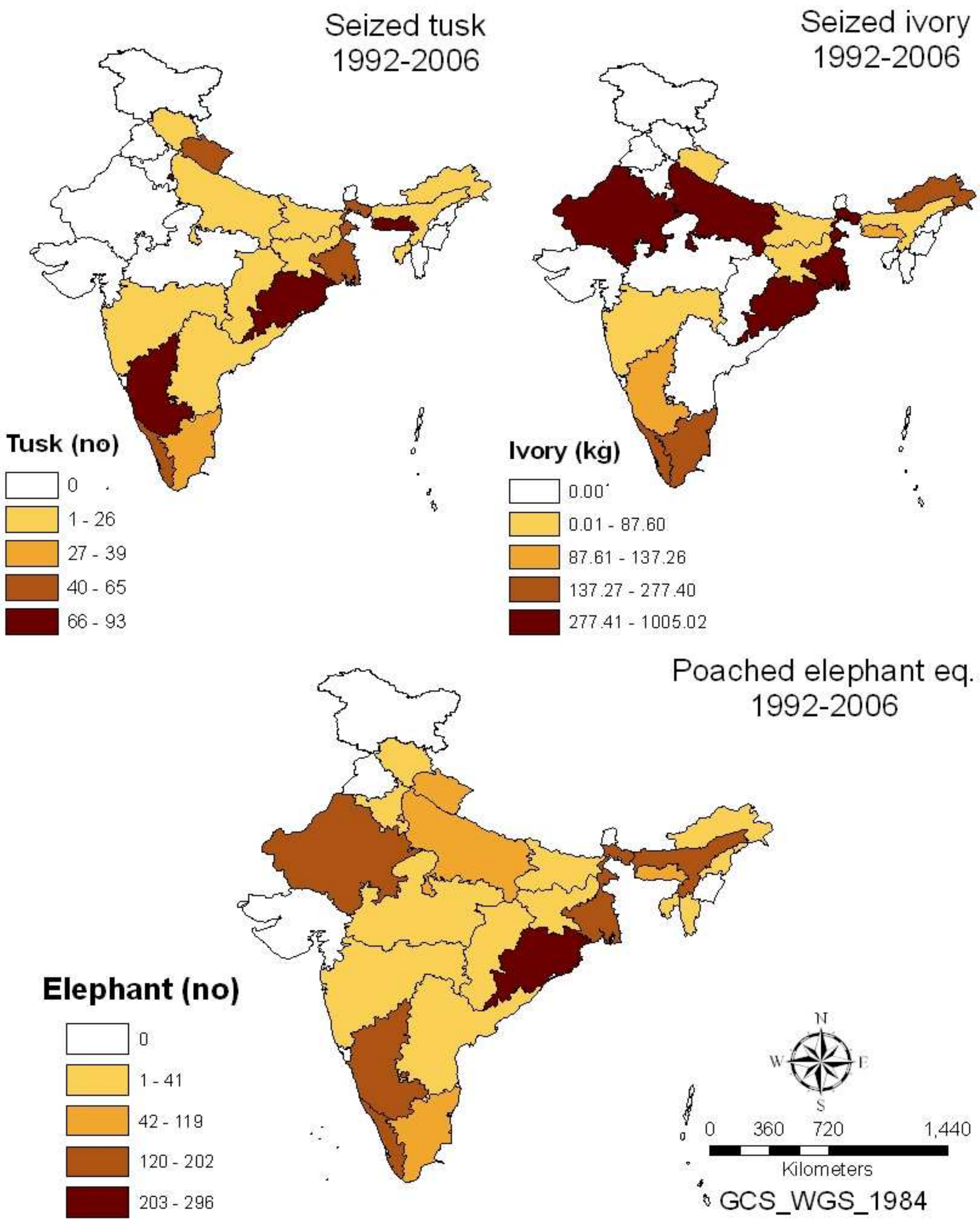
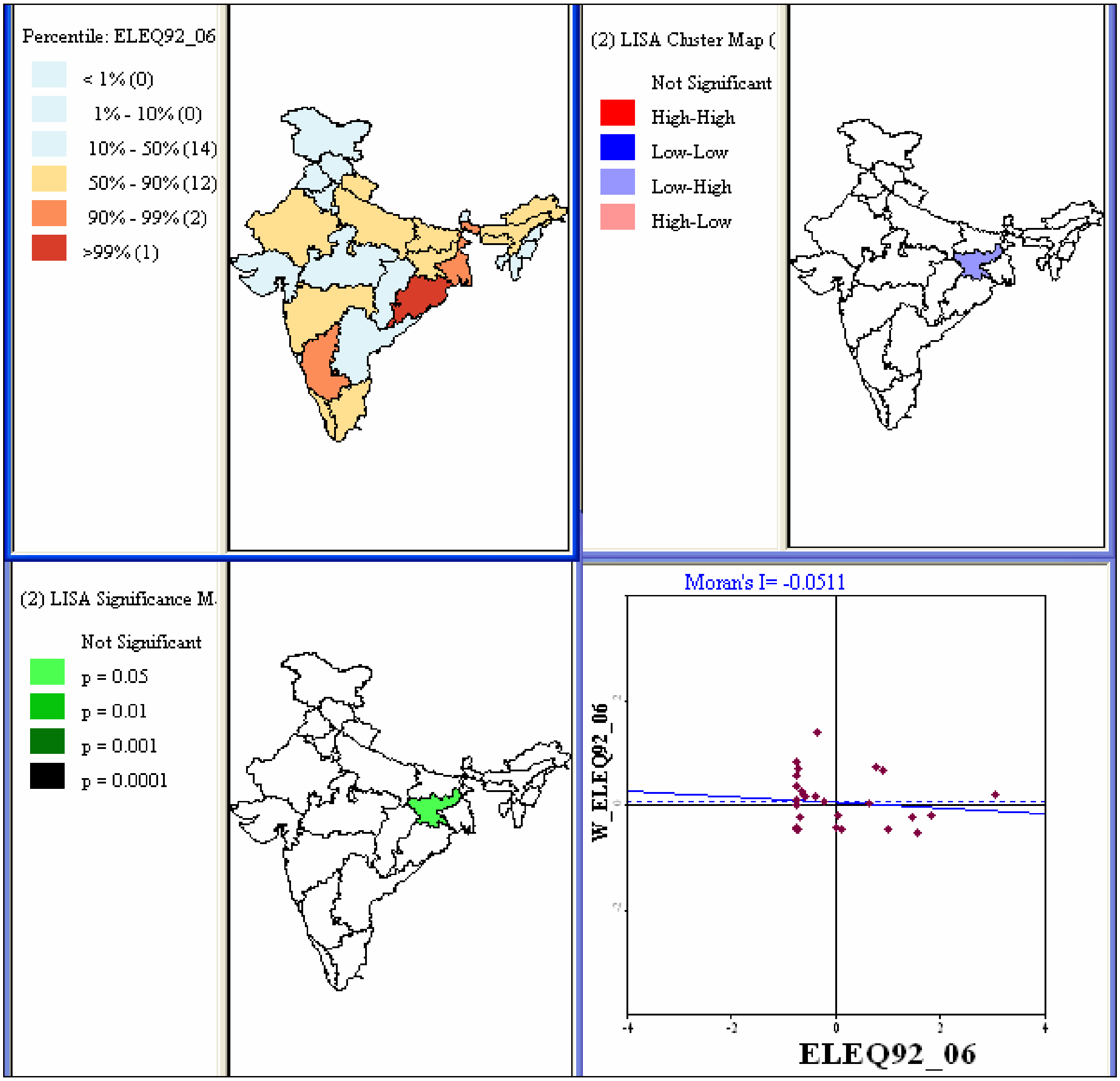


Figure 8. Spatial distribution of elephant poaching and tusk and ivory seizures from India during 1992-2006. The seizures and poaching have relatively wide distribution over many states. Equivalent units were computed based on measurements of body parts or derivatives as would be derived from 1 animal.



ELEQ92_06 = Elephant equivalent units from 1992 to 2006 against its weighted means.

Figure 9. The percentile and local indicators of spatial association (LISA) cluster and significance map of elephant poaching in India from 1992-2006. Only Jharkhand shows an LH cluster reported at the 5% significance level.

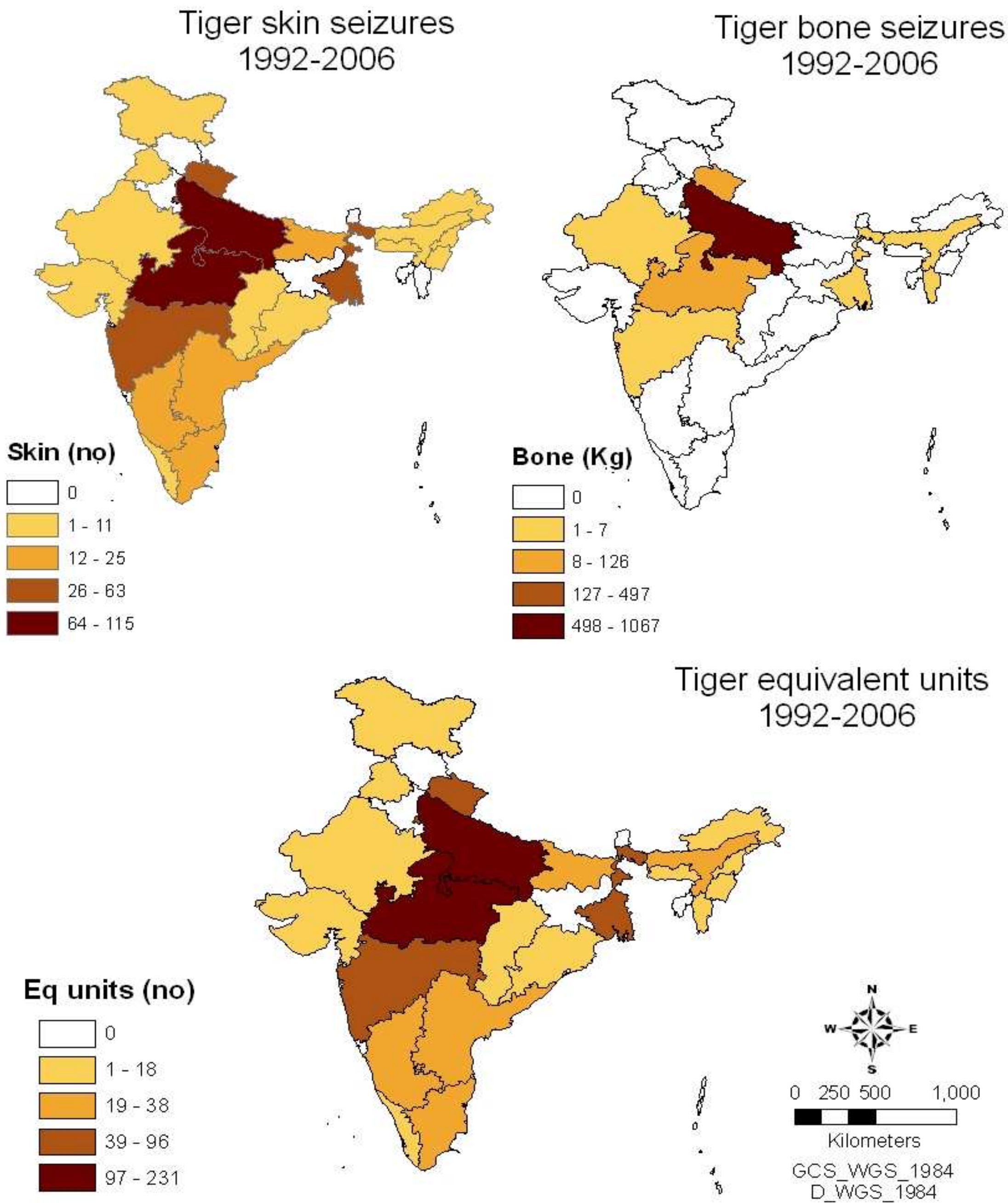
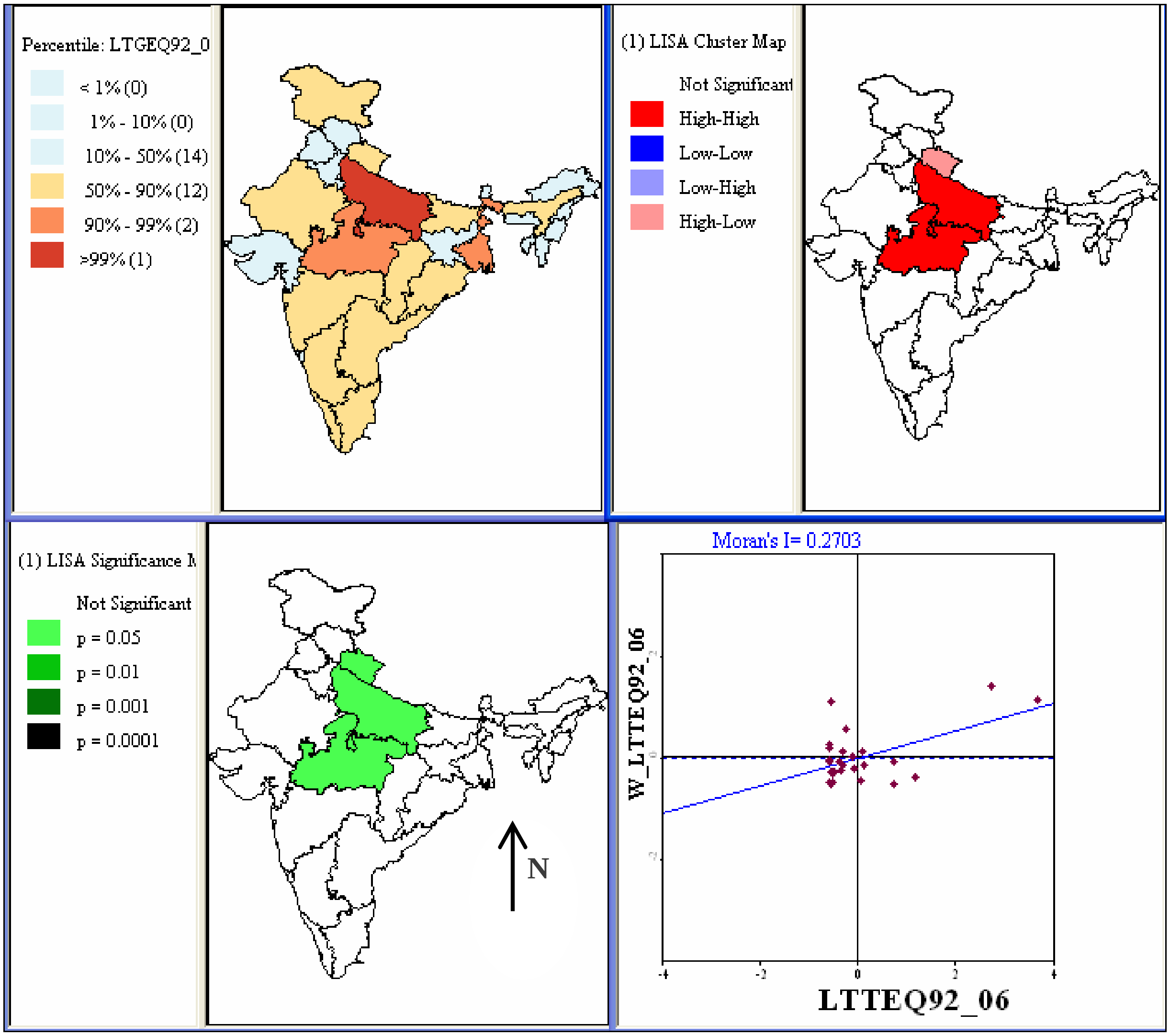


Figure 10. Spatial distribution of tiger poaching and seizures of its parts and derivatives from India during 1992-2006. Equivalent units were computed based on measurements of body parts or derivatives as would be derived from 1 animal.



LTTEQ92_06 = the log transformed tiger equivalent units from 1992 to 2006 against its weighted mean.

Figure 11. The percentile and local indicators of spatial association (LISA) cluster and significance map of Tiger poaching and seizures from India during 1992-2006. Madhya Pradesh and Uttar Pradesh states have High-high (HH) clusters and Uttaranchal has a High-low (HL) cluster reported at the 5% significance level.

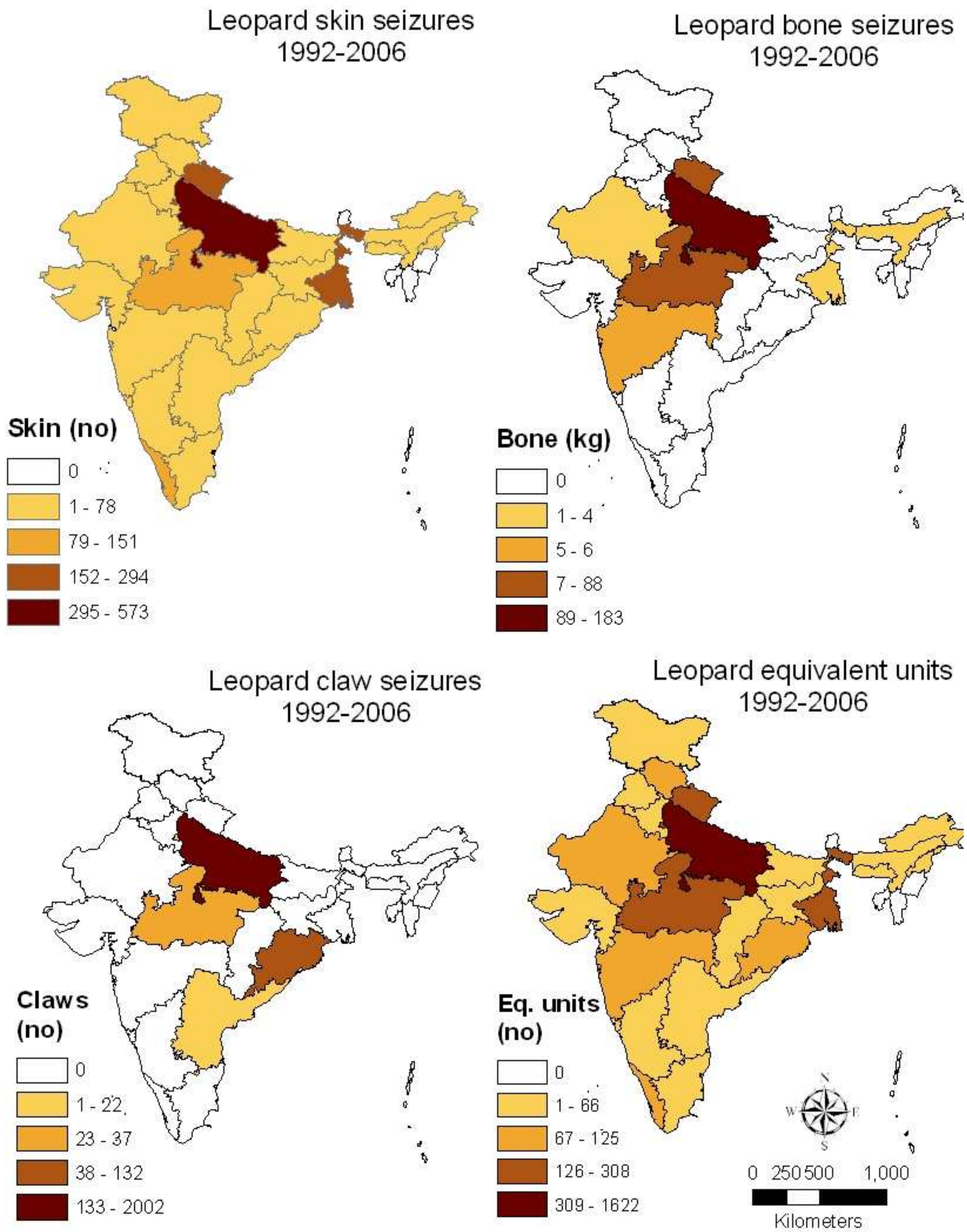
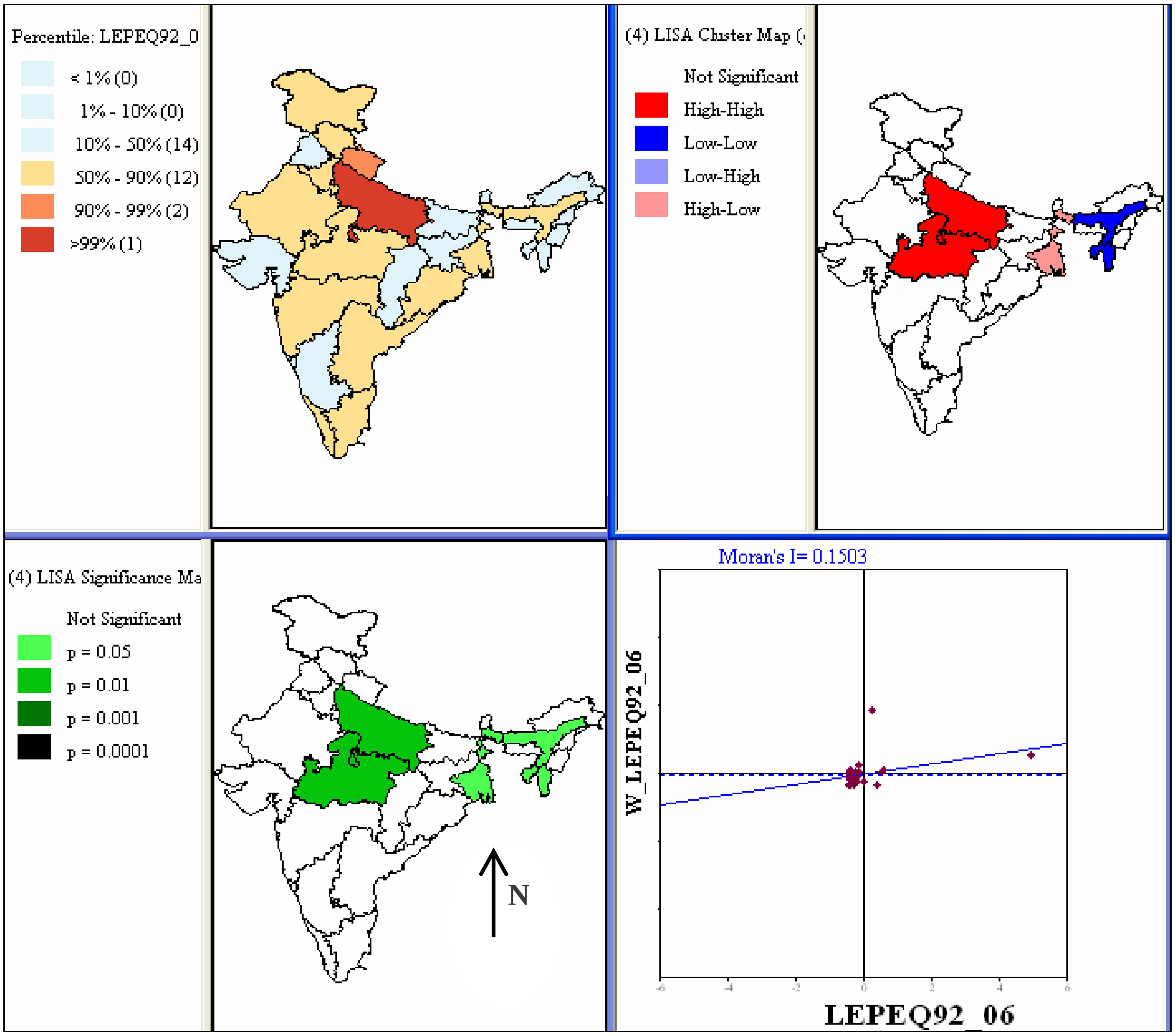


Figure 12. The spatial distribution of leopard poaching and leopard skin, bone and claw seizure from India during 1992-2006. The distribution has a wide range covering nearly all the states in India except the islands and few states in north-east. Equivalent units were computed based on measurements of body parts or derivatives as would be derived from 1 animal.



LEPEQ92_06 = the log transformed leopard equivalent units from 1992 to 2006 against its weighted mean.

Figure 13. The percentile and local indicators of spatial association (LISA) cluster and significance maps of leopard poaching in India from 1992-2006. Uttar Pradesh and Madhya Pradesh show High-high (HH) cluster, West Bengal has a High-low (HL) cluster and Assam, Tripura and Mizoram have Low-low (LL) clusters at the 5% significance level.

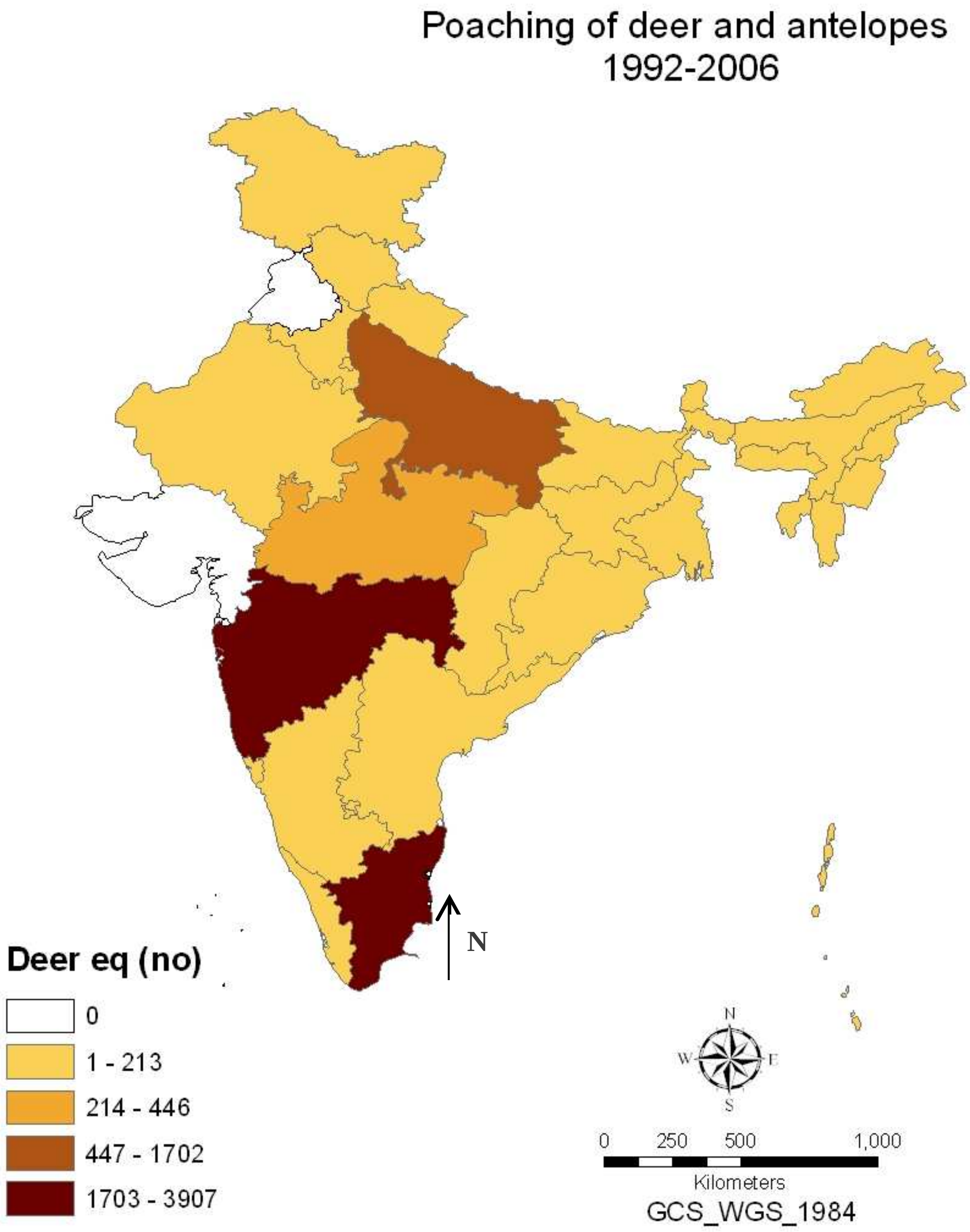
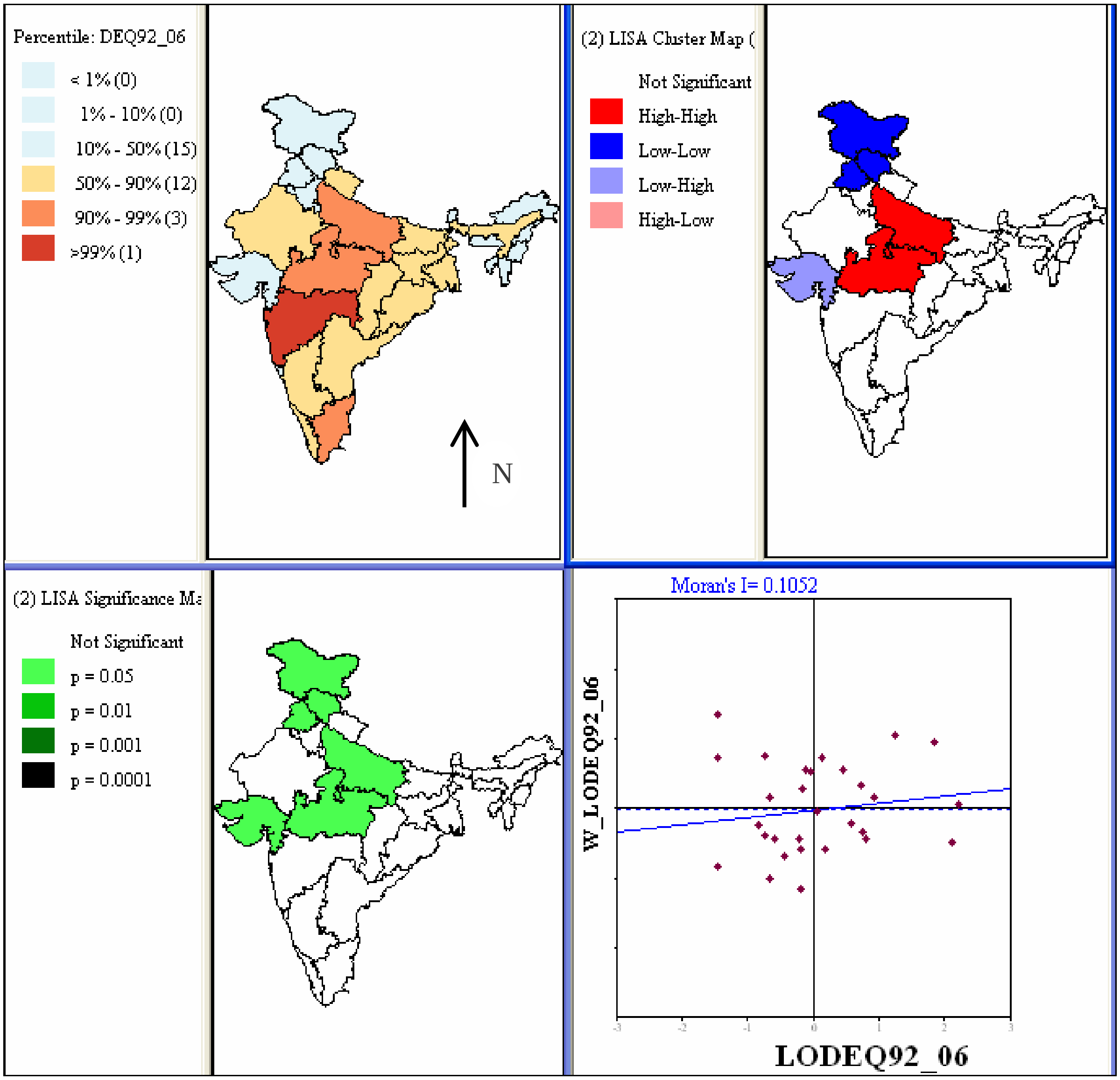


Figure 14. Spatial distribution of poaching and seizures of deer and antelopes, their parts and derivatives converted into equivalent units from India during 1992-06. The distribution covers nearly all the states in India. Equivalent units were computed based on measurements of body parts or derivatives as would be derived from 1 animal.



LODEQ92_06 = the log transformed deer equivalent units from 1992 to 2006 against its weighted mean.

Figure 15. The percentile and local indicators of spatial association (LISA) cluster and significance map of deer and antelope poaching in India from 1992-2006. Uttar Pradesh and Madhya Pradesh have High-high (HH) cluster, Gujarat has an Low-high (LH) cluster and Jammu and Kashmir, Punjab and Himachal Pradesh have Low-low (LL) clusters reported at the 5% significance level.

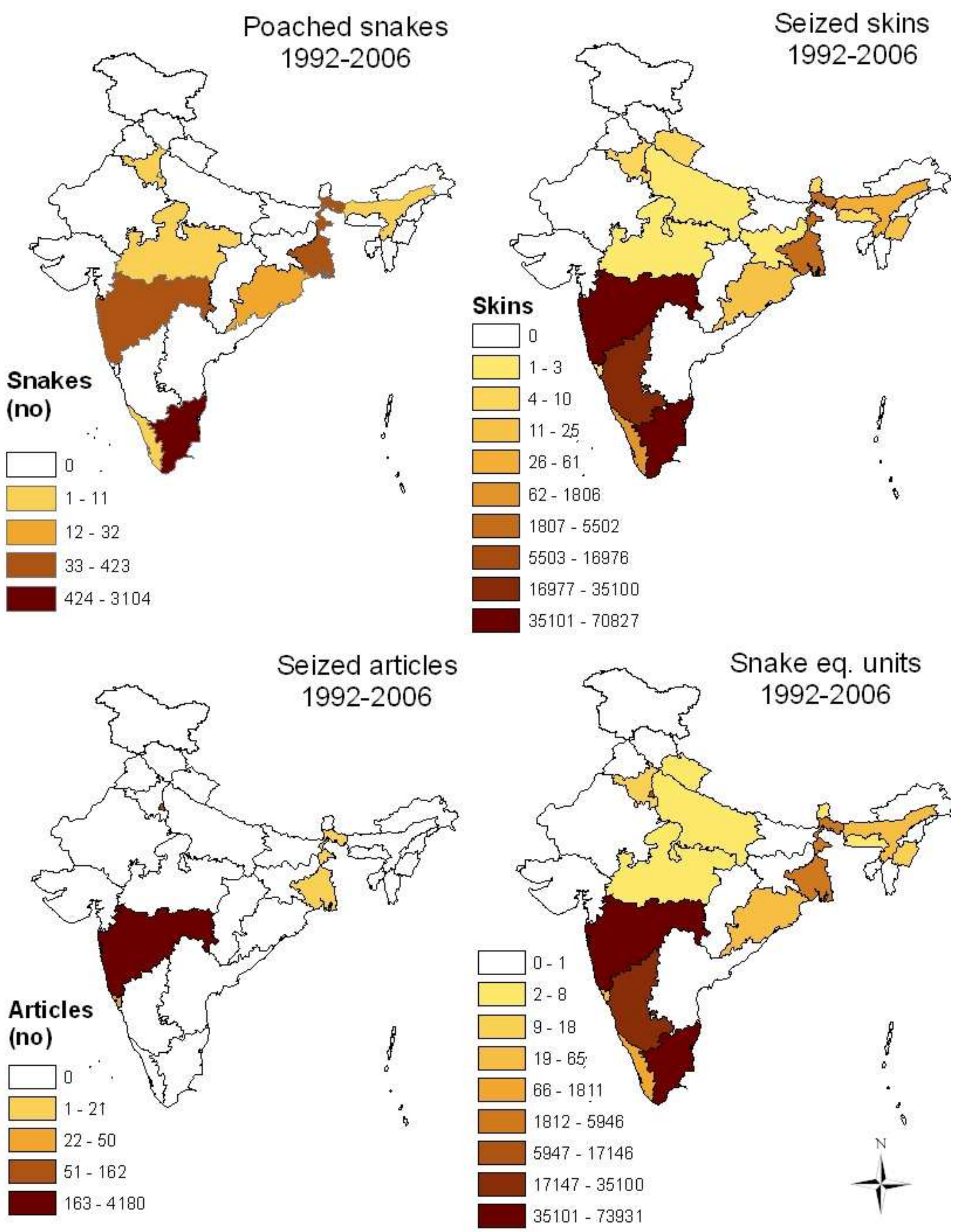
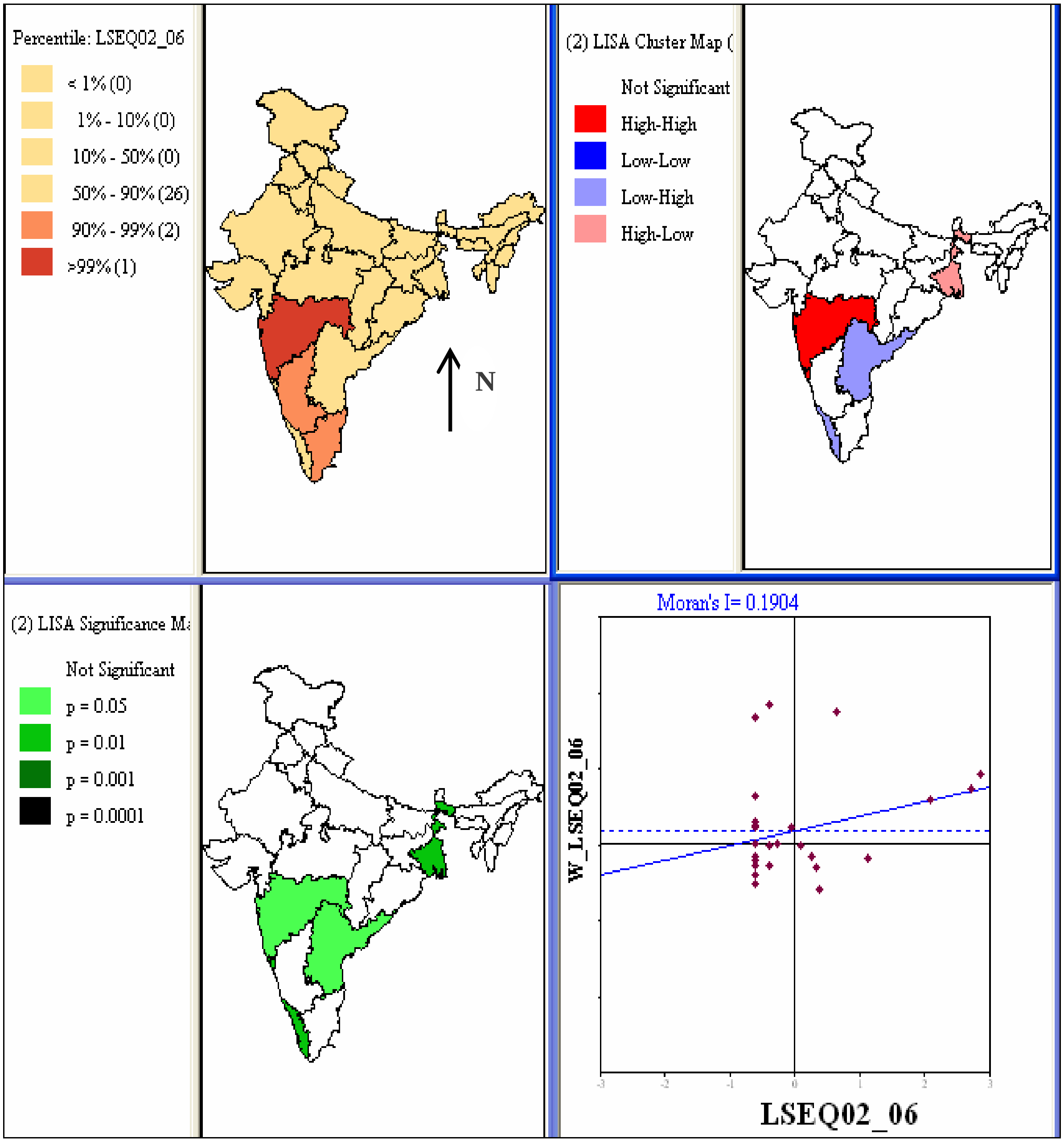


Figure 16. Spatial distribution of snake poaching, seizures of skins, articles and snake equivalent units from India in 1992-2006. The snake poaching also covers a wide region over 1992-2006. Equivalent units were computed based on measurements of body parts or derivatives as would be derived from 1 animal.



LSEQ02_06 = the log transformed snake equivalent units from 2002 to 2006 against its weighted mean.

Figure 17. The percentile and local indicators of spatial association (LISA) cluster and significance maps of snake poaching and seizures in India from 1992-2006. Maharashtra, West Bengal, Andhra Pradesh and Kerala have significant clustering at 5% significance levels.

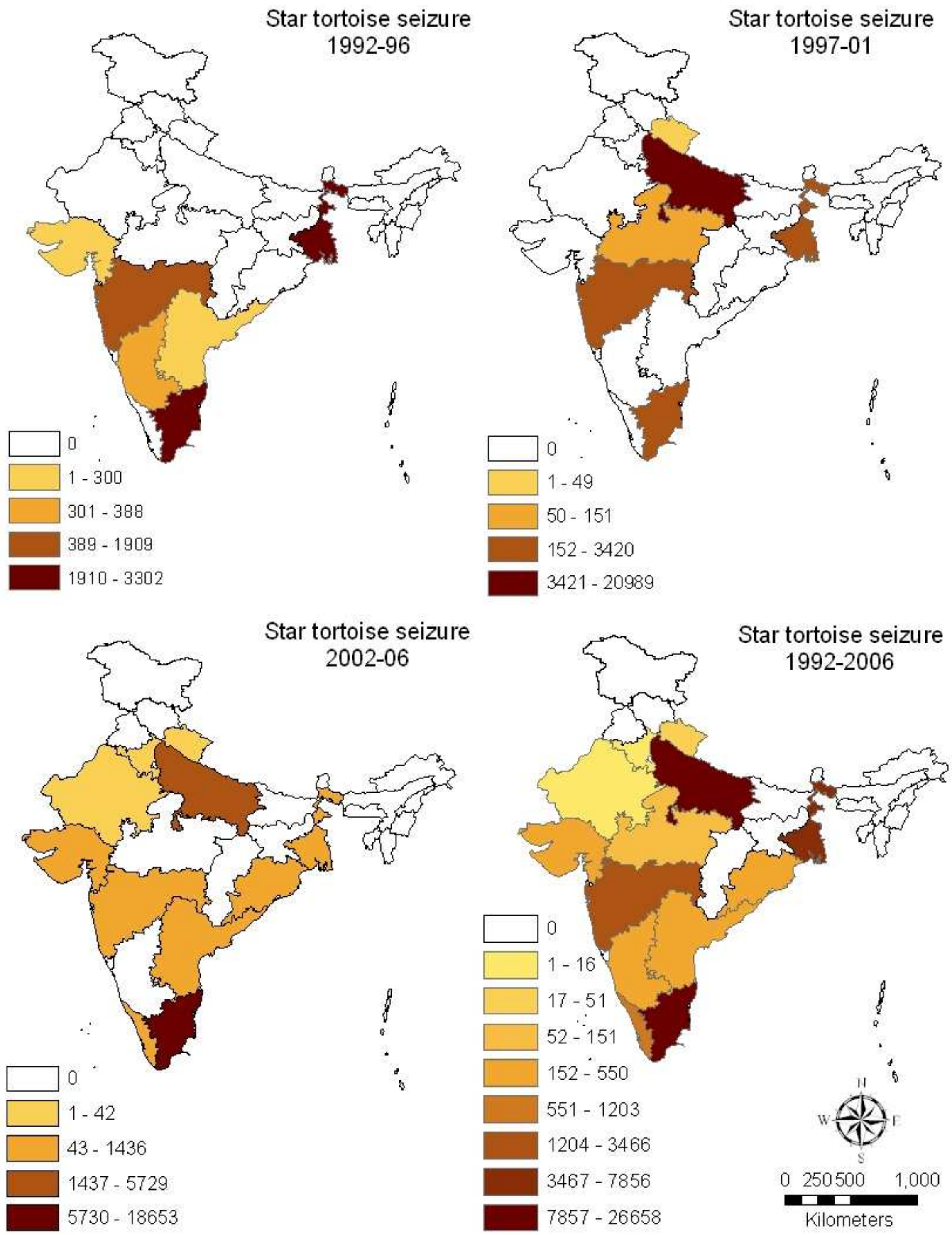
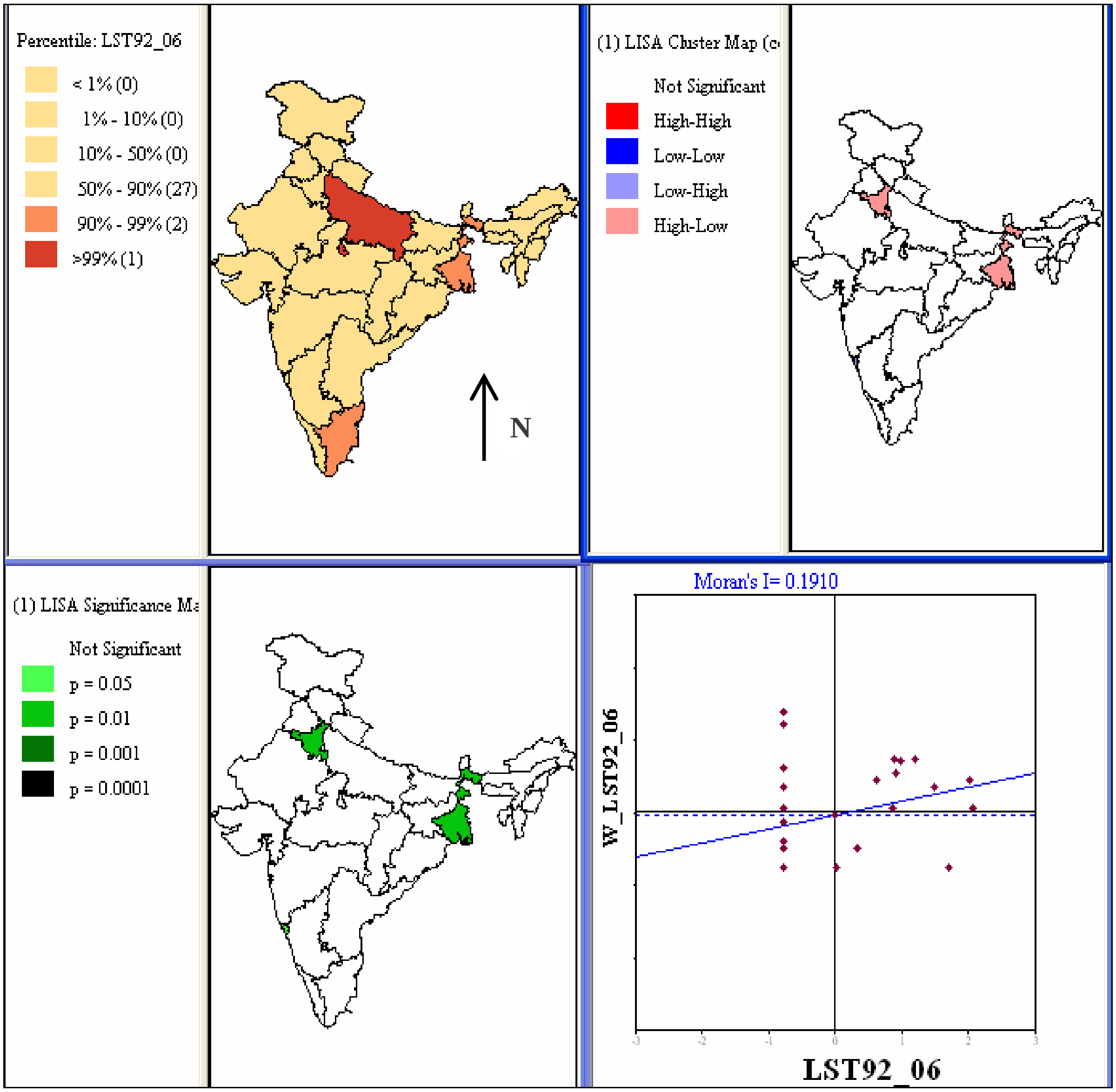


Figure 18. The spatial distribution of star tortoise seizures from India in different time periods between 1992 and 2006. The spread of seizure areas increases between 1992 and 2006.



LST92_06 = the log transformed star tortoise seizures from 1992 to 2006 against its weighted mean.

Figure 19. The percentile and local indicators of spatial association (LISA) cluster and significance map of star tortoise seizures in India from 1992-2006. West Bengal and Haryana show High-low (HL) clusters, whereas Goa and Pondicherry have Low-high (LH) clusters reported at 1% significance level.

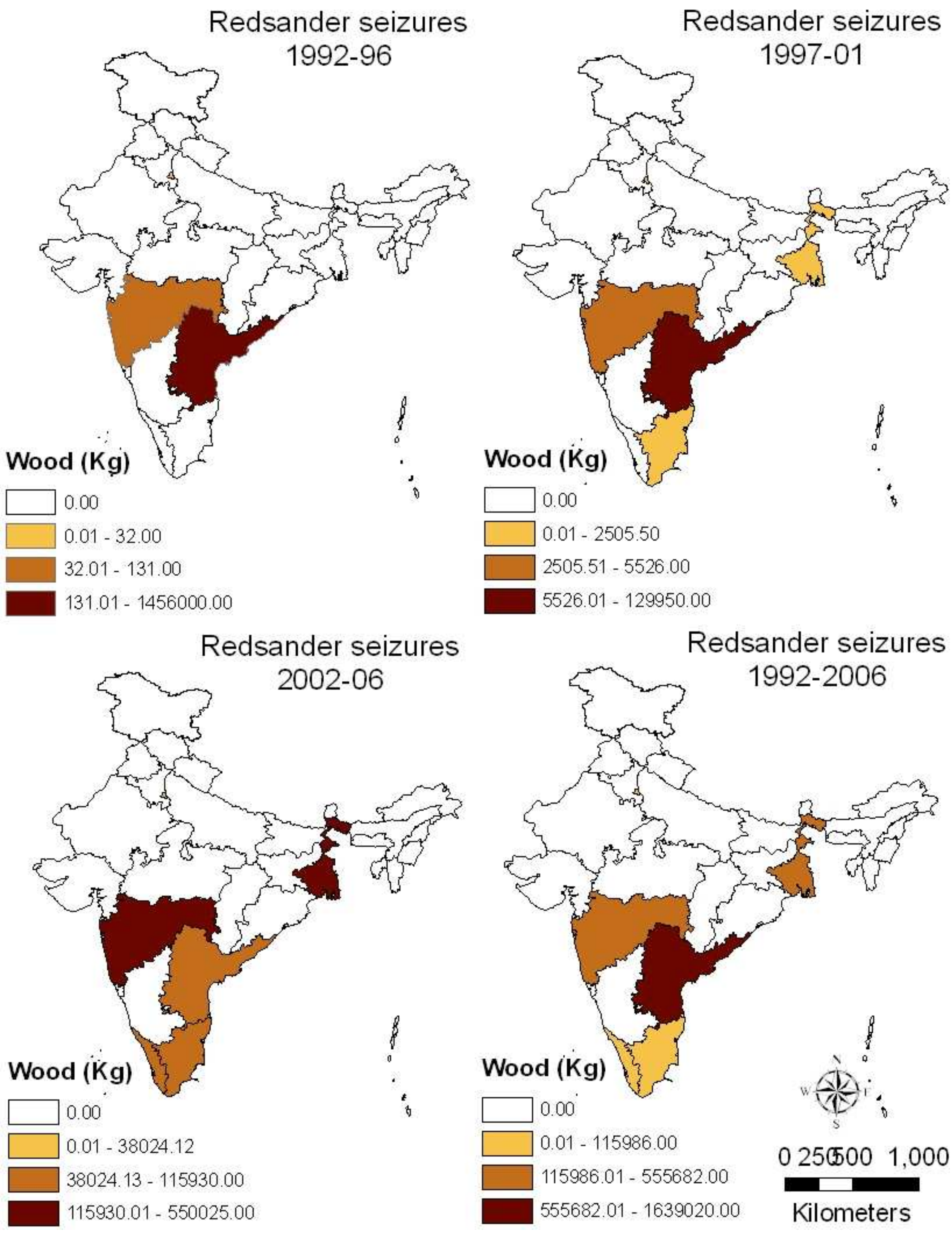
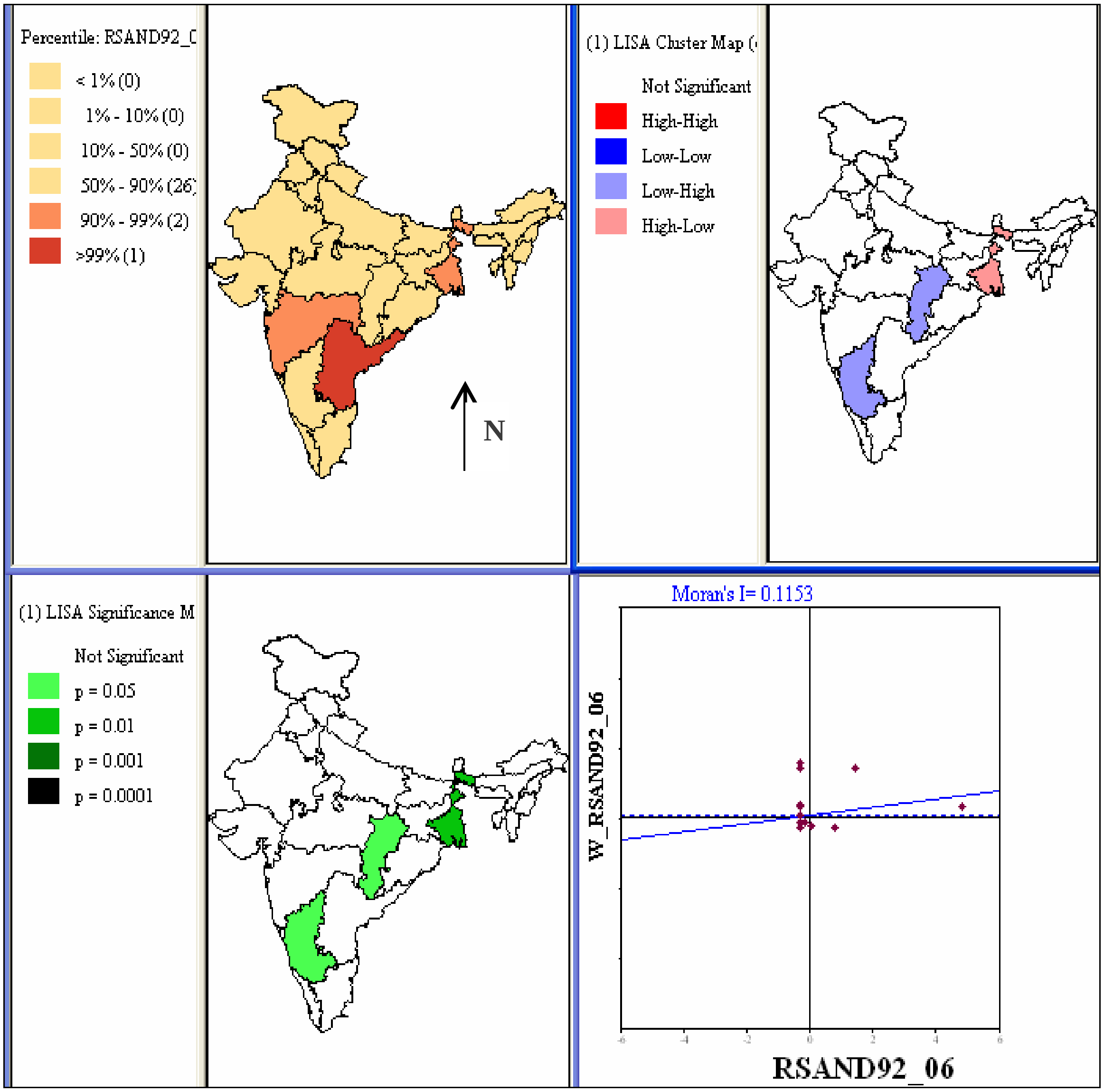


Figure 20. The spatial distribution of red sander seizures from India in different time periods between 1992 and 2006. The spread of seizure areas increases between 1992 and 2006.



RSAND92_06 is the seizures of red sanders from 1992 to 2006 against its weighted mean.

Figure 21. The percentile and local indicators of spatial association (LISA) cluster and significance map of red sander seizures in India from 1992-2006. West Bengal has a High-high (HL) cluster, whereas Chattisgarh and Karnataka have Low-high (LH) clusters at 5% significance level.

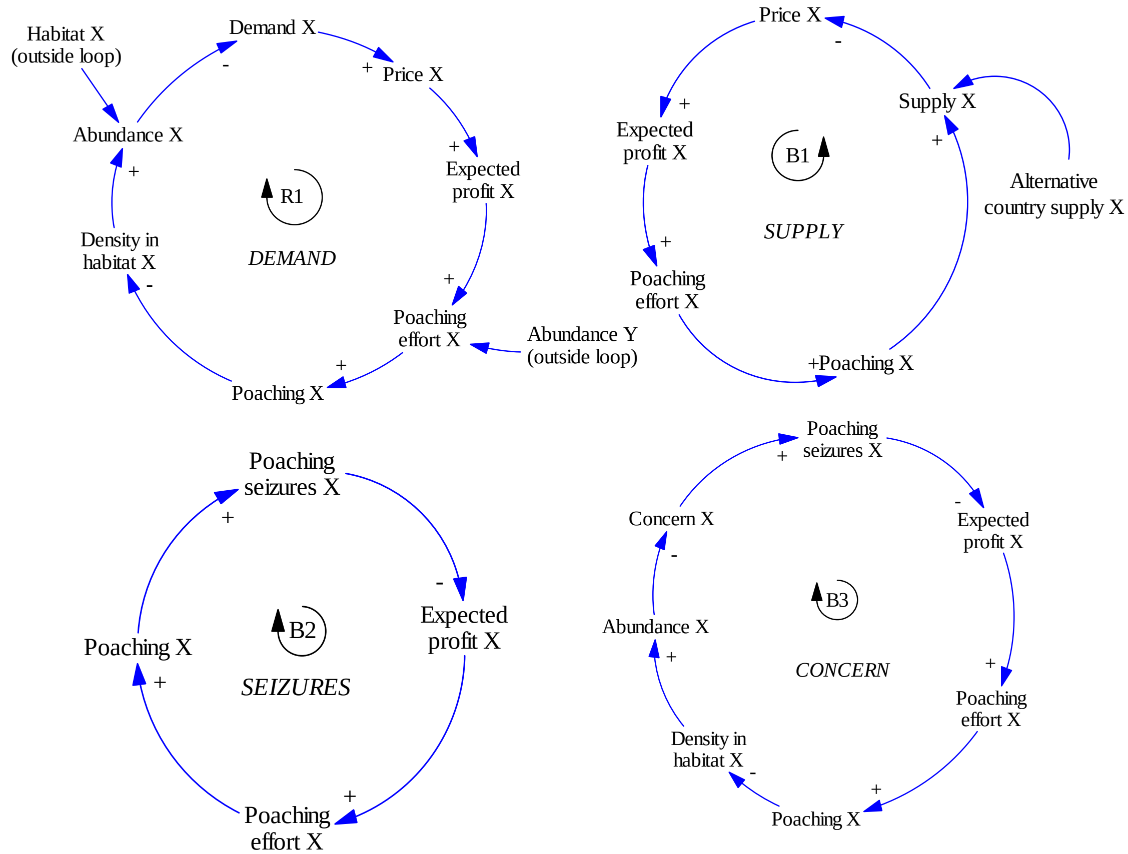


Figure 22. Causal loop diagram of poaching. We identify one reinforcing (R) and three balancing (B) feedback loops, labeled DEMAND, SUPPLY, SEIZURES, AND CONCERN.

APPENDIX 1. Equivalent body parts yielding the number of Indian wildlife poached from 1992-2006.

Species	Indication of 1 animal	Source
Tiger	15 kg bone or 1 skull,18, claws, or 10 teeth 4 paws	Kanha National Park
Leopard	7 kg bone or 1 skull or 18 claws	Kanha National Park
Indian pea fowl	200 tail feathers/bird (500 feathers = 1kg)	Kanha National Park
Spotted deer	≤5 kg antlers = 1 deer	Kanha National Park
Sambar	5.1-10 kg antler = 1 deer	Kanha National Park
Bears	1 gall bladder = 1 bear	Bilaspur Zoological Park
Chiru	125-150 g wool = 1 chiru	Shaller (1998); WPSI 1997
	1 shawl = 375-400 g wool	WPSI (1997)
Mongoose	1 brush = 1 g mongoose hair (without handle)	Yongon (2005)
	1000 brushes/kg mongoose hair	Yongon (2005), WTI (2008)
	50 mongoose / a kg hair	Yongon (2005), WTI (2008)
Musk deer	1 musk pod = 1 deer	Khan et al. (2006)
	25g musk pod = 1 deer	Khan et al. (2006)
Elephant	2 tusks or ≤15 kg = 1 elephant	Mudumalai Wildlife Sanctuary (WS)
	≤13 kg finished ivory or tusk + 10% = 1 elephant	Regional CITES office, Mumbai

Appendix 2. Population and geographical distribution of species reported in illegal trade from India, 2008.

Species	Estimated population (India)	Population trend (IUCN)	Geographical distribution	Habitat sensitive	Man-animal conflict	References
Tiger	1400	D[a]	Sunderbans, Himalayan tracts, Central India, Western ghats, Eastern ghats	Yes	Yes	Mills (1997), Nowell (2000), Wikramanayake et al. 2004, Singh and Goyal (2005)
Leopard	6000-8000	D	Himalayas, Central India, Western and Eastern ghats, dry scrub forests in west	No	Yes	Daniel (1996), Prater (1998), IUCN (2008)
Asian elephant	21000-25000	D	North-east, Himalayas, Western ghats, Semi-evergreen forests	Yes	Yes	Nash (1997), Sukumar (1998), Menon (2002), Stiles (2004)
Great Indian rhinoceros	1800-2000	I[b]	Gangetic and Brahamputra grassland forests in Assam, WB, APR	Yes	No	Mills (1997), Martin (1996), Poudyal and Knowler (2005), IUCN (2008)
Clouded leopard	<1000	D	Upper Himalayas in North and North East	Yes	No	Nowell (2007), IUCN (2008), CITES (2008)

Snow leopard	200-600	D	Upper Himalayas in North and North East	Yes	Yes	Theile (2003), IUCN (2008)
Sloth bear	7000-9000	D	Himalayan tracts, Central India plains, Western ghats, Eastern ghats, Deccan plateau	Yes	Yes	Prater 1971, Chauhan 2006
Brown bear	<1000	NC[c]	Himalayan regions	Yes	Yes	IUCN (2008)
Asiatic black bear	7000-9000	D	North-east forests, Himalayan foothills and middle Himalayas	Yes	No	IUCN (2008), CITES (2008)
Birds (Multiple species)		D	Many different regions	Yes	No	Ali (1996), Ahmad (1997)
Tibetan antelope	<75000	D	Tibetan Plateau, Chinese plains, Laddakh regions	Yes	No	Prater (1971), Fox et al. 1991,WPSI (1997), Shaller (1998)
Deer (multiple species)	UD[d]	D	Many different regions	No	No	Prater (1998), Karanth and Stith (1999)

Blackbuck	<10000	I	Semi-arid regions in Gujarat, Rajasthan. Grassland forests in MP, coastal	No	No	Rahmani (2001)
Snakes	UD	D	Many different regions	No	No	Jekkins and Broad (1994), Bhupathy (1999)
Turtles and tortoises (Multiple species)	UD	I	Gangetic delta, Brahamputra flood plains, Western ghats, reverine plains of east coast	Yes	No	Choudhury and Bhupathy (1993), Van Dijk et al. (2000)
Star tortoise	UD	D	Northern plains, Coastal regions in west, east and south	No	No	Choudhury and Bhupathy (1993), Shepherd et al. (2004)
Otters (Multiple species)	UD	D	Himalayas and hills of Western ghats in south India, North east India	Yes	No	Foster-Turley and Santiapillai 1990, Hussain (1999)
Mongoose (Multiple species)	UD	NC	Throughout North, Peninsular India, West and South India	No	No	Santiapillai et al. (2000), Yonzon (2005) IUCN (2008)

Species (Flora)						
Red sanders	UD	D	Southern part of the Eastern ghats	NA	NA	FRLHT (1995), Manjuanth (2006), CAMP Workshop (2007)
Kuth root	UD	D	Higher elevation in Himalayan tracts in J&K, HP and Uttaranchal states	NA	NA	Siddiqui et al. 1995, Kuniyal et al. (2005)
Agarwood	UD	D	Hilly tracts of North Eastern states	NA	NA	Chakrabarty et al. (1994), Barden et al. (2000)

[a]Decreasing

[b]Increasing

[c]Undetermined

[d]No change

[e]Not applicable

[f]Arunachal Pradesh

[g]Himachal Pradesh

[h]Jammu and Kashmir

[i]Madhya Pradesh

[g]West Bengal

APPENDIX 3. Trade features of Species in illegal wildlife trade from India, 2008.

Species	Destination	Specimen	End use	Estimated Price (US$)-parts and whole[a]	Historical trade[b]
Tiger	China, Thailand, Hong Kong, Taiwan,USA, South Korea	Skin, bone, skull, hair, teeth, claws	TCM[c], trophies, pets, aphrodisiacs	25,000-60,000	Yes
Leopard	China, Hong Kong, Thailand, Singapore, African countries	Skin, bone, skull, hair, teeth, claws	TCM, trophies, sport hunting, religious functions	250-3,000	Yes
Elephant	Japan, China, Thailand, Singapore, Philippines, EC, USA	Tusk, ivory, meat, teeth, tail hair	Japanese henko, artifacts, wedding bangles, trophies, medicines	Henko -25-580 Worked ivory (1,000-1,300)	Yes
Indian rhinoceros	Yemen, Hong Kong, China, South Korea, Japan	Horn, skin	Dagger in Middle East, TCM, aphrodisiac	40,000-60,000	Yes
Clouded leopard	EC, USA, Japan, China, Indonesia, Singapore	Skin, bone, skull, teeth, claw	Winter clothing, trophies, TCM		No
Snow leopard	China, Indonesia, EC, Hong Kong, USA, Singapore	Skin, bone, skull, claw, meat	Winter clothing, trophies, TCM, religious functions	100-10,000	No
Bears	China, India, Thailand, Indonesia	Skin, bile, cub, claws, bone, teeth, fat	Aphrodisiac, medicinal, trophies, display, local sell	20-100	Yes
Birds	EC, USA, India, Pakistan, China, Malaysia,	Live, feather	Pet, food, trophies, religious	1-10,000	Yes

Species	Destination	Specimen	End use	Estimated Price (US$)-parts and whole[a]	Historical trade[b]
	Singapore				
Tibetan antelope	USA, UK, France, Germany, Switzerland, Australia, Hong Kong, Thailand, India	Wool, hair, skin	Shawls, hair, trophies	800-4,000	Yes
Deer	India, Europe, USA, China	Skin, meat, antler	Medicinal, buttons, food, trophies	40-100	Yes
Blackbuck	India	Skin, horn	Trophy	50-200	No
Snakes	Western Europe, North America, Hong Kong, Singapore, Japan, Taiwan	Skin, live	Clothing, wallet, belt, purse, boots	5-100 / piece	Yes
Turtles and tortoises	Western Europe, Japan, USA, Hong Kong, Thailand, Singapore, Taiwan	Skin, carapace, shell, meat, live	Food, decorative, medicinal, clothing, purse, boots, straps	10-500 / piece	Yes
Star tortoise	East Asia, Malaysia, Singapore, USA, EC	Live	Pet, food	200-400	No
Otter	China, Russia, EC, USA, Hong Kong	Skin, fur	Coat, jacket, Tibetan chupas	90-100	Yes
Mongoose	India, Europe, Hong Kong	Fur, skin	Paint brush, trophy	2-10	No
Shells	India, Europe, Hong Kong, Japan, Korea,	Shell, powder, carapace	Ornamental, food, jewelry, medicinal,	1-10,000	Yes

Species	Destination	Specimen	End use	Estimated Price (US$)-parts and whole[a]	Historical trade[b]
	USA		religious		
Red sanders	Japan, China, Malaysia, USA	Wood, bark, extract	Food coloration, dye, furniture, musical instrument , medicinal	10-50/kg	Yes
Kuth root	EC, China	Root, bark, extract	Medicinal	10-20/kg	Yes
Agarwood	Middle east Asia, China, Japan, South Korea, Singapore	Bark, extract, Oil	Perfumery, medicinal	Wood 800-1200/kg oil 50000-80000/liter	Yes

APPENDIX 4. Legal protection to different wildlife species found in illegal trade from India in 2008.

Species	Wildlife Protection Act 1972, year	CITES[a] Appendix, year	IUCN[b] category	Special conservation effort, year
Tiger	SCH[c]1, 1973	APP[d]1, 1975	EN[e]	Project tiger 1973, Global Tiger Forum, WWF Initiatives, UN Program
Leopard	SCH1	APP1, 1975	LR[f], 2002 LR, 1996 TH[g], 1990	None
Asian elephant	SCH1, 1977	APP1, 1975	EN	Project Elephant, MIKE[j] of CITES
Great Indian rhinoceros	SCH1	APP1, 1975	Vu[h]	Asian Rhino Vision 2020, Conservation Program of Assam Government, IUCN-WWF Initiatives
Clouded leopard		APP1, 1975	VU	None
Snow leopard	SCH1, 1973	APP1, 1975	EN	None
Sloth bear	SCH1, 1973	APP3, 1988 APP1, 1990	VU	None
Brown bear	SCH1, 1973	APP 1, APP2	LR	None
Asiatic black bear	NL[i]	APP1, 1979	VU	None

APPENDIX 4. Cont.

Species	Wildlife Protection Act 1972, year	CITES[a] Appendix, year	IUCN[b] category	Special conservation effort, year
Birds	SCH1 SCH2 SCH4	APP1 APP2 APP3	NR, VR, LR, NL	None
Tibetan antelope	SCH1	APP2, 1975 APP1, 1979	EN	EEC Initiatives
Sambar	SCH3		LR, 1996 VU, 2008	None
Blackbuck	SCH1, 1972	APP3 (Nepal) 1975	VU, 1993 NT, 2003	None
Snakes	SCH 1 SCH 2 SCH 4	APP1, 1975 APP2 APP3	VU NT LR	None
Turtles and tortoises	SCH 1 SCH 2 SCH 4	APP1 APP2	VU NT LR	None
Star tortoise	SCH4, 1980	APP2, 1975	LC	None
Otter	SCH1, 1972 SCH2, 1977	APP1, 1977	NT, 2004 VU, 2000 LR, 1996	None
Smooth-coated otter	SCH2, 1977	APP2 1977	VU	None
Asian Small-clawed Otter	SCH1, 1972	APP2, 1977	NT, 2004 LR, 2000	None
Asian small mongoose	<2002, NL SCH2, 2002	APP3 (India) 1989	NT, 2004 VU, 2008	None
Striped-necked mongoose	<2002, NL SCH2, 2002		LC	None
Indian grey mongoose	<2002, NL SCH2, 2002	APP3 (India) 1989	LC	None

APPENDIX 4. Cont.

Species	Wildlife Protection Act 1972, year	CITES[a] Appendix, year	IUCN[b] category	Special conservation effort, year
Indian grey mongoose	<2002, NL SCH2, 2002	APP3 (India) 1989	LC	None
Shells	SCH1, SCH4 2000	APP1, APP2 APP3 1985- 2004	VU, TH, LR	None
Species (Flora)				
Red sander	NL	APP2, 1995	EN	None
Kuth root	SCH6, 1991	APP2, 1975 APP1, 1985		None
Agarwood	NL	APP2, 1995	VU, 1998	None

[a]Convention of International Trade in Endangered Species of Wild Fauna and Flora.

[b]World Conservation Union (IUCN).

[c]schedule of Wildlife Protection Act 1972.

[d]appendix to CITES.

[e]endangered.

[f]lower risk.

[g]threatened.

[h]vulnerable.

[i]not listed.

[j]Monitoring of Illegal killing of Elephant.

Appendix 5. Repeated measures ANOVA with time and border interactive effects. The *F* values are reported at the 95% significance level. Border states included the nested states of Haryana and Delhi.

Species	Model			Border			Time			Time*Border		
	DF	*F*	*P*	DF	*F*	*P*	DF	*F*	*P*	DF	*F*	*P*
Star tortoise	38, 66	5.64	<0.001	1,66	1.00	0.32	2, 66	2.10	0.13	2, 66	1.63	0.20
Snake skins	38, 66	6.40	<0.001	1,66	0.09	0.76	2, 66	1.03	0.36	2, 66	1.81	0.17
Snake equivalent	38, 66	1.05	0.424	1,66	0.16	0.70	2, 66	2.89	0.06	2, 66	0.17	0.85
Red sander	38, 66	6.64	<0.001	1,66	0.23	0.64	2, 66	2.38	0.10	2, 66	3.53	0.04
Birds	38, 66	4.25	<0.001	1,66	0.00	0.98	2, 66	0.59	0.56	2, 66	2.12	0.13
Deer antler (no)	38, 66	1.97	0.007	1,66	0.05	0.82	2, 66	2.30	0.11	2, 66	0.31	0.74
Deer antler (kg)	38, 66	4.44	<0.001	1,66	0.72	0.40	2, 66	1.05	0.36	2, 66	0.25	0.78
Deer equivalent	38, 66	3.81	<0.001	1,66	0.01	0.94	2, 66	2.28	0.11	2, 66	0.43	0.65
Leopard skin	38, 66	5.40	<0.001	1,66	2.35	0.14	2, 66	0.86	0.43	2, 66	0.06	0.94
Leopard bone	38, 66	2.90	<0.001	1,66	0.51	0.48	2, 66	1.35	0.27	2, 66	2.10	0.13
Leopard claw	38, 66	2.74	<0.001	1,66	0.00	0.95	2, 66	2.29	0.11	2, 66	0.60	0.55
Leopard equiv.	38, 66	6.09	<0.001	1,66	1.06	0.31	2, 66	7.18	0.00	2, 66	0.24	0.78
Elephant	38, 66	26.20	<0.001	1,66	0.06	0.81	2, 66	12.73	<0.01	2, 66	0.46	0.63
Elephant tusk	38, 66	5.45	<0.001	1,66	0.05	0.82	2, 66	7.48	0.00	2, 66	1.20	0.31
Elephant ivory	38, 66	1.30	0.171	1,66	3.79	0.06	2, 66	1.02	0.37	2, 66	1.20	0.31
Elephant equiv.	38, 66	10.02	<0.001	1,66	0.29	0.59	2, 66	1.39	0.26	2, 66	1.05	0.36
Tiger skin	38, 66	4.82	<0.001	1,66	0.17	0.68	2, 66	3.31	0.04	2, 66	0.96	0.39

APPENDIX 5. Cont.

Species	Model			Border			Time			Time*Border		
	DF	*F*	*P*	DF	*F*	*P*	DF	*F*	*P*	DF	*F*	*P*
Tiger bone	38, 66	3.17	<0.001	1,66	0.50	0.49	2, 66	3.29	0.04	2, 66	1.09	0.34
Tiger equivalent	38, 66	10.28	<0.001	1,66	0.32	0.57	2, 66	1.21	0.30	2, 66	1.04	0.36

APPENDIX 6. Spatial mean, standard deviation and t statistics for the seizures of species in India between the time periods 1992-1996, 1997-2001, and 2002-2006. The results are reported at the 95% confidence intervals.

	1992-96				1997-01				2002-06				
Species	Mean (border)	Mean (non-border)	t	P	Mean (border)	Mean (non-border)	t	P	Mean (border)	Mean (non-border)	t	P	DF
Leopard skin	23.05	5.17	1.53	0.06	31.61	9.35	1.33	0.09	31.77	12.88	1.19	0.11	33.00
Leopard bone	0.00	3.05	-1.02	0.15	12.16	2.05	1.01	0.15	3.38	0.35	1.37	0.08	33.00
Leopard claw	0.00	0.70	-1.02	0.15	100.11	0.88	0.96	0.17	12.05	9.64	0.17	0.43	33.00
Leopard eq[b]	23.33	7.00	1.37	0.08	93.66	14.23	1.15	0.12	39.77	18.11	1.25	0.10	33.00
Tiger skin	4.27	3.64	0.63	0.26	9.88	5.82	0.82	0.20	3.61	4.23	-0.30	0.38	33.00
Tiger bone	31.44	6.82	0.84	0.20	57.11	0.58	1.26	0.10	1.55	0.41	0.82	0.20	33.00
Tiger eq	9.16	6.17	0.87	0.19	16.44	10.23	0.72	0.23	7.72	6.82	0.24	0.40	33.00
Elephant body	6.66	10.76	-0.67	0.25	7.61	9.52	-0.34	0.36	7.61	7.94	0.13	0.44	33.00
Elephant ivory (kg)	34.78	38.42	0.34	0.36	90.88	41.20	0.88	0.19	29.10	19.50	-0.46	0.32	33.00
Elephant ivory (no)	0.44	0.82	-0.18	0.42	0.05	10.64	-1.46	0.07	0.05	6.64	-1.94	0.03	33.00
Elephant tusk	5.38	1.00	1.08	0.14	7.88	6.35	0.30	0.38	6.55	11.17	-0.87	0.19	33.00
Elephnat eq	12.33	14.05	0.60	0.27	22.05	16.47	0.89	0.18	13.50	17.41	-0.40	0.34	0.33
Deer	0.83	2.41	-0.94	0.17	2.44	7.41	-1.90	0.03	6.72	13.11	-1.04	0.15	33.00
Deer skin	2.72	4.52	-0.54	0.29	14.50	2.82	0.82	0.20	2.38	5.64	-0.93	0.17	33.00
Deer antler (no)	4.61	1.23	0.97	0.16	22.27	4.64	0.94	0.17	10.66	19.58	-0.53	0.29	33.00
Deer antler (kg)	58.55	77.05	-0.75	0.22	280.18	1716.52	-1.28	0.10	21.22	427.29	-1.01	0.15	33.00
Deer eq	28.27	22.47	0.23	0.40	78.00	341.88	-	-1.15	22.61	106.29	-1.04	0.15	33.00
Star tortoise	183.33	343.00	-0.92	0.18	1356.55	229.23	-0.92	0.18	415.16	1255.00	-0.75	0.22	33.00
[a]Star tortoise	447.94	38.75	1.54	0.06	1482.31	9.43	1.67	0.05	1485.42	36.52	1.32	0.09	33.00
Snake skin	1007.67	3955.35	-0.45	0.32	231.27	135.35	0.73	0.23	16.05	5525.25	-1.55	0.06	33.00
Snake eq	1017.66	4364.88	-0.85	0.19	245.83	157.35	0.35	0.36	17.11	5547.70	-1.55	0.06	33.00
Birds	324.72	1360.11	-1.04	0.15	1092.22	1014.82	-0.57	0.28	666.44	11.17	1.51	0.06	33.00
Red sander	1.77	85654.76	-1.03	0.15	139.82	7972.47	-1.05	0.14	19168.61	44637.00	-1.18	0.12	33.00

[a]States with international airports included in border states category.

[b]Equivalent unit was computed based on the measurements of the parts and derivatives.

APPENDIX 7. Mean seizures per state, standard deviation, and t statistics for the difference of means between the time periods 1992-1996, 1997-2001, and 2002-2006 in India. The results are reported at 95% confidence interval for the paired t-test.

Species	Mean 1992-96	SD	Mean 1997-01	SD	*t* (Period1-Period2)[a]	*P*	Mean 2002-06	SD	*t* (Period1-Period3)[a]	*P*	DF
Leopard skin	14.37	34.67	20.80	49.28	-1.71	0.04	22.60	46.50	-2.47	0.01	34.00
Leopard bone	1.48	8.66	7.25	29.00	-1.54	0.06	1.91	6.88	-1.08	0.14	34.00
Leopard claw	0.34	1.99	51.91	300.14	-1.02	0.15	10.88	39.33	-1.99	0.02	34.00
Leopard equivalent	15.40	35.12	55.08	213.27	-2.87	<0.01	29.25	50.84	-3.01	<0.01	34.00
Tiger skin	3.97	8.39	7.91	16.39	-2.01	0.02	3.91	5.84	-0.57	0.28	34.00
Tiger bone	19.48	84.84	29.65	166.11	-0.33	0.37	1.00	4.00	-2.05	0.02	34.00
Tiger equivalent	7.71	16.96	13.42	29.19	-1.48	0.07	7.28	10.66	-0.76	0.22	34.00
Elephant body	8.65	17.67	8.54	16.04	5.39	<0.01	7.77	16.67	3.98	<0.01	34.00
Elephant ivory (kg)	36.55	93.98	66.75	193.79	-0.99	0.16	24.44	68.99	0.73	0.23	34.00
Elephant Ivory (no)	0.62	2.65	5.20	21.36	-1.35	0.09	3.25	12.74	-1.16	0.12	34.00
Elephant tusk (no)	3.25	11.82	7.14	14.70	-2.95	<0.01	8.80	15.32	-2.94	<0.01	34.00
Elephant equivalent	13.17	22.21	19.34	32.70	-1.59	0.05	15.40	28.00	-1.09	0.14	34.00
Deer body (no)	3.60	9.63	8.82	41.20	-2.37	0.01	3.97	10.09	-3.37	<0.01	34.00
Deer skin (no)	1.60	4.87	4.85	11.91	0.79	0.21	9.82	22.18	-1.07	0.14	34.00
Deer antler (no)	2.97	10.05	13.71	54.52	-1.12	0.13	15.00	47.97	-2.02	0.02	34.00
Deer antler (kg)	67.54	193.08	977.83	3284.67	-1.65	0.05	218.45	1166.26	0.80	0.21	34.00
Deer equivalent (no)	25.45	71.93	206.17	668.77	-1.63	0.05	63.25	233.44	-2.11	0.02	34.00
Snake skin	2439.40	10818.63	184.68	640.86	1.72	0.04	2692.22	10558.26	0.19	0.42	34.00
Snake equivalent	2643.45	11337.13	207.48	697.22	-1.73	0.04	2703.40	10602.23	-0.02	0.49	34.00
Bird	827.62	2886.97	1054.62	3155.70	-1.01	0.16	348.17	1285.03	-0.41	0.33	34.00
Star tortoise	260.88	783.02	809.00	3541.95	-0.90	0.36	823.08	3214.30	-1.69	0.04	34.00
Red sander	41605	242567	3944.25	21633	-1.59	0.06	31538.97	107487.91	-1.97	0.02	34.00

[a]Period 1 is from 1992-1996, period 2 is from 1997-2001, and Period 3 is from 2002-2006.

APPENDIX 8. Mean seizures per state, standard deviation, and t statistics for the difference of means between the time periods 1992-1996, 1997-2001, and 2002-2006in India. The results are reported at the 95% confidence interval for the paired t-test.

Species	Mean 1992-96	SD	Mean 1997-01	SD	*t* (Period1-Period2)[a]	*P*	Mean 2002-06	SD	*t* (Period1-Period3)[a]	*P*	DF
Leopard skin	14.37	34.67	20.80	49.28	-1.71	0.04	22.60	46.50	-2.47	0.01	34.00
Leopard bone	1.48	8.66	7.25	29.00	-1.54	0.06	1.91	6.88	-1.08	0.14	34.00
Leopard claw	0.34	1.99	51.91	300.14	-1.02	0.15	10.88	39.33	-1.99	0.02	34.00
Leopard equivalent	15.40	35.12	55.08	213.27	-2.87	<0.01	29.25	50.84	-3.01	<0.01	34.00
Tiger skin	3.97	8.39	7.91	16.39	-2.01	0.02	3.91	5.84	-0.57	0.28	34.00
Tiger bone	19.48	84.84	29.65	166.11	-0.33	0.37	1.00	4.00	-2.05	0.02	34.00
Tiger equivalent	7.71	16.96	13.42	29.19	-1.48	0.07	7.28	10.66	-0.76	0.22	34.00
Elephant body	8.65	17.67	8.54	16.04	5.39	<0.01	7.77	16.67	3.98	<0.01	34.00
Elephant ivory (kg)	36.55	93.98	66.75	193.79	-0.99	0.16	24.44	68.99	0.73	0.23	34.00
Elephant Ivory (no)	0.62	2.65	5.20	21.36	-1.35	0.09	3.25	12.74	-1.16	0.12	34.00
Elephant tusk (no)	3.25	11.82	7.14	14.70	-2.95	<0.01	8.80	15.32	-2.94	<0.01	34.00
Elephant equivalent	13.17	22.21	19.34	32.70	-1.59	0.05	15.40	28.00	-1.09	0.14	34.00
Deer body (no)	3.60	9.63	8.82	41.20	-2.37	0.01	3.97	10.09	-3.37	<0.01	34.00
Deer skin (no)	1.60	4.87	4.85	11.91	0.79	0.21	9.82	22.18	-1.07	0.14	34.00
Deer antler (no)	2.97	10.05	13.71	54.52	-1.12	0.13	15.00	47.97	-2.02	0.02	34.00
Deer antler (kg)	67.54	193.08	977.83	3284.67	-1.65	0.05	218.45	1166.26	0.80	0.21	34.00
Deer equivalent (no)	25.45	71.93	206.17	668.77	-1.63	0.05	63.25	233.44	-2.11	0.02	34.00
Snake skin	2439.40	10818.63	184.68	640.86	1.72	0.04	2692.22	10558.26	0.19	0.42	34.00
Snake equivalent	2643.45	11337.13	207.48	697.22	-1.73	0.04	2703.40	10602.23	-0.02	0.49	34.00
Bird	827.62	2886.97	1054.62	3155.70	-1.01	0.16	348.17	1285.03	-0.41	0.33	34.00
Star tortoise	260.88	783.02	809.00	3541.95	-0.90	0.36	823.08	3214.30	-1.69	0.04	34.00
Red sander	41605	242567	3944.25	21633	-1.59	0.06	31538.97	107487.91	-1.97	0.02	34.00

[1]Period 1 is from 1992-1996, period 2 is from 1997-2001, and period 3 is from 2002-2006.

APPENDIX D. DRAFT MANUSCRIPT TO BE SUBMITTED TO THE JOURNAL OF WILDLIFE MANAGEMENT.

NIRAJ, S. K., V. DAYAL, AND P. R. KRAUSMAN. SYSTEMS FRAMEWORK, HISTORICAL LITERATURE REVIEW, AND STATISTICAL ANALYSIS OF WILDLIFE AND THE ECONOMY.

30 January 2009
Shekhar K. Niraj
School of Natural Resources
University of Arizona
Tucson, Arizona 85721
(520) 621-7255; Fax (520) 621-8801; Email shekhar.niraj@gmail.com

RH: Niraj et al.• Economy and the wildlife

SYSTEM FRAMEWORK, HISTORICAL LITERATURE REVIEW, AND STATISTICAL ANALYSIS OF WILDLIFE AND THE ECONMY

SHEKHAR K. NIRAJ[1,2], School of Natural Resources, Biological Sciences East Building, University of Arizona, Tucson, AZ 85721, USA

VIKRAM DAYAL, Institute of Economic Growth, University of Delhi Enclave, North Campus, Delhi 110007, India

P. R. KRAUSMAN[3], School of Natural Resources, 325, Biological Sciences East Building, University of Arizona, Tucson, AZ 85721, USA

ABSTRACT We assess 3 different views of the interactions between the economy and wildlife, namely, (1) ‘economy hurts wildlife’, (2) ‘eroding livelihoods’, and (3) ‘economy is good’. We examine the support for these views in (1) quantitative literature and (2) historical literature related to India. Since the literature shows that all the 3 views

---

[1]Correspornding author e-mail: shekhar.niraj@gmail.com

[2]Present address: Indian Forest Service, Conservator of Forests (Tamil Nadu Afforestation Project 1), 8 D, Panagal Building, 1 Jeenis Road, Saidapet, Chennai 600015, India

[3]Wildlife Biology Program, 32 Campus Drive, University of Montana, Missoula, Montana 59812, USA

of the complex interactions between wildlife and the economy may be valid, we use system dynamics feedback loop diagrams to develop an analytical framework linking different key economic issues to wildlife variables. We then use a cross-country data set to examine the interactions between key economy and wildlife variables in our feedback loop diagrams. Per capita gross domestic product (GDP) was positively correlated with the proportion of birds that were threatened (Coefficient = 0.16, P-value = 0.06). The use of the feedback loop diagrams in our analytical framework combines the insights of different research methods over different spatial and temporal scales, enhancing the emergent understanding of economics and wildlife. This includes the concern with poaching and its relationship with rising demand for illegal wildlife. It also includes the effects on habitat, which are well documented. We also document the effect of concern for preservation, and the effects on rural livelihoods, which are central to the management of wildlife in developing countries. We show that the system has evolved and different mechanisms or feedback loops gain strength or weaken.

KEY WORDS causal loop diagram, economy, Environmental Kuznets Curve, history, livelihood, parks, wildlife

The Journal of Wildlife Management: 00(0): 000-000, 2009

How are the economy and wildlife related in both developed and developing countries? We attempt to explore this question by identifying 3 distinct views, which we call (1) ‘economy hurts wildlife’, (2) ‘eroding livelihoods’, and (3) ‘economy is good’. In the ‘economy hurts wildlife’ view the expanding economy fragments landscapes, increases human greed and destroys wildlife. In the ‘eroding livelihoods’ view, wildlife preservation results in restrictions on the livelihoods of those who live close to protected areas in developing countries. In the ‘economy is good’ view as incomes rise people will demand more wilderness, contribute to the preservation of charismatic megafauna, and, in developing countries, have alternative, non-biomass based livelihoods.

A varied literature on different aspects of the wildlife-economy relationship exists. Careful studies lend credence to each of the 3 views—Czech et al. (2000) to the economy harms wildlife view, Murty (1996) and Kramer et al. (1994) to the eroding livelihoods view, Pergams et al. (2004) and Damania et al. (2003) to the economy is good view. Czech et al. (2000: 599) note how “the causes of species endangerment tend to correspond to various economic sectors, especially agriculture, mining, logging, ranching, outdoor recreation and tourism, and wild species harvest.” Moreover, they show that these causes of endangerment are associated with each other. A substantial share of the costs of national park (NP) in developing countries may be borne by locals who face restrictions on the use of natural resources (Murty 1996, and Kramer et al. 1994). Growth rates of cumulative revenues to several large conservation organizations were significantly correlated with growth of GDP in the United States of America (Pergams et al. 2004). “An increase in the wages paid for off-farm work lowers poaching effort” was established by Damania et al. (2003: 203).

These 3 different views might all be valid, because the interactions between wildlife and the economy are complex, and evolving. We attempt to develop a more nuanced, and inclusive, perspective of the relation between economic activity and wildlife. We develop a ‘systems’ framework using systems dynamics feedback loop diagrams. “A system is usually defined as a combination of 2 or more elements that are interconnected for some purpose. A bicycle, a car, and a bus are all systems for transportation. And at a larger scale, the collection of freeways, surface streets, and vehicles in an urban area is a system. The distinguishing feature of a system is the impression that the whole is more than the sum of the parts" Ford (1999: 12). For each of the 3 broad views of economy and wildlife we develop dynamic feedback loop diagrams. This includes the concern with poaching and its relationship with rising demand. It also includes the effects on the habitat that is well documented. We also document the effect of concern for preservation, and the effects on rural livelihoods, which are central to the management of wildlife in developing countries. We also show that the system has evolved, meaning that different mechanisms or feedback loops gain strength or weaken.

Methodological pluralism is important (Norgaard 1989). If a system is complex, then 1 method may be insufficient to gain insight into its workings. Ford (1999) encourages the use of different types of information, (e.g., physical science, secondary data, written records, interviews) for understanding complex systems. In the system (i.e., wildlife and economics) we are studying, using statistical analysis is circumscribed by the limited data available. Nevertheless, we also use cross-country data, for that gives us data on GDP (i.e., a measure of economic activity of a country) for several cases, and a large sample. However, the data are available only for recent decades. Moreover, no cross-country data on poaching exists. Therefore, we also review historical literature for India, which go far into the past for us to see how the wildlife economy system evolved in India.

Literature Review: Historical Narratives from India

We draw on a review of literature to examine the historical evolution of interactions between wildlife and the economy in India, and to see how they support the 3 views we have outlined above, drawing on the detailed account by Rangarajan (2006)[1] supplemented by Galster and Eliot (1999), Hemley and Mills (1999), Karanth (1999), Kumar and Wright (1999), Sunquist et al. (1999), and The Energy and Resources Institute (TERI; 1998).

'ECONOMY HURTS WILDLIFE'.—We see that the expansion of the economy especially in its early stages of development reduces habitat and has direct adverse effects. In the 1870s 20,000 animals were killed every year in British India (Rangarajan 2006). The killing of wild animals was associated with land cleared for agricultural expansion (Rangarajan 2006). In British India, in general, areas under agriculture increased and wildlife habitat decreased. The growth of crops (e.g., tea) cultivated in plantations in the hills of Assam reduced habitat. Land cover began to fall into 2 distinct compartments: forest and farm, instead of a less distinct overlapping spectrum from forest to cultivated patches (Rangarajan 2006).

In post-independence India, agricultural production was a priority. DDT and other pesticides helped control malaria and extend agriculture to the hills in the south and the tarai grasslands in the north (Rangarajan 2006). The Indian government's policy between 1947 and 1955, of increasing food production, led to a large number of non-tribal people from surrounding areas settling in Nagarhole NP low-lying grassy swamps (Karanth 1999). The Union government provided a subsidy for killing wild boar (Sus scrofa) and nilgai (*Boselaphus tragocamelus*), key tiger (*Panthera tigris*) prey, to protect crops. Officials were instructed to clear land on the sides of roads (Rangarajan 2006). Gross cropped area in India increased from 132 million ha in 1950-1951 to 185 million ha in

---

[1]Rangarajan (2006) is a book that studies India's wildlife history in detail using the methods of environmental history, and drawing on different kinds of written documents and records.

1990-1991 (TERI 1998). Between 1951 and 1995, about 4.7 million ha of forest land were diverted to other users (TERI 1998). The livestock population in India increased from 292 million in 1950 to 445 million in 1987 (TERI 1998).

Apart from habitat requirements of the economy under British rule, initially hunting was actively rewarded. The British were the first rulers of India to try to exterminate species. Within 2 decades of the Battle of Palashi in 1757 they introduced a reward for the tiger (Rangarajan 2006). This was distinct from poaching, because at this time the tiger was seen as a pest, and its destruction was legally encouraged. The tiger preyed on cattle, and more draught cattle would mean greater cultivation and revenue. Between 1875 and 1925 about 80,000 tigers, 150,000 leopards (*Panthera pardus*) and 200,000 wolves (*Canis lupus*) were killed; and these were kills for which rewards were handed out officially (Rangarajan 2006).

The economy is associated with demand for poaching. Demand would lead to poaching before and after independence in 1947. By the 1930s rhinoceros (*Rhinoceros unicornis*) horn was expensive enough to induce poaching in Kaziranga, an area set aside for protection in 1908 (Rangarajan 2006). Although officials initially denied it, in the face of sustained public pressure they finally accepted, in mid-1992, that poaching had occurred on a large scale in Ranthambhore NP. Poaching had been supplying a new source of demand for Indian poachers: tiger-based medicine (Rangarajan 2006).

‘ERODING LIVELIHOODS’.—Parks, and their historic predecessors, hunting grounds of royalty, were associated with restrictions on grazing and gathering of fuelwood and fodder by villagers. In some areas set aside for wildlife, Indian royalty decreed the banning of cattle grazing (Rangarajan 2006). Relocation of villagers from core areas in the

1970s was conducted in Kanha, Ranthambhore, and Gir protected area (PA). Relocation was often hasty and poorly planned, inflicting considerable costs on those relocated. Alternative sources of fodder, fuelwood, or income generating activities were not found and rural livelihoods suffered (Rangarajan 2006). In the 1980s physical clashes between local people and authorities were reported in 20% of the PAs. India had no mechanisms through which local people could share benefits of the PA (Rangarajan 2006).

In 1955, the northern part of Nagarhole NP was notified as a 'Game Sanctuary' in which hunting of large mammals was legally prohibited. In 1976, Nagarhole was declared a NP. A core zone of 200 km^2 with the ban on both forestry and tourism was set up in 1982 (Karanth 1999). In Kanha Tiger Reserve (TR), the relocation of villages improved habitat for tiger prey, and thereby, for the tiger (Sunquist et al.1999).

Poachers are, generally, villagers who live near the forest and have a close knowledge of wildlife (Kumar and Wright 1999). Often, villagers poison the carcasses of livestock killed by predators, to get rid of them. They may be contacted by agents of poaching networks who give them an additional incentive of money (Kumar and Wright 1999).

'ECONOMY IS GOOD'.— In the 'economy is good' view as incomes rise people will demand more wilderness, contribute to the preservation of charismatic megafauna, and, in developing countries, have alternative, non-biomass based livelihoods. To sustain the base for trophy hunting, Indian royalty (the wealthiest Indians) started protecting some areas (Rangarajan 2006). The present last remaining habitat of the Asiatic lion was first given protection by the royal family of Junagadh (Rangarajan 2006). Kaziranga was set aside for the 1 horned-rhinoceros along the Brahmaputra in 1908. One possible reason that helped setting up this sanctuary was economic: Kaziranga had little timber, and hence low market value, because the river flooded every year (Rangarajan 2006). India's first NP, now Corbett NP, was created in 1935. It was carved out of Reserved Forests (RFs), and while shooting was banned, timber felling was not (Rangarajan 2006).

In the late 1960s concern for the tiger grew. The Prime Minister of India, Indira Gandhi, strongly supported conservation. The World Wildlife Fund was a major catalyst for conservation and changing attitudes (Rangarajan 2006). By the end of the 1990s, various non-government organizations were providing close to 2 million dollars (US) to supplement official efforts to control poaching (Rangarajan 2006). As noted previously, growth rates of cumulative revenues to several large conservation organizations were significantly correlated with growth of GDP in the United States of America (Pergams et al. 2004).

The Wildlife Conservation Act (WPA) was passed in 1972. The huge Project Tiger (PT) project was launched in April 1973. The 9 initial TRs were either old hunting grounds of Indian royal families or RFs from the days of the British Raj (Rangarajan 2006). It is estimated that conservation interventions have increased the number of tigers in Nagarhole NP from 15 in the 1970s to about 50 in the late 1990s. This is attributed to the reduced hunting pressure and the improved habitat conditions that increased tiger prey density in Nagarhole NP (Karanth 1999).

Providing livelihoods to villagers can foster conservation. In Bastar, central India, tribal villagers, who would have lost their livelihood, got together with wildlife biologists to oppose the Bodhghat Dam (Rangarajan 2006). In the Biligiri Rangan Hills of Karnataka, successful cooperative ventures for livelihood of Soligas were established in partnership with scientists and foresters (Rangarajan 2006). The successive restrictions in Nagarhole NP reduced livelihood opportunities for tribals in Nagarhole, but a boom in the coffee plantations adjoining the park provided an alternative (Karanth 1999).

However, it is incorrect to see conservation sentiment only being a result of rising incomes. Several traditional societies historically protected certain areas and species. However, culture varied from place to place, some encouraging protection, others, consumption. While the grey langur (*Semnopithecus* spp**.**) was safe in North India for religious reasons, the Nilgiri langur (*Presbytis johni*), found in certain hills in south India, was killed because its meat was believed to possess medicinal properties (Rangarajan 2006). Perhaps the best known traditional protectors are the Bishnoi community that continues to fiercely guard antelopes to this day (Rangarajan 2006).

Increased financial resources from taxes in a growing economy can enhance poaching control, and reduce illegal wildlife trade. When 400 kg of tiger bones were seized in 1993, there was a strong negative effect, at least temporarily, on the wildlife trade from Ladakh to Tibet (Kumar and Wright 1999).

METHODS

We first develop a conceptual framework using causal loop diagrams. We then analyze quantitative cross-country data for 2004, using bivariate quantile regressions to see what interactions between wildlife and the economy can be discerned.

Causal Loop Diagram

Causal loop diagrams are useful tools to explain dynamics. They show the structure of the relationship between variables (Sterman 2000). In a causal loop diagram, different variables are connected by arrows showing the direction of influence from one variable to another. Each arrow shows a causal link. For example, x → y, implies that x is one of the determinants of y. If the arrow is shown with a positive sign it shows that if the cause increases, the effect increases above what it would otherwise have been (Sterman 2000).

Morecroft (2007) provides an example (Fig. 1) of a simple causal loop diagram of food intake. The relationship between hunger and amount eaten is shown with 2 links. In the top link, more hunger leads to more food consumed. The bottom link depicts that the more consumed leads to less hunger. In this example, the feedback loop is balancing. Feedback loops can be either balancing (negative) or reinforcing (positive). In feedback loops that are balancing in nature, an increase in a given variable leads to a balancing decrease in the same variable when the effects are traced around the loop. In feedback loops that are reinforcing in nature, an increase in a given variable leads to a further increase in the same variable when the effects are traced around the loop (Morecroft 2007).

Statistical Analysis

For statistical analysis with cross-country data, we use the data from the World Bank. This includes data on per capita GDP, land area under parks, rural population density, and the number of birds and mammals that are threatened (Table 1). The statistical analysis is related to the conceptual framework.

Apart from studying correlations between variables, we use bivariate quantile regression in our analysis. 'The p^{th} quantile of a distribution, X, is defined as the value x_p, such that approximately 100p% of the empirical observations have lower values than x_p' (Jacoby 1997: 32). In quantile regression, 'quantiles of the conditional distribution of the response variable are expressed as functions of observed covariates.' (Koenker and Hallock 2001: 143).

RESULTS

Causal Loop Diagram of Wildlife and the Economy

'ECONOMY HARMS WILDLIFE'. —GDP has a direct, adverse, effect on wildlife (Fig. 2). Internal GDP, that is the GDP of the country in which the wildlife exists, has direct effects on the habitat of a species X and the density of the species X in its habitat. The growth of GDP leads to a fall in the abundance of species X (Fig. 2).

Gross domestic product can also increase the demand for poached wildlife. An increase in the demand for poached wildlife species will increase the price of poached X. This leads to an increase in expected profit from poaching X, and encourages greater poaching of X. Greater poaching of X leads to a decrease in the abundance of X, and this increases the demand for X. Thus, an increase in the demand for poached wildlife species can be self-reinforcing (feedback loop R1, Fig. 2). Increases in external and internal GDP can increase incomes and the demand for poached wildlife species X (Fig. 2).

'ERODING LIVELIHOODS'.—In developing countries, parks restrict the extraction of biomass by local people. This reduces biomass pressure and increases the density of species X in its habitat, and therefore, the abundance of species X. This can lead to a decrease in concern for species X, and less pressure to establish parks, completing the third balancing feedback loop labeled B1 (Fig. 3).

A fall in the abundance of species X can increase concern for it, increasing the parks set aside for it. An increase in parks leads to a decrease in biomass livelihoods, which increases poaching effort of X by local villagers, and to a fall in abundance of X (reinforcing loop R2, Fig. 3).

'ECONOMY IS GOOD'.—A decline in the abundance of species X often leads to an increase in concern for species X among governments and the public. The concern for X leads to the establishment of NP, or WS. Parks lead to both an increase in the habitat of species X and the density of species X in its habitat, and thereby, to an increase in the abundance of species X. Thus, a decline in the abundance of species X is balanced in the feedback loops labeled B2 and B3 (Fig. 4). Exogenously, with an increase in income of people within the country and of people outside, (i.e. of internal and external GDP) people have a greater demand for wildlife associated recreation and are willing to pay for preserving wildlife, which are components of the concern for species X (Fig. 4).

Exogenously, more internal GDP can help relieve biomass pressure through 2 related channels: an increase in alternative livelihoods and a fall in rural population density (Fig. 4). An increase in internal GDP can lead to an increase in the alternative livelihoods, which decreases poaching effort devoted to X.

A fall in the abundance of wildlife species X leads to greater concern for it, and this translates into more poaching control and seizures. This reduces profit, poaching, and increases abundance of the wildlife species (balancing feedback loop B4, Fig. 4). Increases in internal and external GDP can augment resources to devote to poaching control (Fig. 4).

VARIATIONS IN LOOP DOMINANCE.—Loops vary over time and space. The direct effects of rising GDP, particularly the expansion of intense production techniques of agriculture or industry into wilderness over time, and increasing concern can give rise to conservation. The loops relating to rural livelihoods have more relevance in developing countries. Using data from 9 Canadian provinces gathered over 37 years, Lantz and Martinez-Espineira (2008) find that the Environmental Kuznets Curve (EKC) hypothesis was valid for 3 of the 5 bird population habitat types that they studied. According to the Environmental Kuznets Curve hypothesis, environmental degradation will be an inverted u-shaped function of the size of the economy. Thus, initially the ‘economy harms wildlife’ view will have more weight, and with time the forces underlying the ‘economy is good’ view assert themselves.

Statistical Analysis

We analyze cross-country data for 2004 to see the support for the conceptual framework (Figs. 2, 3, 4) developed above to shed light on the three views, ‘economy hurts wildlife’, ‘eroding livelihoods’, and ‘economy is good’.

‘ECONOMY HURTS WILDLIFE’.—Although GDP has several effects at different points of the wildlife economy system, its direct effects are the strongest. Per capita GDP is positively correlated with the proportion of birds that are threatened (Coefficient = 0.16, *P*-value = 0.06). The coefficients of the 0.1, 0.25, 0.5 and 0.9 quantile regressions of log of birds threatened against the log of per capita GDP were statistically significant (Table 3). The 0.9 quantile curve slopes upward and away from the 0.5 quantile curve (Fig. 5). Madagascar and the Philippines have a high value of proportion of birds that are threatened even though their per capita GDP is low. New Zealand has a large proportion of birds that are threatened and is well above the 0.9 quantile regression curve. Norway has a very low proportion of birds that are threatened with a high per capita GDP (Fig. 5).

‘ERODING LIVELIHOODS’.—Per capita GDP is negatively correlated with rural population density (Coefficient = -0.26, *P*-value = 0.03). The coefficients of the 0.25, 0.75, and 0.5 quantile regressions of square root of rural population density versus log of per capita GDP are statistically significant at the 6% level (Table 4). Egypt, Bangladesh, Bahrain and Japan have high rural population densities for their respective levels of per capita GDP (Fig. 6).

Rural population density is positively correlated with both bird (Coefficient = 0.36, *P*-value <0.001) and mammal proportions that are threatened. The coefficients of 0.25 and 0.75 quantile regressions of log of proportion of birds threatened versus square root of rural population density have statistical significance close to the 10% level (*P*-values of 0.11 and 0.1) (Table 5). The United States, the Russian Federation and Australia have high values of proportion of birds threatened even though their rural population densities are low (Fig. 7).

'ECONOMY IS GOOD'.—Per capita GDP is positively correlated with the proportion of total land area under PA (Coefficient = 0.32, *P*-value <0.001). The coefficients of the 0.25, 0.5, 0.75 and 0.9 quantile regressions of the square root of land under PA (%) versus log of per capita GDP were statistically significant at the 10% level (Table 6). Zambia and Tanzania have high values of proportion of total land area under PAs with low per capita GDP; Saudi Arabia has a high proportion of total land area under PA with moderate per capita GDP; Germany, Denmark and Austria have a high proportion of total land area under PAs with high per capita GDP; and United Arab Emirates and Ireland have a high proportion of total land area under PAs with moderate per capita GDP (Fig. 8).

DISCUSSION

Our analytical framework used causal loop diagrams to explore the structure related to three distinct views, which we call (1) 'economy hurts wildlife', (2) 'eroding livelihoods', and (3) 'economy is good'. We synthesize the conceptualization and support for the three views of wildlife and the economy in turn.

'ECONOMY HURTS WILDLIFE'.—This view had two aspects: direct effect of GDP, and demand for poached wildlife (Fig. 2). Different production sectors composing GDP reduce space for wildlife (Czech et al. 2000). The bivariate quantile regression using data for different countries for 2004 provides evidence that the direct harmful effect of GDP on wildlife is strong. The review of historical literature for India details the increasing use of land for agriculture from the 1870s continuing till 1995.

For the second aspect, relating to demand for poached wildlife, there is no data available for different countries. However, the review of historical literature for India showed that the British rewarded the hunting of species such as the tiger. It also provided evidence of how demand induced poaching in Kaziranga in the 1930s and in Ranthambhore in the 1990s.

'ERODING LIVELIHOODS'.—This view had two aspects: parks reducing livelihoods while diverting pressure on biomass, and as a result increasing poaching effort (Fig. 3). The support for the reduction in livelihoods rests on careful micro studies (Murty 1996, Kramer et al. 1994) and on the review of historical literature related to India. In several areas set aside by Indian royalty for wildlife, cattle grazing was banned. Relocation of people from park in India after independence in 1947 harmed their livelihoods. The second aspect of this view, that lack of livelihoods is associated with poaching effort is supported by Damania et al. (2003) and Kumar and Wright (1999).

'ECONOMY IS GOOD'.—This view has 3 aspects: (1) concern for wildlife, (2) alternative livelihoods, and (3) seizures of poached wildlife (Fig. 4). Pergams et al. provide quantitative evidence for the concern for wildlife aspect. The quantile regression of land under protected areas against per capita GDP also supports this aspect (Table 6, Fig. 8). The review of historical literature related to India also provides support for the view that falling abundance of species leads to an increase in concern for it. Also, traditional societies protected certain areas and species.

The quantile regression shows the negative effect of GDP on rural population density and the positive correlation between rural population density and proportion of birds threatened. The review of historical literature related to India highlights 2 cases of interest in India. In Bastar, tribals got together to oppose a dam and in Nagarahole the boom in coffee provided alternative livelihoods.

There is no data for different countries related to seizures of poached wildlife. The review of historical literature related to India shows that by the end of the 1990s, various non-government organizations were providing close to 2 million dollars (US) to supplement official efforts to control poaching.

MANAGEMENT IMPLICATIONS

One aspect that is often neglected is that an increase in GDP in developing countries is associated with a decrease in rural population density and biomass pressures. In developing countries, wildlife managers should try to make the most of some positive features of increasing GDP while trying to design mechanisms so that local people can benefit from wildlife conservation. On the part of the government, an improved economy may entail more resources for conservation. At the national level, conservation goals can be furthered by greater and more effective legal and economic instruments to reduce the environmental damage resulting from greater economic production (e.g. taxes on water pollution by industries).

ACKNOWLEDGEMENTS

R. R. Gimblett reviewed the manuscripts and offered useful comments that led to an improved paper. We thank W. W. Shaw and J. L. Koprowski for reading the manuscript and offering useful comments. The Ministry of Environment and Forests, New Delhi, India; School of Natural Resources, University of Arizona, and Arizona Agricultural Experiment Station, Tucson, USA sponsored this research.

LITERATURE CITED

Czech, B., P. R. Krausman and P. K. Devers. 2000. Economic associations among causes of species endangerment in the United States. Bioscience 50:593–601.

Damania, R., R. Stringer, K. U. Karanth, and B. Stith. 2003. The economics of protecting tiger populations: linking household behavior to poaching and prey depletion. Land Economics 79:198–216.

Ford, A. 1999. Modeling the environment. . Island Press. Washington, D. C., USA.

Galster, S. R., and K. V. Eliot. 1999. Roaring back: anti-poaching strategies for the Russian Far East and the comeback of the Amur tiger. Pages 230-242 *in* J. Seidensticker, S. Christie, and P. Jackson, editors. Riding the tiger: tiger conservation in human-dominated landscapes. Cambridge University Press, Cambridge, United Kingdom.

Hemley, G., and J. A. Mills. 1999. The beginning of the end of tigers in trade? Pages 217-229 *in* J. Seidensticker, S. Christie, and P. Jackson, editors. Riding the tiger: tiger conservation in human-dominated landscapes. Cambridge University Press, Cambridge, United Kingdom.

Jacoby, W. G. 1997. Statistical graphics for univariate data. Sage, New Delhi, India.

Karanth, K. U. 1999. Long-term monitoring of tigers: lessons from Nagarahole. Pages 114-122 *in* Riding the tiger: tiger conservation in human-dominated landscapes, edited by J. Seidensticker, S. Christie and P. Jackson, editors. J. Seidensticker, S. Christie, and P. Jackson, editors. Riding the tiger: tiger conservation in human-dominated landscapes. Cambridge University Press, Cambridge, United Kingdom.

Koenker, R., and K. F. Hallock. 2001. Quantile regression. Journal of Economic Perspectives 15:143–156.

Kramer, R., M. Munasinghe, N. Sharma, E. Mercer, and P. Shyamsundar. 1994. Valuing a protected tropical forest: a case study in Madagascar. Pages 159-169 *in* M. Munashinghe, and J. McNeely, editors. Protected Area Economics and Policy. World Bank, Washington, D. C. USA.

Kumar, A., and B. Wright. 1999. Combating tiger poaching and illegal wildlife trade in India. Pages 243-252 *in* J. Seidensticker, S. Christie, and P. Jackson, editors. Riding the tiger: tiger conservation in human-dominated landscapes. Cambridge University Press, Cambridge, United Kingdom.

Lantz, V., and R. Martinez-Espineira. 2008. Testing the Environmental Kuznets Curve: hypothesis with bird populations as habitat-specific environmental indicators: evidence from Canada. Conservation Biology 22:428–438.

Morecroft, J. 2007. Strategic modeling and business dynamics. John Wiley & Sons, Singapore.

Murty, M. N. 1996. Contractual arrangements for sharing benefits from preservation: joint management of wildlife. Pages 127–139 *in* A. Kothari, N. Singh, and S. Suri, editors. People and protected areas: towards participatory conservation in India. Sage, New Delhi, India.

Norgaard, R. B. 1989. The case for methodological pluralism. Ecological Economics 1(February 1989):37-57.

Pergams, O. R. W., B. Czech, J. C. Haney, and D. Nyberg. 2004. Linkage of conservation activity to trends in the U.S. economy. Conservation Biology 18: 1617–1623.

Rangarajan, M. 2006. India's Wildlife History: An Introduction. Permanent Black, New Delhi, India.

Sterman, J. D. 2000. Business Dynamics: Systems thinking and modeling for a complex world. McGraw Hill, Boston, USA.

Sunquist, M, K. U. Karanth, and F. Sunquist. 1999. Ecology, behavior and resilience of the tiger and its conservation needs. Pages 5-18 *in* J. Seidensticker, S. Christie, and P. Jackson, editors. Riding the tiger: tiger conservation in human-dominated landscapes. Cambridge University Press, Cambridge, United Kingdom.

Tata Energy Research Institute. 1998. Looking back to think ahead. The Energy and Resources Institute, New Delhi, India.

Trauger, D. L., B. Czech, J. D. Erickson, P. R. Garrettson, B. J. Kernohan, and C. A. Miller. 2003. The relationship of economic growth to wildlife conservation. Wildlife Society. Technical Review 03-1. The Wildlife Society, Bethesda, Maryland, USA.

World Bank. 2006. World Development Indicators 2006. Washington D. C., USA.

World Bank. 2007. World Development Indicators 2007 CD. Washington D. C., USA.

Table 1. Unit, definition, source and corresponding feedback diagram variable of variables used in statistical analysis, data for different countries, 2004.

Variable	Unit, Definition	Source	Feedback diagram variable
Protected area (%)	% of total land area. Nationally protected areas are totally or partially protected areas of at least 1000 hectares that are designated as scientific reserves with limited public access, national parks, natural monuments, nature reserves or wildlife sanctuaries, and protected landscapes.	World Bank. (2006). World Development Indicators (2006). Washington D C: World Bank	Parks
Mammals threatened (%)	Threatened mammal species as % of total known mammal species. [Threatened mammal species and total known mammal species were the original variables; transformation by authors]	World Bank. (2006). World Development Indicators (2006). Washington D C: World Bank	Abundance
Birds	Threatened bird species as % of	World Bank.	Abundance

Variable	Unit, Definition	Source	Feedback diagram variable
threatened (%)	total known bird species. [Threatened bird species and total known bird species were the original variables; transformation by authors]	(2006). World Development Indicators (2006). Washington D C: World Bank	
Per capita GDP	Constant 2000 international $. GDP (gross domestic product) per capita based on purchasing power parity.	World Bank. (2007). World Development Indicators (2007) CD. Washington D C: World Bank	GDP
Rural population density	Rural population per sq km of arable land.	World Bank. (2007). World Development Indicators (2007) CD. Washington D C: World Bank	Rural population density.

Table 2. 25th percentile, median and 75th percentile of variables used in statistical analysis, data for different countries, 2004.

Statistics	Mammals threatened (%)	Birds threatened (%)	Protected area (%)	Per capita gross domestic product (GDP)	Rural population density
25th percentile	6	2	4	1922	95
Median	9	3	7	5688	198
75th percentile	12	4	12	12181	420

Table 3. Quantile regression (q denotes quantile, and q90 denotes the 0.9 quantile) of log of proportion of birds threatened (%) versus log of per capita GDP, for different countries, 2004.

	Coefficient	*P*-value
q10		
log of per capita GDP	0.416	0.000
Constant	-3.619	0.000
q25		
log of per capita GDP	0.264	0.002
Constant	-1.808	0.023
q50		
log of per capita GDP	0.146	0.044
Constant	-0.249	0.706
q75		
log of per capita GDP	0.105	0.349
Constant	0.530	0.563
q90		
log of per capita GDP	0.237	0.009
Constant	-0.229	0.771
N	137	

Table 4. Quantile regression (q denotes quantile, and q90 denotes the 0.9 quantile) of square root of rural population density versus log of per capita GDP, for different countries, 2004.

	Coefficient	*P*-value
q10		
log of per capita GDP	-1.835	0.134
Constant	24.73	0.025
q25		
log of per capita GDP	-2.161	0.020
Constant	29.47	0.001
q50		
log of per capita GDP	-2.085	0.055
Constant	32.88	0.002
q75		
log of per capita GDP	-3.448	0.034
Constant	50.33	0.002
q90		
log of per capita GDP	-3.328	0.150
Constant	56.46	0.010
N	67	

Table 5. Quantile regression (q denotes quantile, and q90 denotes the 0.9 quantile) of log of proportion of birds threatened (%) versus square root of rural population density, for different countries, 2004.

	Coefficient	*P*-value
q10		
square root of rural population density	0.0134	0.311
Constant	0.454	0.077
q25		
square root of rural population density	0.0158	0.108
Constant	0.714	0.000
q50		
square root of rural population density	0.0187	0.121
Constant	0.856	0.000
q75		
square root of rural population density	0.0281	0.100
Constant	0.964	0.000
q90		
square root of rural population density	0.0251	0.202
Constant	1.397	0.001
N	65	

Table 6. Quantile regression (q denotes quantile, and q90 denotes the 0.9 quantile) of square root of land under protected areas (%) versus log of per capita GDP, for different countries, 2004.

	Coefficient	*P*-value
Q10		
log of per capita GDP	0.0409	0.866
Constant	0.878	0.646
Q25		
log of per capita GDP	0.292	0.031
Constant	-0.444	0.704
q50		
log of per capita GDP	0.186	0.083
Constant	1.043	0.242
q75		
log of per capita GDP	0.378	0.019
Constant	0.322	0.804
q90		
log of per capita GDP	0.502	0.031
Constant	0.252	0.899
N	128	

LIST OF FIGURES

FIGURE

7. Quantile regression curves (q denotes quantile, and q90 denotes the 0.9 quantile) and scatter plots of proportion of birds threatened (%) versus rural population density, for different countries, 2004.
8. Quantile regression curves (q denotes quantile, and q90 denotes the 0.9 quantile) and scatter plots of land under protected areas (%) versus per capita gross domestic product (GDP), for different countries, 2004.

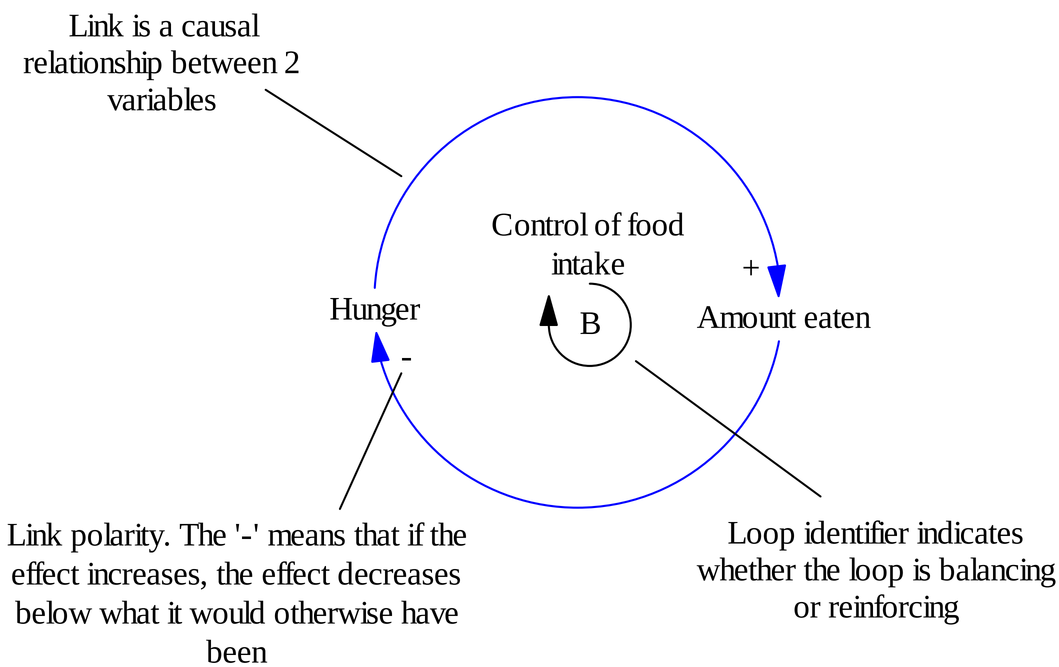


Figure 1. Simple causal loop diagram of food intake (Morecroft 2007: 39)

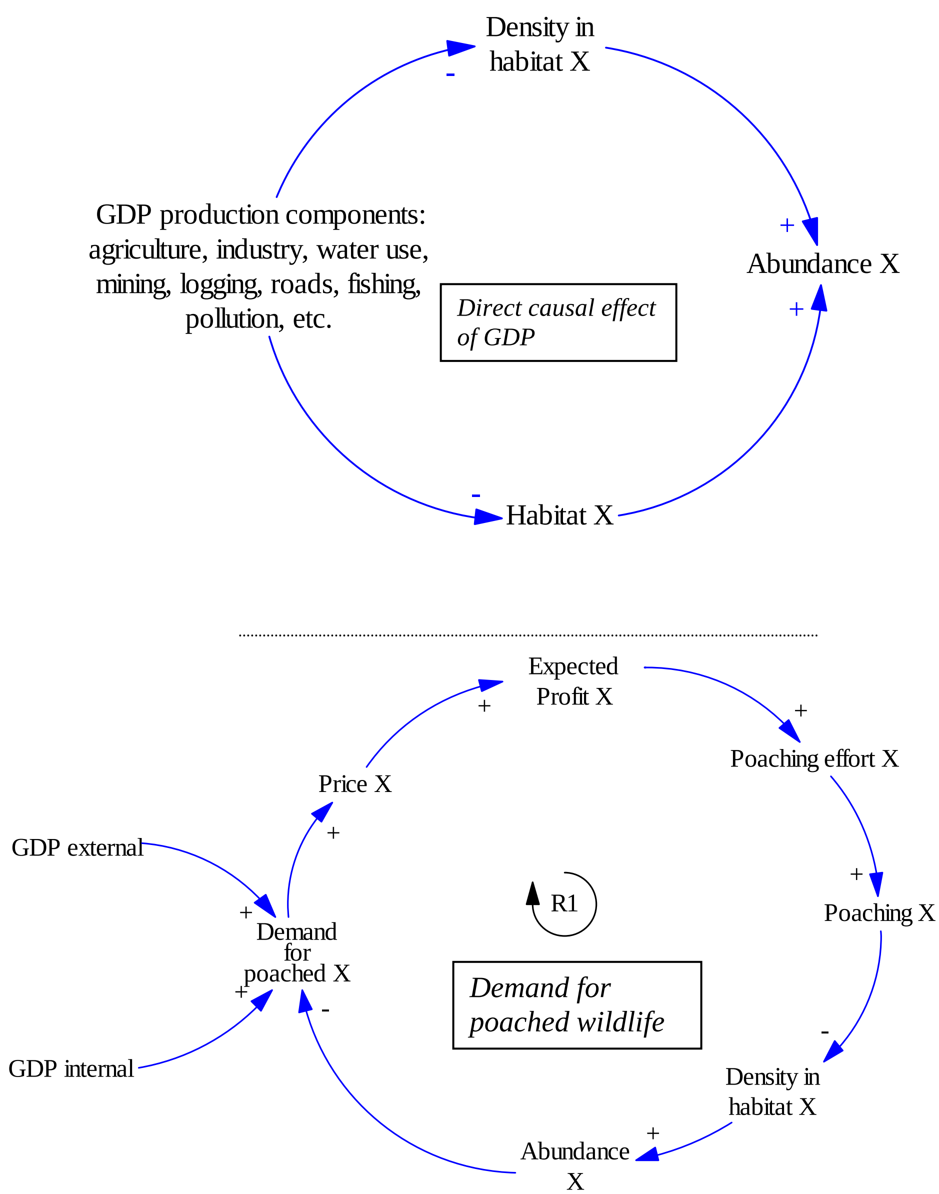


Figure 2. Causal diagrams for 'economy harms wildlife' view. The upper diagram shows the direct causal, and one way, effect of gross domestic product (GDP) on wildlife. The lower diagram shows where demand for poached wildlife leads to further poaching in the reinforcing loop R1.

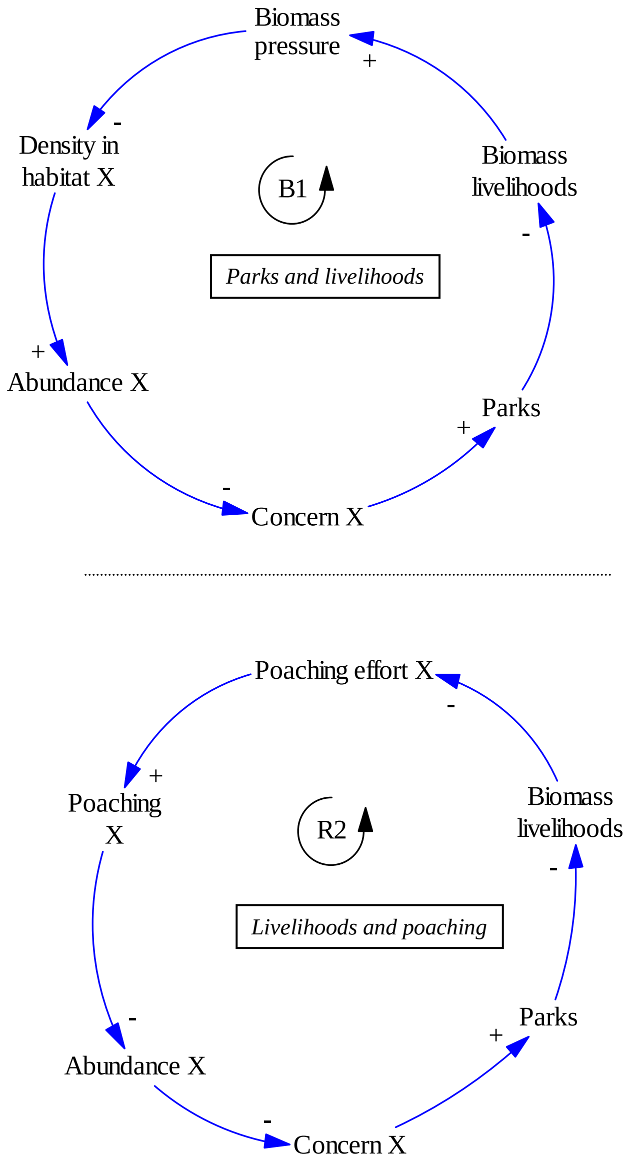


Figure 3. Causal diagrams for ‘eroding livelihoods’ view. The upper diagram shows how concern for wildlife leads to parks being set up, which keep out biomass pressure from habitat, while eroding livelihoods in the balancing loop B3. The lower diagram shows that parks erode livelihoods but thereby encourage poaching effort in the reinforcing loop R2.

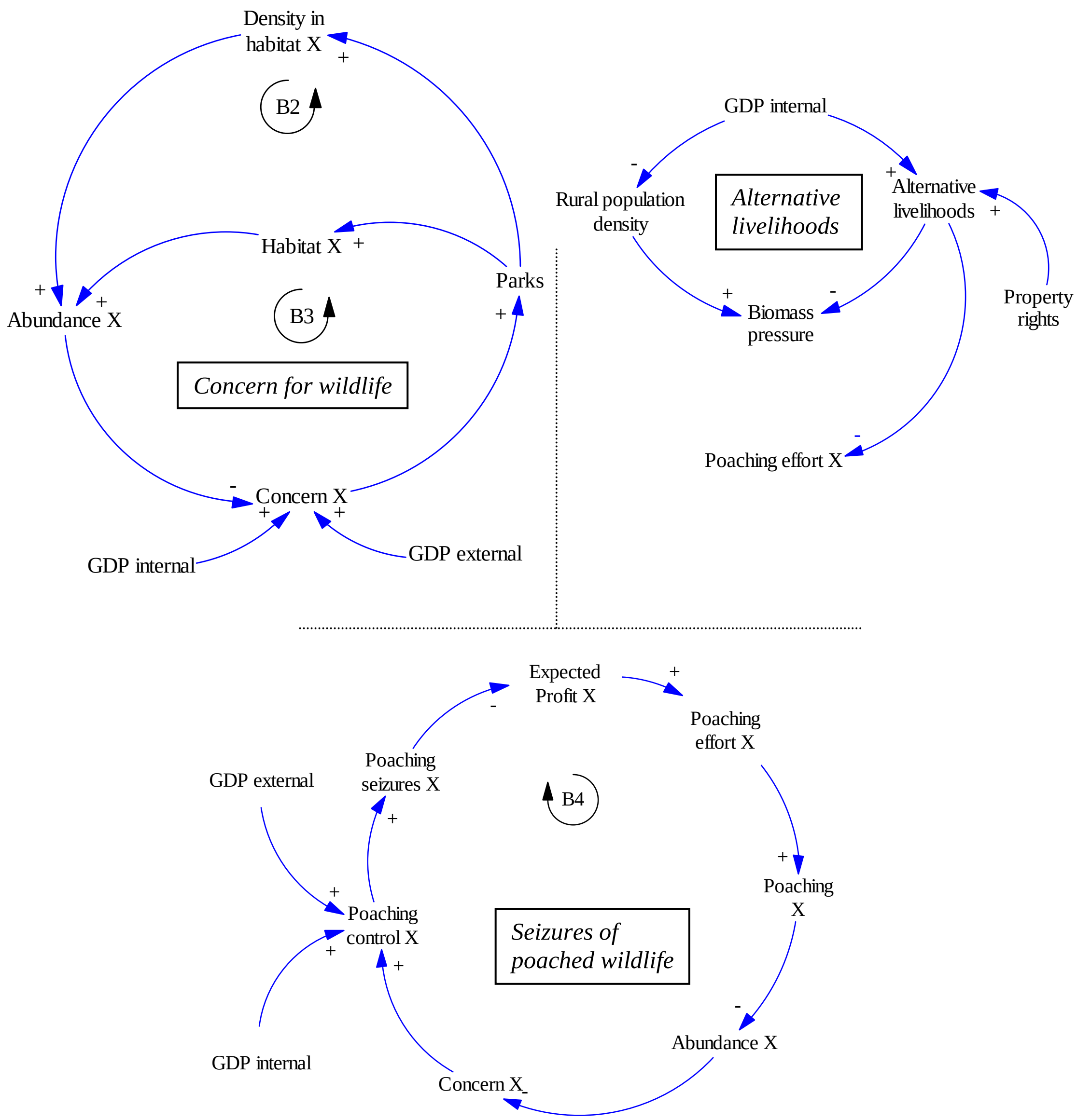


Figure 4. Causal diagrams for 'gross domestic product (GDP) is good' view. Top left diagram shows how GDP can foster concern for wildlife. Top right diagram shows how alternative livelihoods increase with GDP, reducing biomass pressure and poaching effort. Bottom diagram shows how GDP can increase resources for poaching control which is part of balancing loop B4.

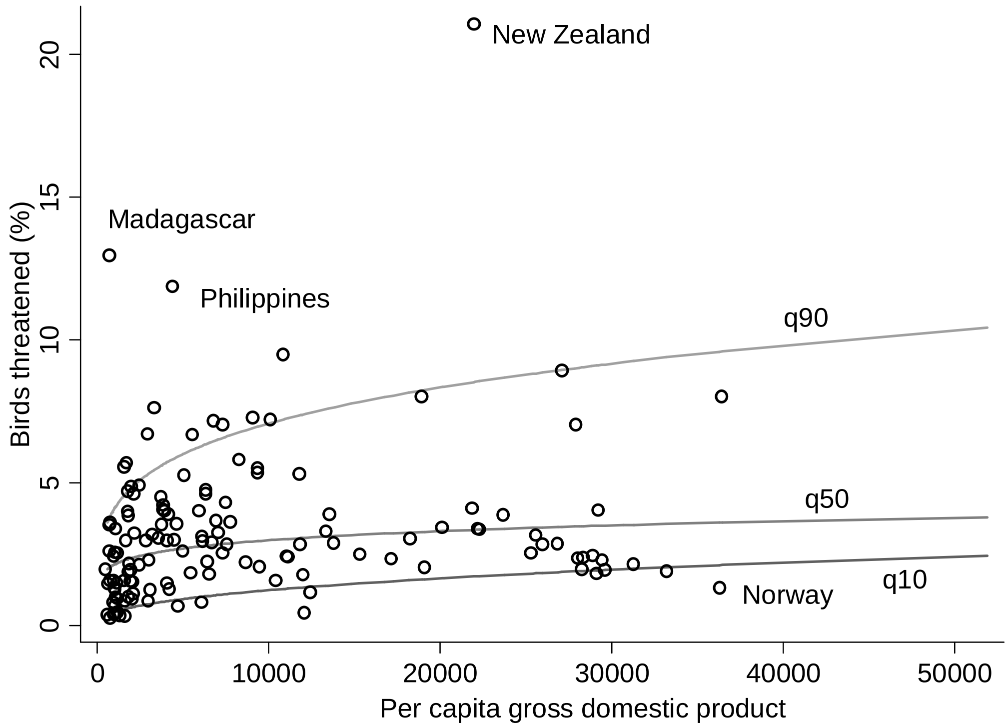


Figure 5. Quantile regression curves (q denotes quantile, and q90 denotes the 0.9 quantile) and scatter plots of proportion of birds threatened (%) versus per capita gross domestic product, for different countries, 2004

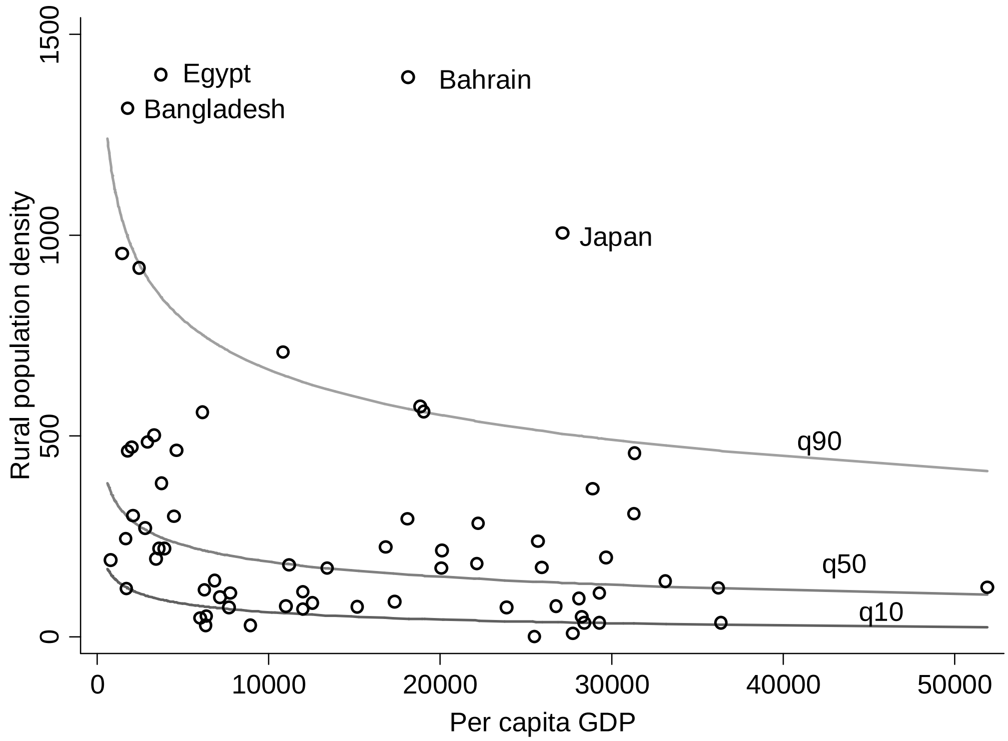


Figure 6. Quantile regression curves (q denotes quantile, and q90 denotes the 0.9 quantile) and scatter plots of rural population density versus per capita gross domestic product, for different countries, 2004

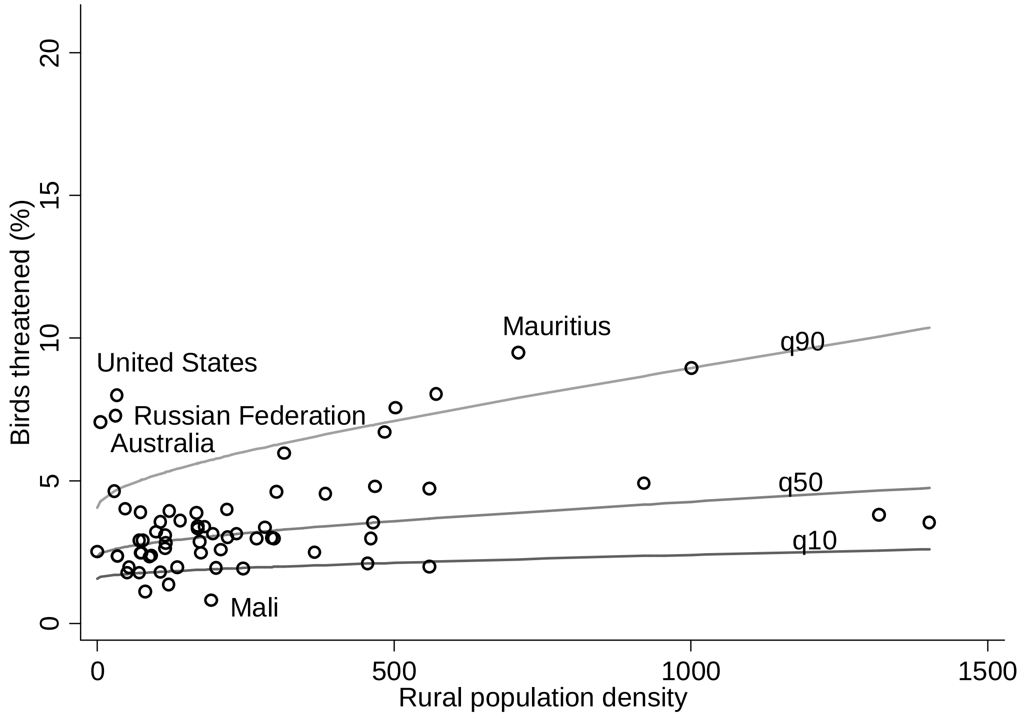


Figure 7. Quantile regression curves (q denotes quantile, and q90 denotes the 0.9 quantile) and scatter plots of proportion of birds threatened (%) versus rural population density, for different countries, 2004

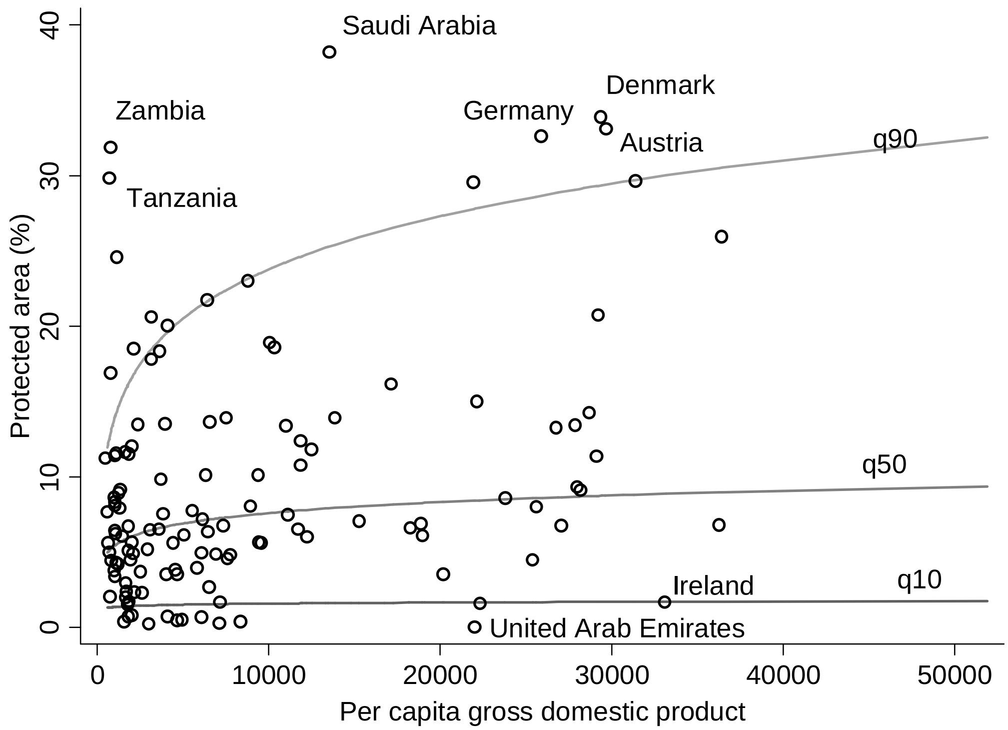


Figure 8. Quantile regression curves (q denotes quantile, and q90 denotes the 0.9 quantile) and scatter plots of land under protected areas (%) versus per capita gross domestic product, for different countries, 2004.