Conservation, conflict and costs: living with large mammals in the Nilgiri Biosphere Reserve, India

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The candidate confirms that the work submitted is her own and that appropriate credit has been given where reference has been made to the work of others.

Dedication

To my parents,

for always believing in me,

supporting me,

and never judging

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They say a PhD is a long and lonely road, but I am fortunate to have had company almost every step of the way. There are many people who have helped make work and life that bit easier throughout, and allowed me to emerge on the other side with my sanity intact.

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Abstract

Human-wildlife conflict is a growing obstacle to biodiversity conservation, while the resulting consequences continue to hamper sustainable development. The Nilgiri Biosphere Reserve in the Western Ghats in South India, characterises a mosaic of land use and biodiversity conservation, human privilege and poverty, and is a case-study for a wide range of conflicts with endangered large mammals such as tiger and Asian elephant.

This thesis explored the social, ecological and economic contexts to conflicts with wildlife over livelihood production systems, namely agriculture and livestock, taking an interdisciplinary approach to determine key drivers of conflict losses and perceptions, ascertain the effectiveness of and decision-making process behind the choices of mitigation measures, and understand how the implementation of more effective community-based solutions may be established.

The presence and intensity of conflict is driven by habitat degradation, forest proximity, and crop or livestock holding extent, while perceptions are strongly linked to proportional loss and economic investment. The most effective intervention methods were electric fences to protect crops, and guarding or the use of sheds and corrals to protect livestock. Households prefer to establish electric fences around fields, given the institutional failings in effectively maintaining electric fences around protected areas; or to utilise more effective guarding practices, but are hampered by issues of cost and labour effort. The majority of households believe that the government Forest Department should be responsible for managing conflicts, accepting very little personal responsibility.

Collective action through community co-operatives can enable access to expensive but effective technologies such as electric fencing, and co-operation can be improved if schemes recognise the importance of landholder demographics in assessing costs and benefits, base contributions on risk, minimise pre-imposed constraints, and understand the problems of community heterogeneity. Reducing risks from conflict and improving livelihood production systems can be a potential and powerful incentive for biodiversity conservation.

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"It's conflicts all the way down": interdisciplinary approaches to the problem of human-wildlife conflict

"*Human-wildlife conflict occurs when the needs and behavior of wildlife impact negatively on the goals of humans or when the goals of humans negatively impact the needs of wildlife. These conflicts may result when wildlife damage crops, injure or kill domestic animals, threaten or kill people*".

- Recommendation 5.20, 2003 World Parks Congress

Conservation conflicts are "*situations that occur when two or more parties with strongly held opinions clash over conservation objectives and when one party is perceived to assert its interests at the expense of another"...* recognising "*that conservation conflicts occur fundamentally between humans".*

- Redpath et al. (in press) TREE

1.1 The nature of the beast

Conflicts over biodiversity conservation, specifically human-wildlife conflicts (HWC), are increasingly recognised as one of the most important and seemingly insolvable issues for conservation today. Conflict is a major obstacle to wildlife conservation, particularly for large and endangered mammals, whilst the underlying causes of conflict and resulting consequences have negative socio-economic implications which hamper sustainable development for those who bear the costs.

There is a wealth of individual case-studies in the literature collated, reviewed and described to great extent in various books (Woodroffe 2005), papers (Osborn and Parker 2003, Dublin and Hoare 2004b, Graham et al. 2005, Treves et al. 2006c, Inskip and Zimmermann 2009a) and theses (Dickman 2009), but it is only very recently that studies have explored the nature of conflict and attempted to establish a theoretical basis for our understanding and management of conflict that draws on an interdisciplinary understanding of the problem (Young et al. 2010, Redpath et al. in press).

This movement towards a unified approach to conflict has highlighted a central problem with the study of conflict amongst researchers and practitioners: the accepted terminology of conflicts. The initial definition of conflict as defined by the WPC (2003; listed above) suggests active negative actions by both parties (people and wildlife) usually manifesting as problems such as crop raiding or livestock depredation, a definition which has been typically adopted by biologists (Gubbi 2012, Guerbois et al. 2012). However, it is notable that in some cases the term conflict has rarely been explicitly defined at all (Dickman 2010). There is now a cautious move towards the social sciences perspective on conflict theories which stem from conflicts over social, political or economic inequalities between stakeholder groups and emphasise that conflicts are between people over wildlife (Marshall et al. 2007a), such as conflicts being a trigger for local issues of settlement and resource access as epitomised by the people and parks problem (Schwartzman et al. 2000). Distinctions have been made with the former referred to as ‘biodiversity impacts’ and the latter as ‘biodiversity conflicts’ (Young et al. 2010), with more recent studies focusing on defining and understanding the diverse nature of both impacts and conflicts (Graham et al. 2011, Linnell 2011).

Part of the difficulty in understanding conflict and addressing drivers of conflict when studying the impact of wildlife upon people, appears to arise because the conflict literature varies in the choice of variables used to measure or represent conflict, again often failing to clearly identify these at the outset of the study which limits the opportunities to compare across studies. Conflicts are described as being ‘perceived’ or ‘actual’, with diverse variation in measurements for both attributes. Actual conflict has been measured in terms of the presence or absence of conflict incidents; frequency of incidents; economic monetary value; absolute measures of loss such as area or trees or number of crops damaged, or numbers of livestock lost; or as representing a market value of economic loss; or can also include indirect costs such as investment and labour (Madhusudan 2003, Inskip and Zimmermann 2009b, Gubbi 2012, Guerbois et al. 2012, Karanth et al. 2012). Perception of conflict has also been measured in a variety of ways, from attitudinal analyses to arbitrary levels (e.g. high, medium, low), or context dependent (e.g. ranked with other problems) (Sillero-Zubiri 2001, Hazzah et al. 2009, Dickman 2010, Karanth et al. 2012). Measurements are therefore often site-specific and not comparable between studies, because they may be monitored over time, or simply reported over a fixed past term, restricted to official reports (e.g. compensation claims) or measured directly from those experiencing conflict, including both verified and unverified incidents (Gubbi 2012, Karanth et al. 2012). Given this diversity in measuring and understanding the terminology of conflict amongst conflict researchers, it is not unexpected that understanding and managing conflicts has made relatively slow progress.

1.2 Valuing the costs of conflict

1.2.1 People and wildlife affected by conflicts

The wildlife causing conflict and impacted by retaliation are often those species which have suffered the greatest loss in habitat and are unable to adapt to changing land uses (Sunquist 2001), vulnerable to extinction due to their typical life history characteristics of size, density, and specialisation (Madhusudan and Mishra 2003), and generally confined to protected areas too small to hold them (Belovsky 1987). Consequently, these taxa are often those of greatest conservation concern, with diminishing populations. However, as more areas of land have been set aside as protected, or as reintroduction or translocation efforts have been made to aid in species recolonisation of natural ranges, this has led to the resurgence of previously reduced wildlife populations. This has generated more opportunities for HWC to occur as interactions between humans and wildlife increase, particularly at the interface between human and wild landscapes such as in areas where networks of protected areas and corridors lie in a mosaic of human development. The strong human opinions towards charismatic but large and potentially dangerous mammals has further polarised the issue.

Humans suffering the consequences of wildlife conflict are often marginalised communities where subsistence or traditional livelihoods are threatened. This analogy is most appropriate in conflict situations in developing countries, but can still be extended to more developed countries where people are suffering an impact on their livelihoods or lifestyles, particularly where there is a minority or other divide, such as urban and rural. Often, conflict is exacerbated when people believe that wildlife is valued more highly than their needs due to conservation efforts and funds seemingly dedicated to preserving wildlife at the expense of community development. Furthermore, in developing countries there are in the majority of cases insufficient resources – funds, personnel and equipment – to address problems of HWC.

In these circumstances, both wildlife conservation and sustainable development suffers. As global biodiversity becomes restricted to remaining tracts of habitat dwindling within a mosaic of human cultivation and development (Laurance 1997), competition for resources intensifies. The most severe conflict cases occur in biodiversity-rich landscapes with high human densities, where problems of habitat and species loss are interwoven with the desperate needs of impoverished local communities, who bear a high cost for conservation (Balmford and Whitten 2003).

Human-wildlife conflict – and in some cases co-existence – has existed since time immemorial (Kruuk 2002), but recent losses in biodiversity have brought it to the foreground as a cutting edge topic in conservation. Given the pervasiveness of global human disturbance, impacting on three-quarters of the earth's habitable land surface (Hannah 1994), active conservation management is necessary to maintain both biological and ecosystem diversity (Hutton and Leader-Williams 2003).

1.2.2 The impacts of conflict

The diversity of human-wildlife conflict is such that it occurs world-wide, in a range of human-influenced landscapes and with many different species. The main impacts of conflict can be categorised into five classes: predation upon livestock, predation upon game species, attacks on humans, crop raiding and disease transmission (Sillero-Zubiri 2001, Thirgood et al. 2005a).

With the diversity of species involved, conflict situations tend to be more extreme when involving large mammals. For example, large carnivores compete with humans for game species and predate livestock, while large ungulates raid crops. Large mammals can also be an immediate threat to human life, engendering fear and hostility towards the presence of these species in close proximity to human settlement (Berg 2001, Sillero-Zubiri 2001, Quammen 2003, Quigley 2005).

1.2.3 Human dimensions of conflict

The conservation of large mammals can thus incur significant costs through conflict, to local communities, industry and government authorities. Quantification of economic costs through direct loss of livelihoods or investment in damage control can and has been explored relatively broadly.

Case-studies of direct crop and livestock depredation costs indicate significant economic consequences on local communities in the developing world, for example in southern India village households lost 12% of their holding to large felines, and 11% of annual grain production to elephants (Madhusudan 2003). Additionally, the cost of carnivore compensation schemes to government authorities can be substantial (Nyhus et al. 2005a); e.g. in 2000 the Norwegian government paid out over US$11.8m in carnivore compensation schemes (Swenson and Andren. 2005). Indirect economic costs are also incurred through investment in damage control strategies, such as husbandry, guarding, and animal control (Breitenmoser

2005, Osborn 2005, Thirgood et al. 2005a), and can sometimes be much greater than the cost of damage, particularly for high technology solutions such as electric fencing.

Indirect effects with no obvious associated economic cost are more difficult to quantify, for example changes in husbandry such as stock corralling or crop-guarding at night (Ogada 2003), or having to share homes with livestock to protect against tigers (Saberwal 1994). The time required for husbandry can also limit time spent in education or harvesting (Norton-Griffiths 1995). Finally, it is virtually impossible – and unethical – to quantify the loss of human life in economic terms. Furthermore, protected areas themselves can impose opportunity costs on local communities, restricting access to natural resources and antagonising local communities towards parks, authorities, and protected species (Schwartzman et al. 2000).

There is a vast and growing body of mitigation techniques for human wildlife conflict, but these can be broadly categorised (Inskip and Zimmermann 2009a) into: financial schemes (e.g. compensation, economic incentives, ecotourism, trophy hunting); improved protection of livestock and crops (e.g. husbandry, guarding, barriers and deterrents); community development and education initiatives; problem animal control (e.g. aversive conditioning, translocation, lethal control); and land management such as zoning; all of which have had varying levels of success and failure (Mishra et al. 2003, Osborn and Parker 2003, Bulte and Rondeau 2005, Shivik 2006). For large and dangerous mammals, lethal control to prevent conflict is often one of several methods used, and can be a major driver in population declines (Treves and Naughton-Treves 2005), as seen with the extirpation or reduction of many large mammal populations throughout the world (Treves and Naughton-Treves 2005).

1.2.4 Investing in wildlife

Biodiversity conservation recognises that large mammals are often keystone species in ecosystems. Large carnivores control mesopredator and prey numbers, including crop pests and species which depredate smaller livestock, while large ungulates shape and maintain habitats and vegetation structure, all are functional components of ecological communities (Terborgh 1999). Non-use values of wildlife include bequest value; preserving species for the benefit of future generations; and existence value, the continued survival of a species (Attfield 1998, Edwards 1998). Many people place higher values on charismatic megafauna, and support international conservation efforts for these species (Walpole and Leader-Williams 2002).

Large mammals are often used as flagship species to coordinate landscape conservation efforts and protect smaller and less charismatic species (Caro 2003, Sergio et al. 2008).

Yet these intangible benefits may be outweighed by the potential direct benefits that wildlife conservation can bring to local communities. Direct use can be consumptive in a variety of ways. Trophy hunting can generate substantial revenues (Leader-Williams and Hutton 2005) although there are issues of equitable revenue distribution (Leader-Williams and Hutton 2005) and sustainability (Hoyt 1994). Alternatively, species may be traditionally important for food and medicinal uses, or in traditional practices (Edwards 1998).

However, the majority of revenues can be obtained through direct non-consumptive use such as tourism (Edwards 1998), and attempts have been made to value individual animals (Martin 1988). Some ecotourism schemes appear successful, generating revenue and enabling community development (Gosling 1999), though revenue sharing can again be a problem and there is the danger of habituating dangerous animals to people (Saberwal 1994). Ecotourism requires participatory planning but can generate sufficient incentive for communities to tolerate conflict causing species (Lindsey et al. 2005).

1.2.5 Protected areas are not enough

Currently, protected areas cover over 11% of the world's surface (Chape 2003), but this is likely to be insufficient for viable long-term conservation of many large mammals. Legal protection is not always effective at a local level, due to a lack of resources for law enforcement and/or a local need for natural resources that cannot be fulfilled elsewhere (Bruner et al. 2001). The home ranges of many large mammals are often significantly larger than that of most reserves (Belovsky 1987), and conflict situations on the borders of protected areas that result in increased mortality can drive population declines (Woodroffe 1998.). Furthermore, the remnant ranges of many endangered species do not fall within protected areas (Nowell 1996).

Conservation of these species thus requires landscape level approaches over a mosaic of different land uses, which necessarily must involve human-wildlife conflict mitigation measures to be successful. Maintaining corridors and permitting traditional migrations can help to ensure the conservation of viable populations of large mammals (Simberloff 1992).

1.3 Changing perspectives in human-wildlife conflict management

There has been an increasing drive to address HWC, with a wealth of case-specific literature throughout the years. Conservationists were the first to address HWC from an ecological perspective, though recently social scientists have explored the human dimensions of conflict amidst calls for greater interdisciplinarity of approaches.

1.3.1 A question of biology

Biological-based reviews have periodically attempted to focus, collate, and direct research on HWC in general (Woodroffe 2005), for felids (Inskip and Zimmermann 2009a), and African elephants (Osborn and Parker 2003, Dublin and Hoare 2004b). In particular, a multitude of opinions, commentaries and perspectives have addressed human-carnivore conflict (Treves and Karanth 2003, Karanth and Chellam 2009).

However, many solutions proposed to conflict have failed to successfully address conflict issues and resolve the situation, yet continue to be implemented without better success worldwide. Over the years many studies have described utilising a number of new and improved approaches, for example, more quantitative approaches calculating damage to estimate compensation or targeting resources to address localised issues (Woodroffe 2005). Critics state that as yet limited success has been achieved as few studies measure the range and spatial distribution of damages, while the quantification of loss is counter-intuitively a poor prediction of human attitudes and responses to HWC (Borgerhoff-Mulder 2006).

There has been significant recognition that top-down methods utilised and advocated by conservationists have failed to incorporate human dimensions and thus are unable to address HWC, for example the enforcement of protected area laws and penalisation of retaliatory actions against wildlife (Schwartzman et al. 2000). It is evident that more advanced tools are necessary to deal with the human aspects of conflict, and for these it is becoming increasingly popular to look to other disciplines. Integrating biological science with economics and social science methods can allow the emergence of solutions that are widely accepted at all levels with a greater chance of success, and it is in this direction that conflict management is evolving.

1.3.2 The panacea of participation

Socio-economic reviews of HWC have linked policy process with carnivore conservation (Primm and Clark 1996), landholder participation in conservation (Kabii and Horwitz 2006), and evaluated investments reducing HWC (Gore et al. 2008). A change has been seen from previous top-down approaches, to a bottom-up approach which involves local communities in conservation planning and provides economic incentives or compensation for costs borne from living with wildlife. The premise here is that the bottom-up approach with economic benefits will encourage local communities to have a more positive attitude towards wildlife conservation (Lewis 1990).

Thus, participatory conservation incorporating stakeholders has gained ground as the new humane approach to conservation, an ideal way to mitigate conflicts between humans and wildlife while reconciling conservation with development (Lewis 1990, Gadgil 1992, Child 1993, Western 1994, Nepal 1995). In particular it has been taken on board by biologists, leading to the proposal of co-management of conflicts using biological research and participatory planning (Treves et al. 2006a, Treves et al. 2006c). Examples of initiatives include Community Based Conservation (Western 1994), Integrated Conservation and Development Programs (Barrett and Arcese 1995), and Community-Based Natural Resource Management (Turner 1999). Further support comes from those who claim that HWC is not inevitable, and that evidence of cultural tolerance and coexistence can provide tools for use elsewhere (Madden 2004).

Yet, very few successes have been reported (Lewis 1990), and these ventures have been widely criticised for a number of reasons due to their simplicity (Barrett and Arcese 1995, Songorwa 1999, Kellert et al. 2000). In many cases, the participation of local communities has been symbolic (Alpert 1995, Gibson and Marks 1995), or only as pawns for those in power (Gibson and Marks 1995, Kellert et al. 2000). It has also been apparent that of themselves, economic incentives alone are insufficient to change attitudes to achieve conservation (Gillingham and Lee 1999, Langholz 1999), some communities lack interest in participation (Songorwa 1999), whilst initiatives have failed to deliver promises or address the needs of the local communities (Songorwa 1999). There is evidence that communities fail to invest in the environment or act with restraint in natural resource use (Milner-Gulland and Bennett 2003), and that traditional practices cannot be extrapolated to the scale of present use (Du Toit 2002). Galvin *et al.* (2006) claim that there has been a failure to test the basic economic hypothesis –

that economic benefits for local communities will provide an incentive to tolerate wildlife – as in the majority of cases revenues have not reached their destination. The idea of the 'noble savage', where primitive communities and cultures have lived peaceably with wildlife, is rapidly being discounted as attitudes change in today's world, and few communities voluntarily choose to eschew Western patterns of consumption (Balmford and Whitten 2003).

Essentially, current community based conservation approaches tend to create divisions between people and the environment by failing to consider parties equally (Mara 2003, Homewood 2004). Critics claim that successful recoveries of endangered wildlife populations have been in locations where human population densities are relatively low and rural economies are not reliant on subsistence agriculture, and have even noted that recovery in other cases may be reliant on a history of expatriate colonialism (Borgerhoff-Mulder 2006). With rising human densities, socio-economic and political problems of corruption, poverty, lack of access to education, and conflicts over land rights as land shortage grows more apparent, costly coexistence with large mammals that are a danger to life and livelihood can only be marred by conflict. Clearly the need to mitigate conflict is vital, otherwise conservation efforts will be in vain as those bearing the cost will ultimately refuse to do so.

1.4 Integrating interdisciplinarity

There are a multitude of difficulties in creating a successful stakeholder-inclusive approach to resolving conservation conflicts, therefore there is scope for truly interdisciplinary approaches to integrate social, political and economic contexts with the ecological basis for conflict in order to find a way forward. However, there continue to be several issues with such an approach beyond the initially described problem of terminology, only one example of the potential conflict amongst researchers and practitioners.

1.4.1 Conflicts between disciplines

Human wildlife conflict falls into a particular type of identified interdisciplinary problem: *"distinctly multidisciplinary problems generated increasingly by society and distinguished by relatively short-time courses calling in some cases for a policy-action result and in other cases for a technological quick fix."* - (Sigma 1988)

The problems of an interdisciplinary approach are commensurate with the general problems ascribed to interdisciplinarity. Normative arguments that support a disciplinary approach are the conceptual and theoretical framework, depth of inquiry, systematic rigour, academic values and shared language. Critics claim that they are self-limiting, repetitive, bound by academic social hierarchies, and unable to address real-world problems (Heberlein 1988), problems which can be overcome using an interdisciplinary approach. Despite the merits of interdisciplinary research, general acceptance has been slow, and disciplinary approaches continue to be traditional. This is also in part due to barriers of communication and conflicts in practice between different disciplinarians, particularly between the social and natural scientists (Campbell 2005, Fox et al. 2006).

1.4.2 Reporting disparities and unevaluated outcomes

A significant obstacle to the analysis and resolution of HWC is the lack of coherence and cohesiveness in the literature, with few systematic approaches to rationalising the choice and use of particular tools. The literature continues to be heavily case-specific – not always useful to conservation practitioners. Critics have raised issue with the efficiency of disseminating management information (Borgerhoff-Mulder 2006, Inskip and Zimmermann 2009a). Many studies provide site-specific and locally appropriate recommendations and strategies, to be used as part of a toolbox of methods. Yet the range of HWC control methods are vast, and continually increasing, thus calls have been made for this knowledge to be made available in such a way as to aid in conflict management situations, to compare approaches implemented in similar circumstances (Borgerhoff-Mulder 2006).

Furthermore, few conservation initiatives evaluate the efficacy, success or otherwise of the measures taken, and publish this in the literature. For example, only 31% of implemented management strategies addressing human-felid conflict have been evaluated scientifically (Inskip and Zimmermann 2009a), and the effectiveness of control methods for human-elephant conflict has not been properly quantified with few cost-benefit analyses (Osborn and Parker 2003). A lack of systematic and standardised reporting of HWC is also evident in the literature (Inskip and Zimmermann 2009a), and this must be addressed in order to enable identification and resolution of global patterns and trends in HWC, and to compare conflict between locations and species. For conservation practitioners to deal with a HWC situation, there is no comprehensive toolbox available that can be utilised given the particular components that feature in individual HWC cases.

1.4.3 Transcending disciplines

The trans- and inter-disciplinary nature of the problems facing humans and wildlife in HWC situations have been acknowledged. Many reviewers have called for greater collaboration with the social sciences (Manfredo and Dayer 2004b, Treves et al. 2006c, Inskip and Zimmermann 2009a, Redpath et al. in press), that HWC solutions must be driven by both biological and social scientific data (Brown and Decker 2005, Redpath et al. in press), and while technological advances may lead to improvements in management, some of the tools most desperately needed are social ones (Treves and Karanth 2003, Shivik 2006), with emphasis being placed on giving responsibility to the communities affected (Osborn and Parker 2003). Some have proposed approaches for exploring the social and cultural aspects of HWC in order to advance our understanding (Manfredo and Dayer 2004b). Fewer have noted that social science research can assess economic feasibility and sustainability of interventions (Treves et al. 2006c), particularly since the incorporation of economic costs and benefits into conservation planning can achieve larger gains given limited budgets (Naidoo et al. 2006). However, many still stress the vital role of ecologists in providing scientifically formulated interventions above and beyond a simple reliance on community based solutions (du Toit et al. 2004), particularly important in light of the previously described criticisms of these approaches.

Although interdisciplinarity is emerging with some overlap between the sciences, there is still a significant division between the biological and social sciences in the conflict literature. Many studies of HWC continue to be predominantly ecological, conversely, socio-economic analysis of HWC is not often conducted from the perspective of conservation interests – more usually from a welfare perspective. For example, in a review on co-managing conflicts (Treves et al. 2006b), less than a quarter of citations were from dedicated socio-economic journals; as opposed to a socio-economic study (Galvin et al. 2006) that utilised an integrated modeling approach to resolve conflicts with pastoralists in East Africa, which cited only eleven papers from dedicated conservation biology journals out of 133 citations. Thus, there is still some division between the disciplines in the literature, despite the topic being a recognised applied interdisciplinary problem.

A more interdisciplinary approach to studying conflict is therefore a relatively recent phenomenon, but one interesting example is the focus on raptor-grouse conflict which runs the gamut from biological data collection to social studies in order to address the contentious issue of predation on grouse by raptors. Publications include ecological factors driving raptor predation on grouse (Thirgood et al. 2000a, Amar et al. 2004), as well as conflict and management analysis (Thirgood et al. 2000b), and social studies on stakeholders and decision-making (Redpath et al. 2004, Marshall et al. 2007b), and evaluation of different mitigation techniques (Redpath et al. 2001). This illustrates the utilisation of a suite of biological and social science methodology to understand and attempt to manage conflicts with landowners and other interest groups to reconcile hen harrier conservation with traditional game keeping (Redpath and Thirgood 2009).

1.4.4 Models of management

An interdisciplinary approach can allow the transfer and emergence of new types of tools for understanding and managing conflicts. For example, one potential option may be in the incorporation of modeling techniques as a tool to determine effective HWC management. Spatial modeling has already been proposed in the biological sciences to predict sites of conflict, such as in predicting regional human-wolf conflict in the US (Treves et al. 2004), or predicting spatial aspects of human-elephant conflict (Sitati et al. 2003), or for wildlife-vehicle collisions (Juan E. Malo 2004, Andreas 2005). Spatial simulations of Iberian wolf populations have further incorporated the impact of socio-economic trends through using road traffic density and urbanisation of habitat as key variables, to produce a more realistic model predicting future wolf depredation of livestock (Santos et al. 2007).

Ecological economic modeling in the social sciences has been utilised to a much greater extent to model environmental and wildlife resource management decisions, although few explicitly deal with HWC. Significant advances have been made over the past few years in using models to study complex systems, where modeling can quantify processes and interactions within a system, and integrated models can incorporate the complexities of human-wildlife systems. Integrated models illustrate the relationships between the natural and social dimensions of natural resources economies and have been used to model problems such as the sustainability of bushmeat hunting (Ling and Milner-Gulland 2006), cost-benefit analysis of protected areas (Albers and Robinson 2007), and fishing stocks within marine reserves (Pezzey et al. 2000). Resource management models illustrate dynamic interactions between human management and an evolving natural resource within spatially structured landscapes, increasingly using bioeconomic modeling and game theory in a variety of settings (Bischi 2004, Bhat and Huffaker 2007). The development of agent-based models enable modeling of multi-agent systems for ecosystem management (Bousquet and Le Page 2004), examples include hunting activities (Bousquet et al. 2001), the costs and benefits of protected areas (Albers and Robinson 2007), and management of deer as a resource and a pest (Touza et al. in press). Developing these bioeconomic modeling tools using both biological and socio-economic parameters therefore has potential to assist in modeling HWC management scenarios to determine best practice with limited funds.

Some models have been explicitly developed to deal with HWC, but focused within the social and economic disciplines, such as purely theoretical mathematical economic approaches for modeling endangered large mammal pest species in a developing country (Skonhoft 2007). Another example incorporating more real world socio-economic values is an Integrated Modeling and Assessment System (IMAS) to explore tradeoffs among different conservation policies in East Africa to mitigate conflict (Galvin et al. 2006). Alternative models use a real options framework to analyse wildlife management policies for human-wolf conflict and reintroduction (Bakshi 2004), and for reconciling the conflicting goals of managing endangered caribou populations and commercial forestry exploitation (Morgan 2007, S.B. and P. 2007). In particular, forestry management is incorporating interdisciplinarity into modeling approaches (Papaik 2008). The economic costs of conserving certain species known to cause conflict can be assessed using functional response models from population ecology to estimate associated welfare costs, such as with carnivores in Sweden (Bostedt and Grahn 2008), useful for advising policy decisions on the costs and benefits of wildlife conservation. Similar studies have modeled fox predation and preventative measures on UK sheep farms to determine a financially optimal solution (Moberly et al. 2004). Multiple criteria analysis developed for use in natural resource management is another approach that can be utilised to aid economic investments in environmental decision-making, to maximise conservation benefits within a limited budget (McCoy 2003, Marinoni et al. 2009). The scope and diversity of potential tools that could be borrowed from other disciplines indicates that true interdisciplinarity is only now emerging.

1.5 Thesis questions and structure

Although human wildlife conflict is an interdisciplinary problem in conservation biology, it is only recently that mitigation efforts and the literature have begun to take a truly interdisciplinary approach that incorporates ecological, social and economic contexts in order to understand and effectively manage conflicts. Since many mitigation measures and conflict solutions have so far failed to successfully address and resolve conflict issues, exploration and utilisation of interdisciplinary approaches and methodologies can facilitate better understanding of conflict situations and enable the emergence of mitigation measures with greater chances for success. This thesis aimed to contribute to this gap in our understanding of conflict, through exploring the context to conflict in a particular region, to understand how communities relate to wildlife and other stakeholders given the impact of wildlife on their lives and livelihoods, and to understand the potential for uptake of more effective mitigation measures given particular socio-economic contexts.

The Nilgiri Biosphere Reserve (NBR), *c.*7,500 sq. km. of the Western Ghats in South India, characterises an anthropogenic/protected area mosaic where some of the largest remaining populations of endangered Asian mammals interact with an ever-growing rural human population. The NBR is a diverse landscape in terms of people, land use, habitats and wildlife. The precipitation and altitudinal gradients support a vegetative gradient ranging from endangered semi-evergreen forests, to moist and dry deciduous forest and scrub and thorn jungles, with extensive riparian forests and the increasingly rare high elevation shola forests and grasslands. Land uses have changed over time from indigenous low productivity landscapes to efficient production landscapes in the time of the British. Now, plantations of timber, tea, coffee and spices mix with vegetable farms, along a gamut of commercial corporate plantations and private subsistence farmers, and pastoralists keeping small personal herds to those supplying organic dung for international coffee growers. An extensive protected area network runs through the NBR, dating back to British hunting and timber reserves, supporting high biodiversity and the last stronghold for many large carnivores and herbivores, including tiger and Asian elephant. This mosaic of land use and biodiversity conservation, privilege and poverty, is a case-study for a wide range of human wildlife conflicts.

The general aim of this research was to investigate the ecological and socio-economic context to human-wildlife conflicts in the Nilgiri Biosphere Reserve, India in order to understand and propose management options for resolving these conflicts.

Specifically, the research questions to be answered were:

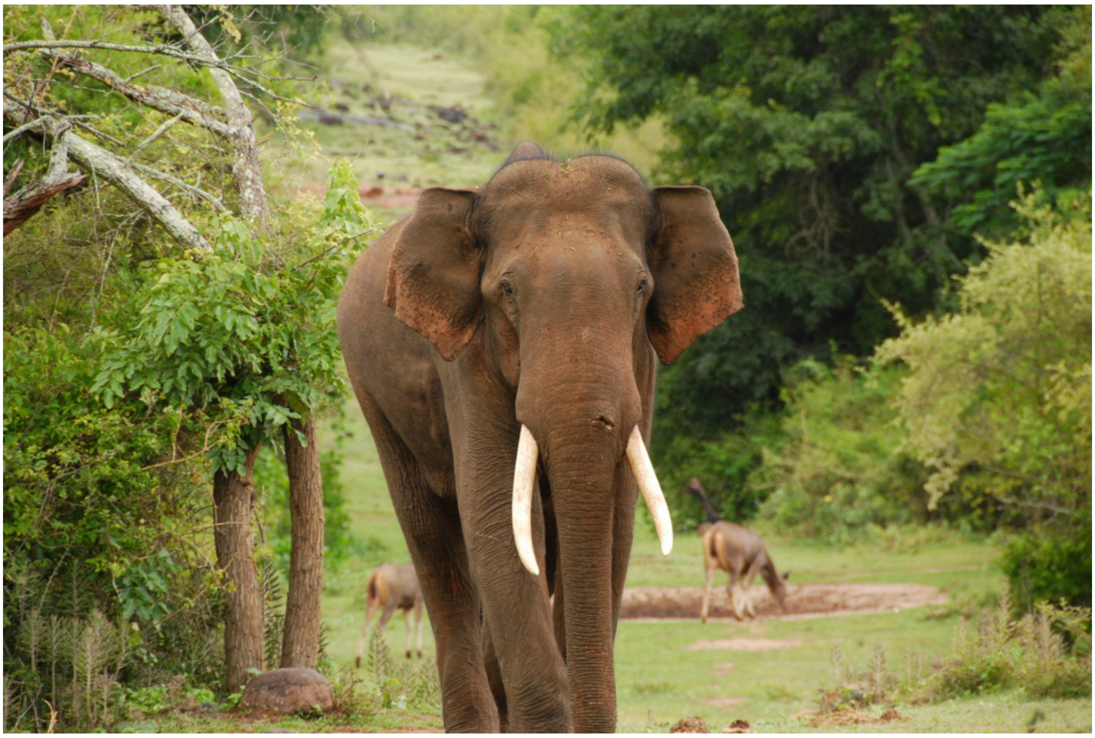
(i) Given the difficulties in establishing a conflict terminology, and the diversity of aspects of conflict that are often reported in the literature (presence of loss, intensity of loss, economic loss, perception):
   a. What are the landscape-level social, economic and ecological drivers of different aspects of conflict across the region;
   b. How do these different aspects to conflict relate to each other;
   c. Can knowledge of these site-specific drivers and their relationships with different aspects of conflict provide lessons for conflicts in other areas;

(ii) Considering the lack of studies on the effectiveness of mitigation measures, and on how individuals make their choices of which mitigation measures to implement:
   a. What are the most effective mitigation measures currently employed in the region;
   b. Which criteria are important in the household decision-making process whereby existing and potential future mitigation measures are chosen;
   c. Which stakeholder group or institution should bear most responsibility for managing conflict and how does this interact with the decision-making process;

(iii) With an understanding of the main drivers of conflict in combination with identifying the most effective mitigation measure and how it might feasibly be implemented, an agent based model of co-operative conflict mitigation was constructed to:
   a. Understand some of the underlying mechanisms for the difficulties in achieving sufficient investment in community-based conflict mitigation schemes;
   b. Suggest alternative designs to enhance participation in community-based schemes to reduce problems generated by human-wildlife conflict.

Although this study is focused on a particular region and will inform effective conflict management both in the NBR and in India, the interdisciplinary approach taken is transferable and can permit a greater understanding of conflict in other sites. Not only that, but the theoretical studies of the relationships between different aspects of conflict, and the agent based model of co-operative conflict mitigation, as well as the practical study on mitigation effectiveness, are generic findings that will help in the understanding and management of conflicts in other areas.

Chapter 2
People and wildlife in the Nilgiri Biosphere Reserve, India



2.1 The landscapes of the Nilgiri Biosphere Reserve, Western Ghats

The Western Ghats in India is one of the world's biodiversity hotspots (Myers et al. 2000), with 58 Protected Areas covering 9.06% of the landscape (CEPF 2004). However, these are isolated islands embedded in a human-dominated landscape, and some of the highest biodiversity in the Western Ghats exists outside protected areas in regions supporting some of the highest human densities globally (Das et al. 2006). Within the Western Ghats, the Nilgiri Biosphere Reserve (NBR) typifies many conservation issues associated with problems of high human and wildlife densities. In an area of c.7,500km^2, of which *c*.4,500 km^2 is protected, the NBR encompasses all the topographic and climatic variation, all the major forest types and much of the species diversity found across the Western Ghats.

2.1.1 Overview of the NBR

The NBR is India's first Biosphere Reserve, designated in 1986 under UNESCO's Man and Biosphere Reserve program, and now under consideration as a World Heritage Site. The NBR lies in the three Indian states of Kerala, Karnataka and Tamil Nadu, from 11°15' - 12°15'N, 76 - 77° 15' E (Appendix A1), and has been divided into six geo-climatically and culturally distinct units (Prabhakar 1994): the Nilgiri Wayanad Plateau, Nilambur Plain, Sigur Plateau, Nilgiri Plateau, Coimbatore Plains, Attapadi Plateau (Appendix A2). These units were used to aid in sampling across the NBR for this study, ensuring a representative selection of villages across socio-ecological gradients, and adapted further with some subdivision where necessary to facilitate a regional management approach to conflict for conservation practitioners. Each of these geo-climatic units is detailed in the following sections.

The landscapes of the NBR includes over 30 indigenous communities known as Adivasis or tribals (Bird-David 1994, Daniels 1996) many of them forest dwellers and hunter gatherers, as well as settlers from the major Indian castes, religions and communities. Given this study's interest in conflict impacts on rural communities, many villages included a significant percentage of Adivasis. Indigenous tribal groups have inhabited the Nilgiri Biosphere Reserve for many centuries, and before British occupation indigenous communities relied on settled and shifting agriculture, hunting and gathering. The lands were colonised by the British in the early 1800s, and over the past few centuries there has been an influx of settlers from the plains, especially in the decades since independence. The consequences for indigenous communities have been displacement into less productive areas and land seizures; while exploitation has led to their alienation, dispossession of land and public disturbances. Further, within the rural communities across the NBR, many people are of castes listed as ‘Scheduled’ or ‘Other Backward Castes’, recognised by the Indian Government as historically discriminated against or economically backward, respectively, for the purposes of affirmative action. These changes have been coupled with widespread changes in land use, from an insular cultural landscape reliant on subsistence agriculture and pastoralism to one of commercial production. Nowadays, land ownership in the NBR ranges from small private holdings of less than a hectare, to giant corporate holdings of hundreds of hectares. Timber plantations range from exotic wattle *Acacia spp.*, eucalyptus *Eucalyptus spp.* and pine *Pinus spp.* at higher elevations to more valuable species such as teak *Tectona grandis* forests at lower elevations, many of which were reserved by the British and local royalty for timber and for hunting. Plantations of tea *Camellia sinensis,* coffee *Coffea spp.* and spices such as cardamom *Elettaria spp.* and *Amomum spp.,* are widespread, while many vegetable farms supply markets in the plains. For smaller farmers the main growing season is monsoon dependent, from May – November, although for those with irrigation dry season crops are also grown. Crops include staple millets such as *Sorghum vulgare* and *Eleusine coracana,* pulses such as *Dolichos lablab, Cajanus cajan, Cicer arietinum,* paddy *Oryza sativa*, arecanut *Areca catechu,* coconut *Cocos nucifera*, fruit trees such as banana *Musa spp.*, and jackfruit *Artocarpus heterophyllus.* Pastoralists keep several types of cattle: milk cows, scrub cattle for dung which supplies major organic coffee and spice growers (Madhusudan 2005), and oxen for draft animals; as well as buffalo, goats, and sheep. Livestock graze in nearby forests during the agricultural growing season, and in both the forests and fallow croplands at other times.

As is the case in the Western Ghats, there is a strong precipitation gradient of high westerly rainfall (up to 7000mm / year) to the drier east (as low as 500mm / year), with three distinct ecoregions: the south Western Ghats moist deciduous forests, south Western Ghats montane rainforests, and south Deccan Plateau dry deciduous forests. Habitat types thus transition from westerly tropical semi evergreen and moist deciduous forests, through deciduous and dry deciduous forests, to the dry scrub and thorn forests of the east. There is also a strong altitudinal influence, with higher elevations associated with wet montane shola forests and grasslands.

As one of the critical catchment areas of peninsular India, several major watercourses such as the Bhavani, Moyar and Kabini rivers provide fresh water and hydroelectric power to the towns and cities within and surrounding the NBR, to the southern Deccan Peninsula, and the plains of southern Tamil Nadu. However, the multitude of dams and hydrological projects, particularly in the Kundah, Bhavani and Moyar basins, have changed the hydrology of the NBR. Part of the Western Ghats mountain range, the rugged terrain spans the main massifs, leveling out towards the eastern plains. For much of the NBR, the heavy showers of the north-east monsoon fall in October to December, while the south west showers are more intermittent between June to September, particularly in the easterly parts which lie in the rain shadow of the Western Ghats.

Approximately 4,500km^2 is protected at a high level (Table 1 and Appendix A2) as either National Parks (IUCN Category II Protected Area) that permit no anthropogenic use and are managed by the National Board for Wildlife; or as Wildlife Sanctuaries and designated Project Tiger Reserves (IUCN Category IV Protected Area) which may assign rights to indigenous groups under the State Board for Wildlife. More land is protected to a lesser extent in Reserve Forests, declared at the state government level, much of which forms a contiguous network across the NBR. Protected areas in India are managed under the Wildlife (Protection) Act 1972, as amended, and also falls under the remit of the Indian Forest Act 1927, Forest (Conservation) Act 1989, Environment (Protection) Act 1986, Biological Diversity Act 2002, and the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act 2006. Additional funding for protected areas is provided by the Ministry of Environment and Forests to State/Union Territory Governments under three main schemes: Integrated Development of Wildlife Habitats, Project Tiger and Project Elephant.

A high proportion of the Western Ghats' biodiversity is represented in the NBR (Daniels 1993), with several species endemic to the NBR: 23 species of fish, the Nilgiri laughing thrush *Garrulax cachinnans* and the mouse *Mus famulus*, while 156 of the 285 species of vertebrates endemic to the Western Ghats are found in the NBR. Rich in floral diversity, 132 flowering plant species are endemic to the NBR, including the genus *Baeolepis* and 8 endemic orchids.

The NBR hosts significant populations of large mammals, including some of the highest densities of large carnivore and herbivore species in Asia, and a last stronghold for the tiger *Panthera tigris* and Asian elephant *Elephas* *maximus* (Karanth and Sunquist 1992, Kumar 1999, Karanth and Sunquist 2000). With a diverse predator and prey assemblage, other carnivores include leopard *Panthera pardus,* dhole *Cuon alpinus*, sloth bear *Melursus ursinus,* and herbivores such as gaur *Bos gaurus*, sambar *Cervus unicolour,* chital *Axis axis,* wild pig *Sus scrofa,* and muntjac *Muntiacus muntjak.* Recent elephant and tiger censuses highlight the NBR mosaic of protected areas as containing the majority of the remaining Indian populations, holding between 5,000 – 8,000 elephants (Rangarajan et al. 2010) and 382 tigers (Jhala et al. 2011). It is becoming increasingly apparent that significant populations of wildlife are present outside of protected areas and moving throughout the wider landscape (Bhagwat et al. 2005, Bali et al. 2007).

From February/March until May/June, in India's summer months, large mammals migrate from Mudumalai Wildlife Sanctuary in Tamil Nadu (the easterly part of the NBR), through Bandipur Tiger Reserve in Karnataka, into Wayanad Sanctuary in Kerala (the westerly part of the NBR) following the availability of water (CEC 2000). However, with the loss of large areas of forest throughout the NBR, it appears that traditional migratory routes, such as for elephants, have been disturbed (Menon et al. 2005). The protected area network is thus increasingly fragmented, and much of the biodiversity rich areas in the Western Ghats falls outside protected areas (Das et al. 2006) that still retain native vegetation, such as plantation landscapes of shade coffee and tea, or heterogenous farming or pastoral landscapes. These are also more likely to be subject to conflicts between people and wildlife. Villages surveyed for this study ranged from being within a Protected Area (PA) to up to 35km away, but given the mosaic nature of the landscape, were never more than 4km from a forested area, usually designated as Reserve Forest.

Culturally, in India tolerance for wildlife has been a long-standing tradition, particularly towards large mammals (Sukumar 1994, Madhusudan and Mishra 2003) which continue to persist despite the highest human densities globally. Religious practices continue to revere and worship deities symbolised by wild animals, such as Ganesha the elephant god, and the tiger as the steed of the goddess Durga, as positive forces (Rangarajan 1998). Hunting continues to be illegal in India, and although it is considered a serious threat (Velho et al. 2012) there is little Indian tradition of extermination or persecution, as opposed to European and North American histories (Schwartz et al. 2003); despite the best efforts of the British, who established hunting preserves and bounties on pest species (Rangarajan 2001).

Table 1: Protected areas in the NBR (designation, area, and date established)

State	**Protected Area**	**Area (km^2)**	**Date designated**
Kerala	Wayanad WLS & ER	364	1973
Kerala	Silent Valley WLS	237	1980
Kerala	Mukurthi NP	81	2001
Tamil Nadu	Mudumulai WLS & TR	344	1940
Tamil Nadu	Sathyamangalam WLS	1,412	2008 (enlarged 2011)
Karnataka	Nagharole / Rajiv Gandhi NP & TR	707	1988
Karnataka	Bandipur NP & TR	877	1973
Karnataka	Biligiri Rangaswamy Temple WLS & TR	540	1974 (enlarged 1987)

Abbreviations: WLS = Wildlife Sanctuary; ER = Elephant Reserve; NP = National Park; TR = Tiger Reserve;

Key threats to the NBR include habitat fragmentation and loss, over-exploitation of forest resources, and large-scale development projects that have cleared large areas of wildlife habitat, for roads and major highways, hydroelectric dams and reservoirs.

An ongoing influx of settlers and an increasing human population has led to significant changes in forest cover. Non-native monoculture plantations threaten many of the native tree species, with extensive timber plantations of *Eucalyptus spp.*, and *Acacia spp.*, and cash crops of tea *Camellia sinensis* and coffee *Coffea spp.*, which are increasingly becoming less shade grown or reliant on non-native shade trees such as silver oak *Grevillea robusta*. Agricultural expansion is encroaching into both reserve forests and protected areas. High altitude native habitats such as shola forests and grasslands are especially threatened by land use changes. Fuelwood collection has been cited as a major driver of forest degradation (Puyravaud et al. 2010) and there are claims that collection of non-timber forest products may also be unsustainable (Davidar et al. 2010). However, it is difficult to quantify the extent of forest degradation in India, given official government reports of increasing forest cover and the lack of rigorous independent studies (Davidar et al. 2010, Puyravaud et al. 2010), although there is some evidence that land use change has resulted in decreasing forest cover in the Western Ghats (Jha et al. 2000, Davidar et al. 2010).

Livestock keeping is also a growing issue, with estimates of 65 cattle/km^2 in the Sigur region (Ganesan 1993), to 236 animals/km^2 on the northern boundary of Bandipur National Park (Madhusudan 2005). Livestock compete with wildlife for resources, depressing populations (Madhusudan 2004) and potentially reducing fodder availability (Baskaran et al. 2012).

The hill stations and protected areas in the NBR are major tourist attractions, and unregulated tourism has led to a proliferation of resorts and the associated impacts on wildlife and habitats. This has been particularly noticeable with recent media and political attention on the 2012 temporary ban on tourism in tiger reserves[1]. Tourism proponents claimed banning tourism would cause the extinction of tigers without monitoring by tourist operators and the loss of public support fuelled by tiger tourism; while tourism opponents claimed tourism was the main threat to tigers due to the disturbances it caused and that tourist use of protected areas was favoured over the rights of local people (Karanth and Karanth 2012). This latter accusation has been further compounded by the 2006 Forest Rights Act, which has recently been implemented in practice to award local communities traditional rights and responsibilities over their local forests. This has divided personal opinions of conservationists and the urban population, many of whom strongly believe rural communities are unable to sustainably manage these resources[2].

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[1] The interim order of the Supreme Court in Writ Petition 12351/2010 (Ajay Dubey vs the National Tiger Conservation Authority)

[2] http://www.conservationindia.org/articles/whose-forest-is-it-anyway

2.1.2 Nilgiri Wayanad Plateau

The Nilgiri Wayanad Plateau extends for nearly 740 km^2 in the north western part of the NBR, separated from the Nilgiri and Sigur Plateaux by the Moyar River. Since British times, the deciduous forests have been managed for teak and timber. Now, the eastern fringes of the plateau are protected within Wayanad Wildlife Sanctuary, Nagharole National Park, Bandipur National Park, and Mudumalai Wildlife Sanctuary. Human populations are highest in the central and western parts of the plateau, where shade coffee cultivation (*Coffea arabica* and *C. robusta*) is prevalent. Rice is grown in swampy valleys, and tea plantations are dispersed at higher elevations. The region sampled in this study focused on the villages located in Wayanad district, Kerala. The terrain in Wayanad is primarily hilly and mountainous, contributing to the isolation of this area over the centuries and the lack of railways. Ranging from 700 – 2100m asl with the average elevation on the plateau being 800m asl, annual rainfall varies from 1500-2500mm/yr. The forests comprise semi evergreen patches in the west, to moist and dry deciduous forests in the east. The entire district was heavily forested in the past, with much of the remaining forest located in the Wayanad Wildlife Sanctuary. The Sanctuary is split into North and South divisions, and is part of one of India's largest elephant reserves. The Kabini River drains the entire district.

The major Adivasi (tribal) groups include the Paniyas, Kattunaickens, Kuruchiars and the Mullu Kurumbas, many of which have been displaced into the hilly and least accessible parts of the district. Much of the forest was converted into estates of coffee, rubber, tea and other cash crops during land seizures. Human wildlife conflict in the area has been focused on agricultural crops (92% of damage), with low incidences of human injury (1.1%) and death (0.6%) (Bashir 2000). The livelihoods for most of the tribal communities is wage labour or forest product collection, except for the Mullu Kurumbas and Kuruchiars who own some land. Forest products are the primary livelihood, based on collecting honey, fruit of the *Acacia concinna* (shikakai), the ayurvedic herb *Sida acuta* (kurunthotti), tree and stone moss; particularly for commercial production, but also for personal and medicinal use. Although the forests are protected, they are intensively used, with grazing pressures from the Karnataka side. Many people from the northern part of Wayanad migrate to Coorg as estate workers, given limited labour opportunities. Wayanad is considered to be an important contributor to foreign exchange earnings for Kerala, despite the problems of land and settlers.

2.1.3 Nilambur Plain

The 355km^2 Nilambur Valley lies to the west of the Nilgiri Plateau, which descends from over 2500m asl to 80m asl. Precipitation is high, from 2500-5000mm/yr, and coupled with the altitudinal variation has resulted in high botanical diversity with several forest types. The area includes two forest divisions, Nilambur North and South and the New Amarambalam Reserve Forests. Part of a forest belt running through Kerala, the Nilambur forests are contiguous with Silent Valley National Park to the south. West coast tropical evergreen forests are found at 800-1250m asl, with rainfall of over 2500mm/yr, changing to west coast semi-evergreen *Dipterocarp* forests at 500-800m asl. Moist deciduous forests eastwards experience more anthropogenic disturbances than the west coast forests. Southern sub-tropical evergreen (hill) forests and southern montane wet temperate forests are found along the ridges and upper reaches, with shola forests and grasslands at the highest elevations. The extensive teak *Tectona grandis* plantations in the region are the oldest in the country, and most of the remaining forests have been used for timber production due to easy transport along the Chaliyar river. These remnant lowland evergreen forests are one of the most threatened forest types in the Western Ghats. The forests provide the western part of the district and much of Kerala with water, the most important rivers being the Chaliyar and the tributaries of Karimpuzha and Cherupuzha.

The Adivasi tribes in Nilambur place great importance on the forests for social, cultural and economic purposes, major hill tribes being the Cholanaickens, Kattunaickens, Pathinaicken, Paniyas and Aranadans. For most of these communities, gathering for food has been replaced by gathering for income. Livelihoods are split into forest and non-forest activities. Forest products include honey, resin, bamboo, rattan, forest fruits, and roots with medicinal value. Other activities include wage work in agricultural fields and rubber estates, in plantations, bamboo cutting, collection of reeds, keeping livestock or practicing some agriculture. In this area, poaching is a major problem, usually attributed to outsiders entering the forest at night and hunting. Conflict with wildlife is increasing in the border regions of the forest and agricultural lands, including human injuries and death. Collection of non-timber forest products may be unsustainable, and human induced forest fires are increasing in some areas.

2.1.4 Sigur Plateau

The Sigur Plateau lies in the north east of the NBR, covering 340km^2 at an average elevation of 1000m asl. In the rain shadow of the Nilgiri Plateau, the average rainfall is approximately 1000mm/yr in the western parts to 500mm/yr in the east, with a dry season of up to 8 months. Low rainfall and the prevalence of malaria have contributed to low human populations. This rainfall gradient is reflected in the botanical diversity, from deciduous forests and riparian tracts with mighty trees in the west to a stunted scrub vegetation in the east. The Sigur Plateau is connected to the deciduous forests of Bandipur National Park and Mudumulai Wildlife Sanctuary in the west, and Sathyamangalam Wildlife Sanctuary to the east. The Moyar gorge divides it from the Mysore plateau to the north.

Within the Sigur Plateau, this study focused on two regions that include the major protected areas: the eastern edge of Mudumulai National Park in Tamil Nadu; and the region surrounding the Sathyamangalam Wildlife Sanctuary and Biligiri Rangaswamy Temple Wildlife Sanctuary which overlaps Sathyamangalam in Tamil Nadu and Chamrajnagar in Karnataka. The landscape to the east of Mudumalai National Park links a number of protected areas, hence supports high densities of large mammals and is an important elephant corridor within the NBR. Threats include heavy overgrazing, invasive plants and human population growth. Before independence, the Nilgiri Game Association was formed in this area in 1877 to regulate hunting, giving exclusive rights to the ruling elite and excluding the indigenous populations of Adivasis. After independence, there was a focus on hydropower projects across the plateau with numerous dams; and pastoralism, with cattle being reared for milk and dung in the savanna woodlands, most recently to provide manure for organic farming (Madhusudan 2005). The Sathyamangalam forests form a large tract that runs from the Moyar Valley to the Dhimbam hills, including Sathyamangalam Wildlife Sanctuary, under the Sathyamangalam Forest Division. Typifying the Eastern Ghat ecotype, the forests are tropical dry forests, part of the South Deccan Plateau dry deciduous forest ecoregion, and including thorn forest, dry deciduous, and tropical hill forest. The major Adivasi groups are the Irulas and the Soligas, traditional hunter-gatherers which are now primarily settled in isolated agricultural villages. The main crops are rainfed vegetables and ragi, and each family typically has 1-2 acres of land. Recently, drought has caused poor yields and food has become scarcer. The Adivasis also continue to depend on NTFPs (Non-Timber Forest

Products), predominantly *amla* and *seemar*; and work as wage labourers on nearby estates. Chamrajnagar district lies in the lee of the Nilgiris, mostly semi-arid rain-dependent flatlands and forested hills. Forest types range from scrub to deciduous and riparian, with extensive coffee plantations. The main protected area is the Biligiri Rangaswamy Temple Wildlife Sanctuary, contiguous with the forests of Sathyamangalam, where the Western Ghats ecotype meets the Eastern Ghats. The main Adivasi group is the Soligas, who depend on the forest for NTFPs, collecting honey, gooseberry *Phyllanthus spp., Phoenix spp.,* and lichen. The Soligas also practice shifting cultivation to grow ragi as their staple diet.

2.1.5 Nilgiri Plateau

The Nilgiri Plateau is a gently rolling plateau with an average elevation of 1800m asl, colonised for several centuries. In the 1800s the British established coffee and tea plantations, and replaced native species with pine *Pinus spp.*, wattle *Acacia spp.,* bluegum *Eucalyptus spp..* Natural shola forests and grasslands are now restricted to the southwest, in Mukurti National Park. The plateau contains eight large reservoirs that provide water and electricity to more than a million people on the plains.

Within the Nilgiri Plateau, data collection focused on the Kotagiri area in Tamil Nadu. The Kotagiri slopes rise dramatically from 300m asl in the valleys to 2000m asl on the plateau, with precipitation ranging from 800-1500mm/yr, with much less rain in the easterly slopes. The Moyar river runs to the north, flowing through the gorges of the Sigur range, and to the west is the plateau of the Ooty region. The Kallar river valley separates the Kotagiri slope from the Coonoor slopes to the south. Much of the remaining forests are located on the slopes which support good wildlife populations, with the vegetation on the plateau fragmented by tea estates. On the slopes below 1000m asl, there are dense dry deciduous forests and savanna woodland, and tracts of riparian forests which include the endangered *Cycas circinalis.* From 1000-1800m asl, species-rich semi-evergreen forests hosting the endangered *Canarium strictum* (Agasimami 2003) are under threat from expanding tea estates. The high altitude shola forests on the plateau, although protected as Reserve Forests, are highly fragmented and face pressures from fuel wood collection. There are several Adivasi groups in the region. The Irulas and Kurumas have forest settlements typically located at 800-1000m asl. These groups practice shifting cultivation and collect NTFPs, including fruit of the *Phyllanthus emblica*, and leaves of the *Phoenix humilis,* and honey gatherers frequent the rock bee *Apis dorsata* nests in the cliffs of the eastern slopes. There is also access to wage labour, which is on the increase. The Todas and Kotas live in hamlets on the plateau, as pastoralists, agriculturalists, and employed in government jobs. The Kotagiri region is the source of many major rivers which flow into the Bhavani and the Moyar rivers.

2.1.6 Coimbatore Plains

The Coimbatore Plains lie to the east of the NBR, extending for 525km^2 at an average elevation of 300m asl. In the southwestern rain-shadow of the Nilgiri Plateau, rainfall ranges from 500-1250mm/yr during the northeast monsoon. Access from the plains of Tamil Nadu and the presence of Coimbatore, a large trading town, means that this region has been densely populated historically until the present day, and remnant forests are degraded, exploited for fuelwood, bamboo, sandalwood and other forest produce.

Within the Coimbatore Plains, this study focused on Pillur, in an isolated part of Coimbatore district. It is densely forested and relatively less populated over hilly terrain. Pillur borders the Kerala forests to the west and the Coonoor slopes of the Nilgiris in the north. The botanically diverse forests range from dry deciduous to scrub savanna woodland, with riparian evergreen patches and bamboo breaks. Major groups in Pillur include several villages of Adivasi Irulas, some traders linking the tribal communities to the outside world, and a large village of recent settlers. Villages in this region are forest settlements close to the single major road passing through the area. Several of the more isolated villages have been provided with government solar fences to protect crops from raiding by elephants. The area is well supplied with water due to its westerly aspect, and some villages have access to irrigation. Land parcels are usually large with families typically owning 4-5 acres. Crops grown include sesame, horse gram, ragi, and many vegetables. The main Adivasi occupation is NTFP collection, especially honey gathering, and people depend on the forest for much of their needs, bartering forest products in markets for produce such as cereals. Other villages practice agriculture or take wage labour for richer farmers or tea estates, or are employed in government run projects or for the forest department.

2.1.7 Attapadi Plateau

The Attapadi Plateau covers c. 840 km^2 at an average elevation of 800m asl, bordered by the Nilgiri Plateau and the Palghat Gap, a lowland separating the Nilgiris from the southern Western Ghats. Rainfall varies from 800-4000mm/yr across the west-east rainfall gradient. Vegetation varies along this gradient from westerly evergreen forest to scrub-savanna in the east. The forests have been extensively used for timber since the 1800s under British control, and there are plantations of eucalyptus and teak, although commercial timber extraction is now rare. Several tributaries drain into the major Bhavani river which flows through Tamil Nadu. This region contains Silent Valley National Park, still relatively undisturbed, with high floral and faunal diversity and described as the sole surviving major tract of evergreen forest in the Western Ghats. Towards the east of the plateau the vegetation is dry deciduous forest.

The area surrounding Silent Valley National Park was the focus of this study. The landscape has been mostly fallow but recent development interventions have promoted cultivation with the establishment of teak and bamboo plantations. Indigenous Adivasis are primarily Irulas, with some Mudugas and Kurumbas; and settlers have also come from both Tamil Nadu and other parts of Kerala. Local communities have traditionally practiced shifting cultivation although this has diminished over time. Other livelihood activities include agriculture such as the cultivation of millets, NTFP collection and wage labour. Forest degradation and the lack of irrigation has affected the livelihoods of residents, particularly the tribal groups.

2.2 Demographics of villages within the NBR

2.2.1 Sample villages and survey methodology

Across the NBR, 62 villages with differing community composition, population size, and ecological attributes were sampled to investigate levels of human-wildlife conflict (table 2, Appendix A2). These villages comprised both tribal and non-tribal communities, and were sampled based on variation in ecological and socio-economic attributes, but also for logistical reasons of access. Preliminary visits invited interested representatives to attend a group interview on behalf of the village as a whole. To standardise data collection, training workshops were held with the field staff who conducted the interviews, piloted in four villages and refined during the course of training. A village-level standardised semi-structured questionnaire survey was then conducted at each village with a small group of representatives to obtain data at a village level (appendix B), between May 2009 to August 2009. Villages selected for the village-level and household-level surveys are listed within their respective zone in Table 2 and also shown in Appendix A2.

Eighteen villages out of the original 62 surveyed were chosen for an in-depth assessment at the household level. These villages were chosen on the basis of a number of criteria, in the following order of importance: 1) dependence on livelihoods vulnerable to human-wildlife conflict (HWC); 2) perception of conflict combined with measures of actual and proportional loss (including retaliation and negative attitudes); 3) areas where large mammals of conservation concern are causing conflicts. Villages that fulfilled multiple criteria using data from the initial village level survey were prioritised. The villages chosen for the household-level survey included villages from all zones, excepting Attapadi, which was subsequently excluded for logistical reasons as access became too difficult over the course of the study. The selected villages were of different sizes, and covered a range of communities, generally divided into Adivasis and non-tribals (also known as settlers) for the purpose of this study. Ecologically, the villages covered the main precipitation, altitudinal and hence vegetation gradient. However, the subset of villages reflected the original sample size, focusing on villages near protected areas, and those with tribal communities.

These final 18 villages were then the focus of a range of data gathering exercises, for which training was undertaken with the field staff to ensure a standardised approach across survey personnel. Households in each village were questioned using the household level survey (appendix C1). General data on the village was obtained, such as decision-making structures, infrastructure and development, resources and access to opportunities. A conflict monitoring scheme was set up at each village whereby incidents of conflict were reported to and recorded by field staff (appendix C2). This record of conflict incidents throughout the study period enables validation of actual losses against reported losses in the questionnaires, and allows for the measurement of the effectiveness of intervention measures.

Full details of the data collected at both village and household level are given in the relevant data chapters. Contextual description of some of the results are presented in the following sections to characterise the conflict landscape of the NBR.

Table 2: Surveyed villages in which the Perception Survey and Evaluation Survey (in bold) were undertaken, classed in their respective regions

Zone (from west to east)	No. villages (village-level surveys)	No. villages (household-level surveys)	Village Names
Nilgiri Wayanad Plateau	10	5	**10th mile,** Cheengod, Cheeyambam73, **Chegadi, Chembra, Koloth, Pazhuppathur,** Puthiyoor, Valluvadi, Varayal;
Nilambur Plain	9	2	Ettapara, **Nedungayam,** Nellikuttu/Randampadam, Palakayam, Pattakarimb, Pothukal, Punchakoli, Uchukulam/Theekady, **Vallipoola;**
Attapadi Plain	7	0	Chindakki, Kallamala, Karuvara, Puthuoor, Puthuvepadam, Thadikkundu, Uppalam;
Coimbature Plain	7	2	Baralikadu, **Kadamankombei,** Kandiyur, Kil sengalur, Kodiyur, Maanar, **Poochamarathur;**
Nilgiri Plateau	11	4	**Bangalapadigai, Bikkapathy mund,** Eelada, **Garikiyur,** Jakkanarai/Banagudi, Kambattikombei, **Kilcoupe,** Masakal, Mund(koduthen mund), Nedugula, Vellarikombei;
Sigur	18	5	Anaikatti, Boothanatham, **Chemmanatham, Kurumbarpallam,** Singara, Siriyur, Vazhaithottam; Bejalhatti, Bhudipadagai, Bhuthalapuram, Kaangarai, Kadambur, **Mavalla,** Odayarpalayam, Pulinjur, Pulinjur/Muneeswara Colony, **Ramaranai, Talamalai;**

2.2.2 Social attributes

The villages sampled covered a range of demographics (Table 3). Population and household numbers were variable, although household size was fairly consistent. Villages and individuals were asked which community they belonged to, and volunteered the level of detail they were willing to provide, although the resulting data were presented as split by Adivasi and non-tribal. Specific details on caste were not asked or presented to follow ethical guidelines. The proportions of Adivasis and non-tribal or settler communities were variable, but biased towards Adivasi communities to some degree. However, the total number of households in a village was significantly negatively correlated with the percentage of Adivasi communities present: larger villages held a greater proportion of non-tribal communities.

Table 3: Social attributes (population size, household number, household size, and percentage of Adivasis) of areas sampled in the Nilgiri Biosphere Reserve

Social Attributes	**Nilgiri Wayanad**	**Nilambur**	**Attapadi**	**Coimbatore**	**Nilgiri**	**Sigur**
Av. population size	332.2 ±100.5	270.3 ±99.1	217.1 ±43.1	106.6 ±23.2	403.5 ±181.8	373.1 ±62.9
Av. household number	80.9 ±25.5	68 ±23.4	40.1 ±8.8	23.6 ±4.1	97.3 ±44.0	84.9 ±15.7
Av. household size	4.5 ±0.2	3.8 ±0.23	5.5 ±0.4	4.3 ±0.6	4.2 ±0.5	4.6 ±0.4
Av. Adivasi %	60.6 ±13.2	69.6 ±15.4	70.1 ±18.1	100 ±0	66.7 ±14.2	82.3 ±7.5

2.2.3 Land and ownership

To obtain an overview of village/zone level economic status, a number of variables were investigated: village size, land holdings, irrigation, commercial crops, and overall crop or livestock holding (Table 4). These can all be considered as indicating a higher economic status. As expected, larger villages tend to hold, own, farm, commercialise or irrigate more land, and have a greater worth of crops and/or livestock, showing a significant positive correlation between these variables. Since all these variables are closely linked, they appear to reliably indicate a measure of economic status.

Table 4: Economic attributes (village land, farmland, irrigation, ownership, crop holdings and livestock holdings) for each area sampled in the Nilgiri Biosphere Reserve

Economic Attributes	**Nilgiri Wayanad**	**Nilambur**	**Attapadi**	**Coimbatore**	**Nilgiri**	**Sigur**
Av. village land	214.4 ±105.0	57.2 ±43.3	55 ±16.1	74.6 ±14.4	165.3 ±88.1	158.9 ±37.2
Av. farmland	204.7 ± 102.5	12.7 ±5.9	51.1 ±14.6	30.6 ±10.2	64.3 ±23.0	125.3 ±29.7
Av. irrigated farmland	44 ±25.0	2.9 ±2.2	2.3 ±1.7	6.9 ±4.6	3.2 ±1.8	1.6 ±1.1
Av. owned land	209.3 ±105.9	56.1 ±43.5	41.7 ±17.1	17.3 ±7.6	65.7 ±22.7	52.2 ±17.8
Av. commercial crop acreage	144.9 ±80.3	19.6 ±9.0	18.2 ±10.9	16 ±5.2	125.1 ±81.3	80.9 ±25.2
Av. crop holding (lakh Rupees)	8.8 ±4.9	15.4 ±8.2	8.0 ±5.6	1.4 ±0.8	11.9 ±7.6	2.5 ±0.9
Av. livestock holding (lakh Rupees)	10.3 ±3.1	1.1 ±0.3	5.7 ±2.0	2.2 ±0.8	3.3 ±1.0	19.7 ±8.3

Correlated variables were removed from later data analysis, and only farmland was retained as a potential predictor for the statistical models. The 'wealthiest' to the 'poorest' zones through a combination of these attributes emerge as: the Nilgiri Wayanad Plateau, Nilgiri Plateau, Sigur, Nilambur Plain, Attapadi Plain, and Coimbatore Plain.

Other community issues are apparent from the data. For example, the percentage of tribal communities is negatively correlated with village land, owned land, irrigated farmland, numbers of households owning land, the acreage of commercial crops, and the total value of the crop holding; while it is positively correlated with the land cover of crops palatable to wildlife. This would suggest that tribal communities own less land, with less ability to irrigate, grow less commercial crops and more palatable subsistence crops, with implications in terms of access to investment for irrigation and the growing of commercial crops. The dominance of palatable crops may also predispose these communities to crop-raiding by wildlife.

2.2.4 Livelihood dependencies

Data were gathered on the main sources of livelihoods within each village. These were agriculture, livestock, forest related (forest products and forest watchers) and employment (wage labour, other employment, and leasing of land). Agriculture and livestock are the livelihoods subject to the most intense conflicts.

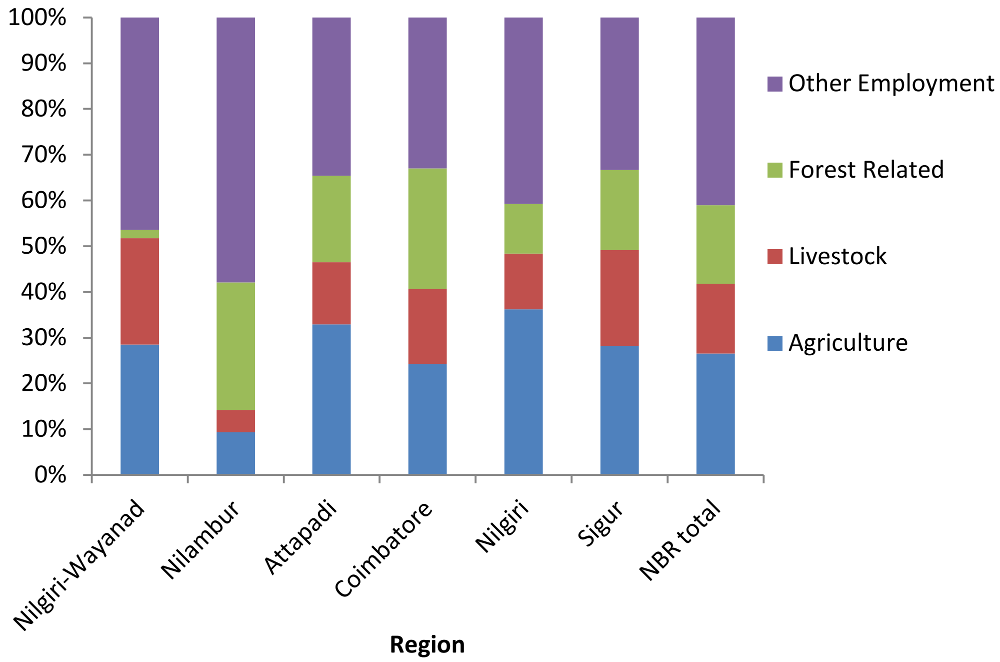


Figure 1: Livelihood dependencies (employment, forest related, livestock, agriculture) for villages in the regions of the Nilgiri Biosphere Reserve

Within each zone, the villages sampled covered the range from no dependency on these two livelihoods to wholly dependent, and the average dependency per zone is shown in Figure 1. Across zones, there is a significant difference in reliance on these two conflict-prone livelihoods (ANOVA: $F_{61,6} = 3.182$, $p = 0.009$, $n = 62$), implying that different zones may have different levels of vulnerability to conflict given their varying reliance on these livelihoods. Overall, employment makes up a just over a third of livelihood dependency, agriculture just over a quarter, while the remainder is split fairly equally between forest related and livestock. Almost all the areas depend on agriculture and livestock for approximately 50% of their livelihood, excepting Nilambur for which these livelihoods make up less than a quarter.

The level of reliance on agriculture and livestock correlates with a number of other variables. Agricultural reliance positively correlates with the number of households owning land, acres of owned land, percentage reliance on commercial crops, percentage land cover of commercial crops, but also with the acreage and percentage of abandoned land. This suggests that an increasing reliance on agriculture is coupled with increasing land ownership and increasing crop commercialisation, and possibly the economic leeway to permit the abandonment of unsuitable lands or those prone to crop raiding. Reliance on livestock keeping is correlated with the percentage of households sharecropping, and the percentage of acreage used for sharecropping, suggesting that the need for subsistence agriculture or fodder is met in this way alongside the keeping of livestock. Increasing livestock reliance is also correlated with numbers of large livestock (cattle and/or buffalo) and the total value of the livestock holding. The combined reliance on agriculture and livestock also correlates with the land cover of crops palatable to wildlife. This implies that households relying on both practices for income may also need to grow more fodder for livestock and subsistence foods for themselves that would also be palatable to wildlife, and may be associated with higher levels of conflict.

2.3 Agricultural practices and crop raiding contexts

Crop production experienced a variety of problems according to villagers, and the percentage occurrence with which each problem was cited is displayed in Figure 2 for the entirety of the NBR region, along with the average ranking, and average percentage of crop reported as lost to that problem. The mean rank of each crop problem is significantly different for each crop problem type (problem ranking Kruskal-Wallis: $p < 0.001$, $n = 62$), but there is no significant difference in the average percentage of crops lost to each problem type. This suggests that problems are perceived differently although the losses suffered are similar.

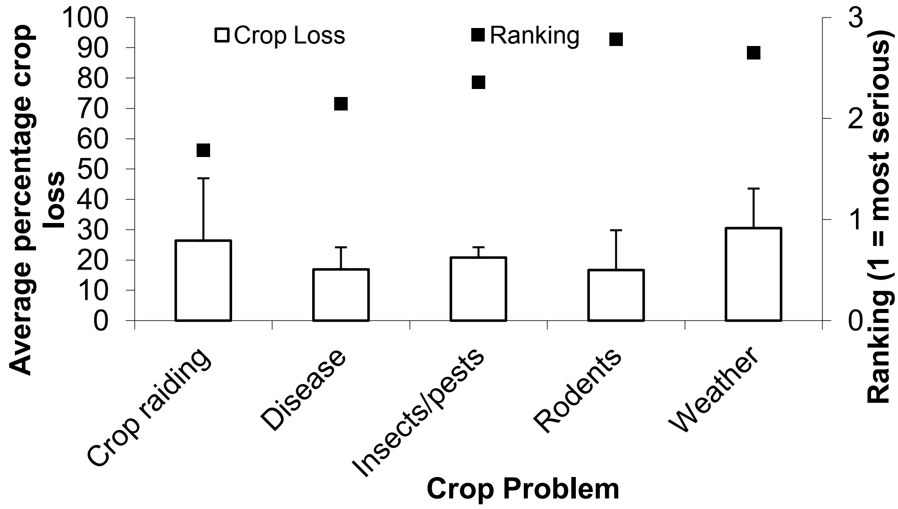


Figure 2: Average percentage of crop lost, and average ranking where 1 = most serious, for each problem facing crop production across the NBR

It is evident from the data that crop raiding is consistently ranked as the highest threat to crop production. By zone, the percentage contribution of each crop problem to loss is not quite the same, with weather causing the most losses, closely followed by crop raiding, then insects/pests, rodents and disease (Figure 3). Weather affects all zones to a major extent except Attapadi, although different weather problems are zone specific: only Nilgiri Wayanad lists climate change as a problem; heavy wind only affects Nilambur and Attapadi; while frost only affects Nilgiri. Drought is prevalent everywhere except Attapadi. Rodents and insects/pests also affect all zones except Nilgiri Wayanad.

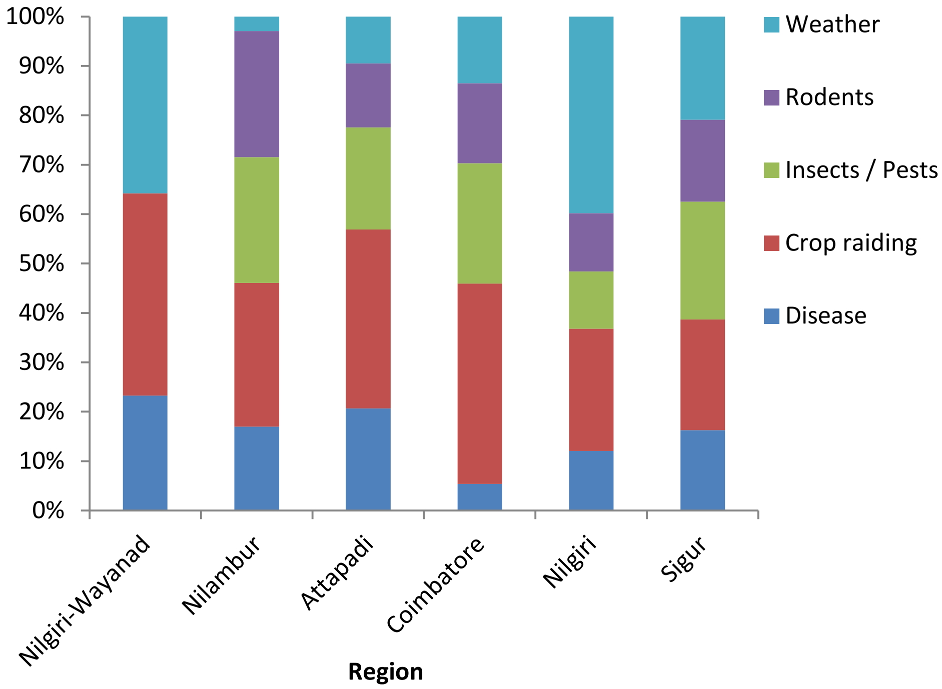
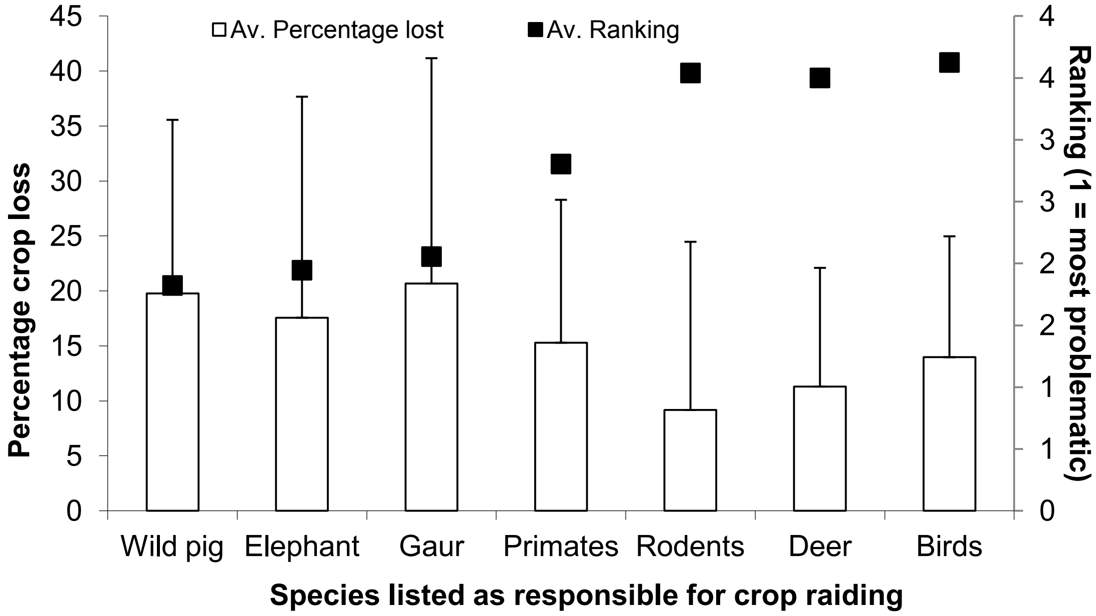


Figure 3: Percentage contribution each cited problem (weather, rodents, pests, crop raiding, disease) makes to overall crop losses by region in the NBR

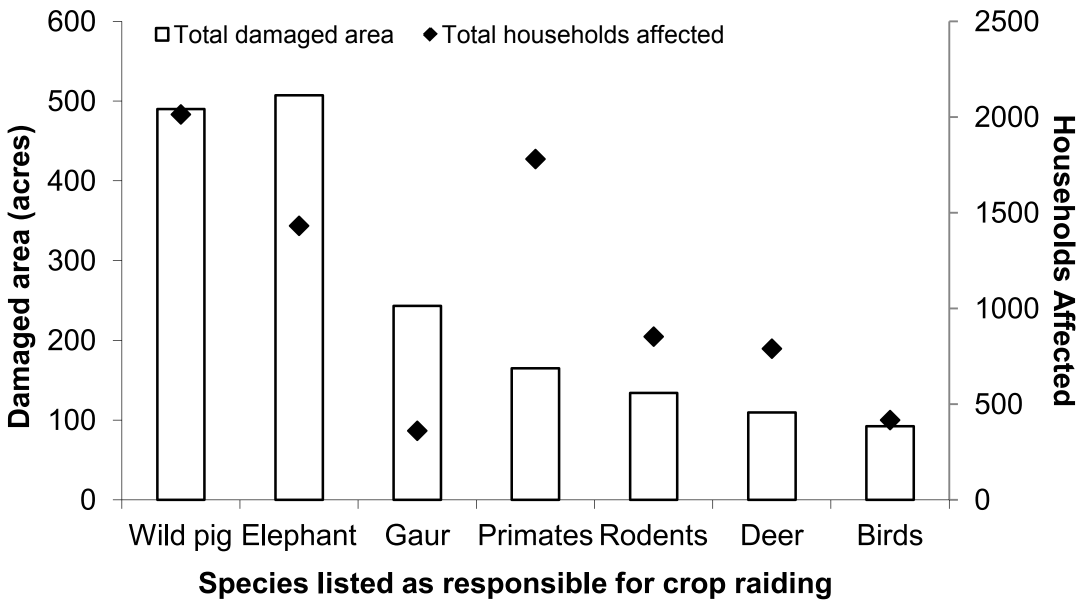
A total of 1456 households in 50 villages (out of 4471 households in 62 villages) reported suffering from crop raiding from 2007 - 2009, losing an average of 26% of their crops over an estimated 1778 acres, and a total of 14,325,650 Indian Rupees (143 lakh Rupees, equivalent to £162,278) from 2007 - 2009.

2.3.1 Wildlife species responsible for crop raiding

Wildlife species or groups of species that were perceived as most problematic across the NBR are displayed in Figure 4a, as the average ranking achieved (where 1 is the most serious or problematic species), and the average percentage of crop lost to that species. Figure 4b also shows the total reported area of crop lost to that species, and the total numbers of households affected by that species. There is a significant correlation between perceived rank and proportion lost, and between damaged area and numbers of households affected. Species perceived to be problematic are, in order of decreasing importance, wild pig, elephant, gaur, primates, deer (primarily sambar and chital but also muntjac), rodents (primarily porcupines), and birds. In general, species ranked as more problematic are responsible for greater percentages of crop loss, damaging larger areas and affecting more households. However, there are a few exceptions, such as gaur which affect very few households but are reported as causing a great deal of damage, or primates who affect very many households but cause much less damage.



(a)



(b)

Figure 4: Wildlife species across the NBR responsible for crop raiding showing (a) the average percentage crop loss and average ranking as a problem by taxa; (b) the total damaged area and households affected by taxa (wild pig, elephant, gaur, primates, rodents, deer, birds)

When analysing crop raiding by all species, perception, loss and impact of crop-raiding is significantly different by zone (perception Kruskal Wallis: $p < 0.001$, $n = 62$; proportion lost ANOVA: $F_{1,6} = 12.870$, $p < 0.001$, $n = 62$; damaged area ANOVA: $F_{1,6} = 7.823$, $p < 0.001$, $n = 62$), meaning that each zone suffers to a different extent from each species. Table 5 lists the top three species ranked as problems and the top three species causing the greatest proportion of crop losses in each region. These species are not always the same: elephants are perceived as problems in every zone, but actually cause the greatest losses in Nilambur, Coimbatore, Nilgiri and Sigur, but not in Nilgiri Wayanad or Attapadi. Wild pig are consistently problematic in all zones. Gaur are an actual problem in Nilgiri, though are perceived as problems also in Sigur. Other problematic species or groups include sambar, chital, porcupines, primates and birds.

Table 5: Top three wildlife species perceived as problems to crop production, and top three species actually responsible for causing the highest average proportion of crop losses

Zone	**Perceived problem species**	**Species causing highest average proportion loss**
Nilgiri Wayanad	Elephant, Sambar, Primates	Chital, Wild Pig, Primates
Nilambur	Porcupines, Wild Pig, Elephant,	Elephant, Birds, Wild Pig
Attapadi	Wild Pig, Chital, Elephant,	Wild Pig, Chital, Barking Deer
Coimbatore	Elephant, Primates, Wild Pig	Elephant, Primates, Wild Pig
Nilgiri	Elephant, Gaur, Wild Pig	Elephant, Wild Pig, Gaur
Sigur	Gaur, Elephants, Wild Pig	Wild Pig, Elephants, Porcupines

2.3.2 Seasonality

Crop raiding is strongly seasonal, with two clear peaks in numbers of incidents throughout the year, around May, just before the south-west monsoon, and in November, during the rains of the north-east monsoon (Figure 5), both corresponding with the main agricultural growing seasons. However, each peak is attributable to a different species – elephants in May and wild boar in November. The May incidents are most likely due to the lack of rain, and therefore fodder before the start of the south-west monsoon, when the forests become very dry and hence elephants may be supplementing their food sources with growing crops (Madhusudan 2003). During the north-east monsoon the growing crops are primarily raided by wild boar. Presumably there are sufficient forest resources during these rains to explain the reduced crop raiding by elephants at this time.

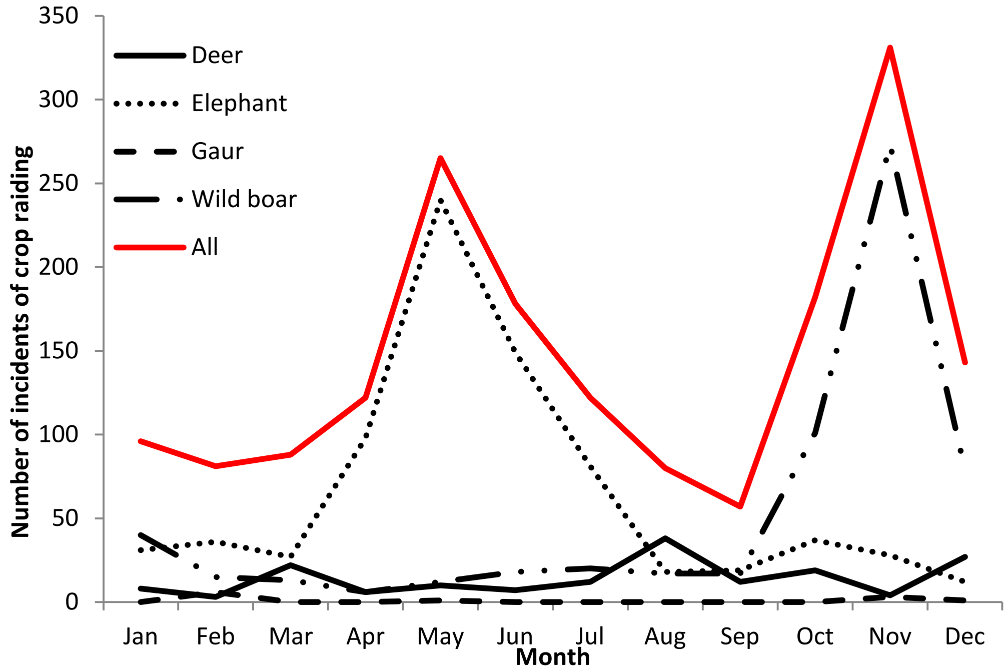


Figure 5: Seasonality in crop-raiding by wildlife species

In terms of temporal changes in crop raiding, 47.2% of villages considered crop raiding to have increased over time, as opposed to 30.6% who thought it had decreased and 22.2% who believed it had not changed.

2.3.3 Government awarded compensation for crop losses

The primary method of conflict mitigation in India is state-awarded compensation. Although electric fences and / or trenches are established around parts of protected areas, these are subject to varying degrees of maintenance and effectiveness (Rangarajan et al. 2010), hence recompense is awarded for losses. However, many problems with the existing compensation scheme have been cited, such as inadequate remuneration, delays, and corruption (Madhusudan 2003, Ogra and Badola 2008a, Rangarajan et al. 2010).

The village-level survey revealed that 262 households in 21 out of 62 villages had previously applied for compensation for crop losses. Of those, 57 households from 3 villages in Nilgiri Wayanad reported receiving compensation, a total value of R30,000 against the claimed-for loss in those three villages of R340,000 (Figure 6).

The household level survey in 18 sub-sampled villages revealed that only 18 households in 6 villages out of the 478 households surveyed had applied for compensation. Thirteen households in four villages had received some compensation, ranging from R300 – R20,000, although in some cases it took up to two years for compensation to be granted. Five households never received anything. A total of R63,500 was granted in compensation, just over 10% of an estimated loss of R610,000.

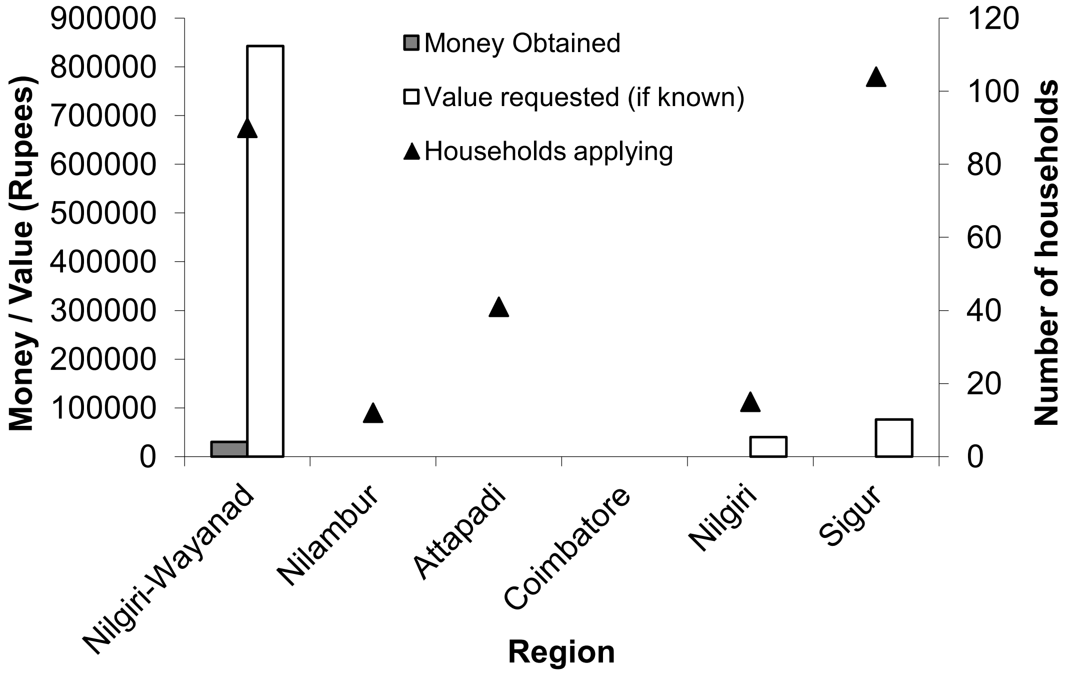


Figure 6: The number of households applying for compensation, the total money obtained, compared against the value applied for (where known), for each region in the NBR

2.4 Livestock keeping practices and depredation contexts

Livestock keeping experienced a variety of problems according to villagers, and the average numbers of major livestock reported as lost to each problem across the entire NBR from 2007 – 2009 is displayed in Figure 7 along with the average ranking of seriousness. The mean livestock numbers lost were not significantly different per problem type, however, the mean ranking did differ by problem type (Kruskal Wallis: $p < 0.041$, $n = 62$) implying that depredation is considered a main threat to livestock keeping despite similar losses per problem. Depredation was the main cause of loss, followed by disease, accidents, natural causes, fodder availability and drought. Perceptions of threat were slightly different, with depredation and disease ranked as most important, followed by fodder availability and accidents, drought, and finally natural causes.

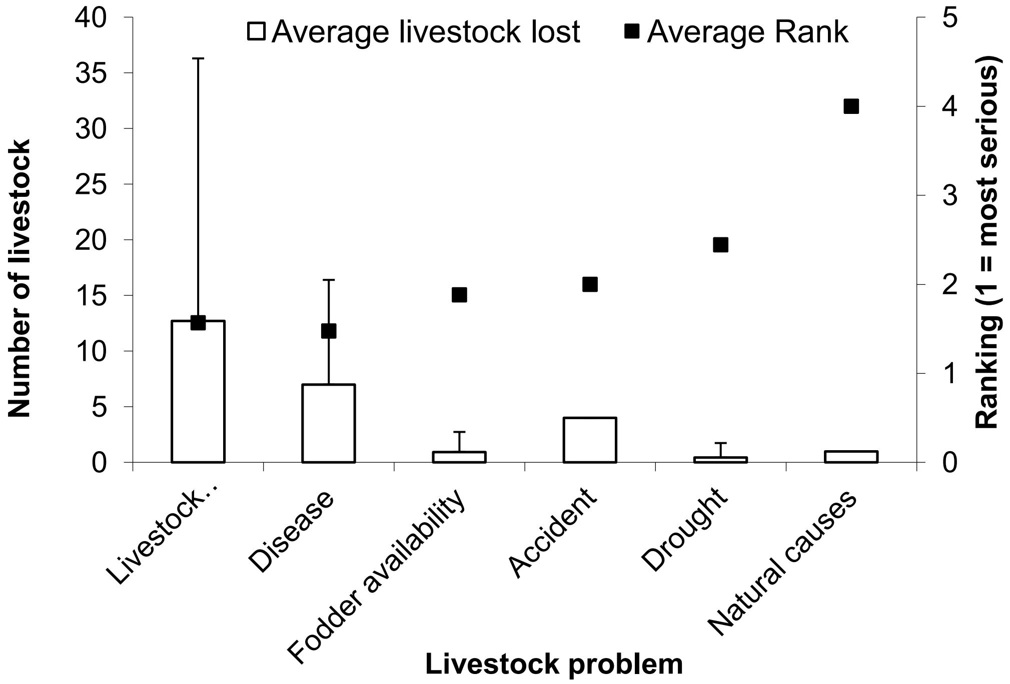


Figure 7: Average reported numbers of livestock lost to problems listed by villagers, and average ranking of seriousness, where 1 = most serious, across the NBR

Livestock problems were broken down further by zone, to analyse perception and loss. Livestock depredation was ranked as the most serious problem in Nilgiri Wayanad, Nilambur, Coimbatore, Sigur, but not Attapadi or Nilgiri, where disease was more serious. Livestock depredation affects similar numbers of households to drought and fodder availability, and on average is responsible for the most livestock losses, closely followed by disease (Figure 8). There were no significant differences by zone in the average numbers of households affected or average numbers of livestock lost to wildlife, implying that actual losses are similar across the NBR.

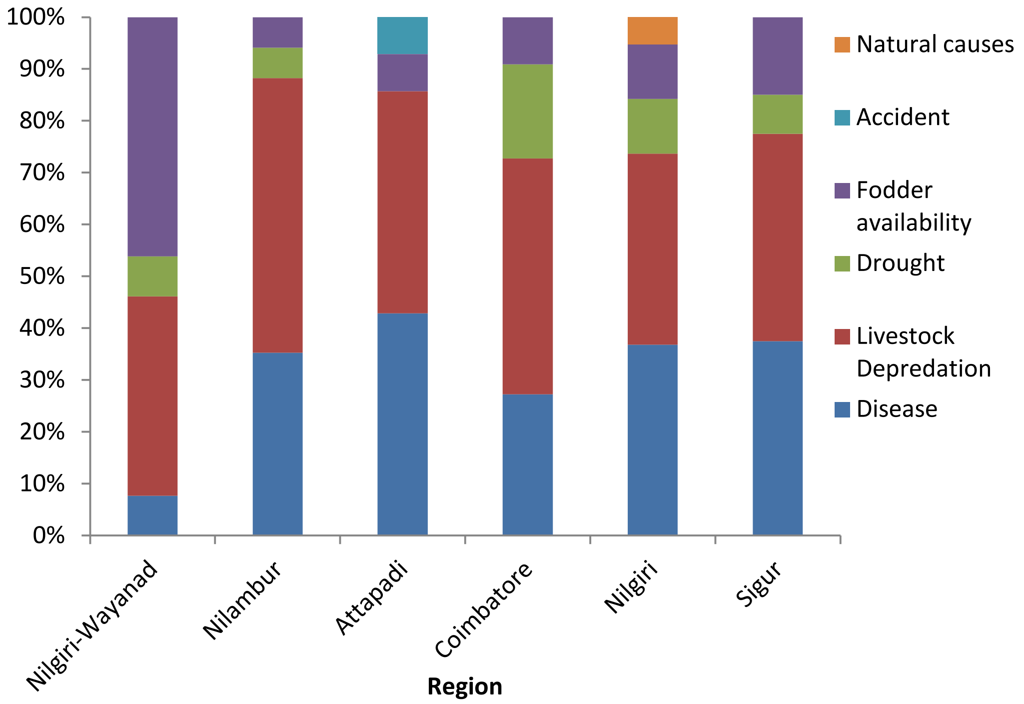


Figure 8: Percentage of occurrence of particular problems in village generated ranked lists of livestock problems (natural causes, accident, fodder availability, drought, livestock depredation, disease), by region

A total of 538 households in 48 villages (out of 4471 households in 62 villages) reported suffering from livestock depredation, losing a total of 1059 animals from 2007 - 2009, valued at 1,804,310 Indian Rupees (equivalent to £20,555), an estimated 3.2% of their livestock holding. During the monitoring period in 2010 - 2011 when losses were verifiable, a total of 308 animals were lost from 85 households across 18 villages, valued at 587,545 Indian Rupees (equivalent to £6,693), an estimated 9.3% of their livestock holding.

2.4.1 Wildlife species responsible for depredating livestock

Wildlife species perceived as most problematic across the NBR are displayed in Figure 9, as the average ranking achieved (where 1 is the most serious or problematic species), average number of livestock lost, and average value lost. Species considered problematic are, in order of decreasing importance, leopard, tiger and dhole, followed by small carnivores, including wild cat, mongoose, civet and fox.

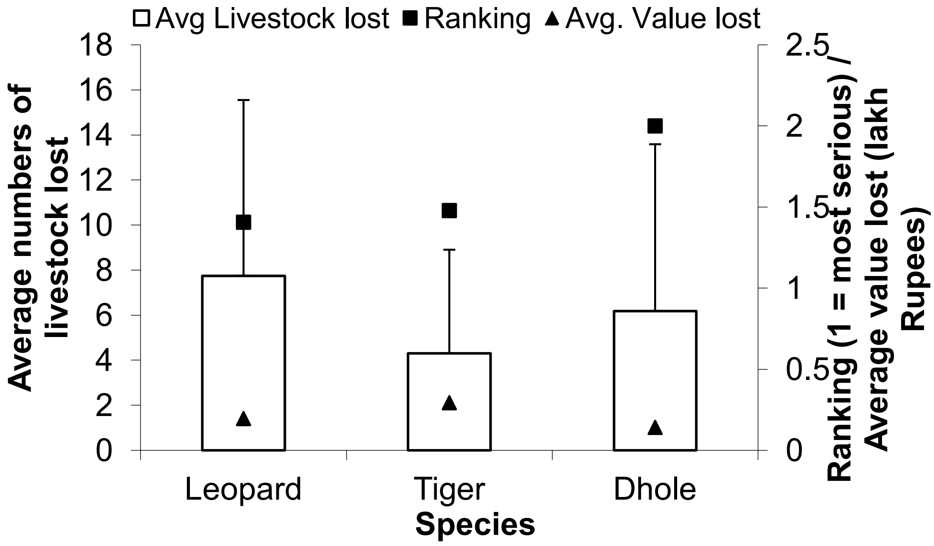


Figure 9: Wildlife species across the NBR responsible for livestock depredation, showing the average numbers of livestock lost, and average ranking as a problem, and the average value lost

When considering the entirety of the NBR, the following variables were significantly different between species: perceived ranking (Kruskal Wallis: p = 0.001, n = 62), numbers of livestock depredated (ANOVA: $F_{1,2} = 3.290$, p = 0.001, n = 62), value lost (ANOVA: $F_{1,12} = 2.788$, p = 0.003, n = 62). This means that each species has a significantly different level of depredation, and thus perceived ranking. But, when analysing livestock depredation by all species factored by zone, there were no significant differences by zone in perception or loss, meaning that all zones suffer to a similar extent from livestock depredation.

2.4.2 Seasonality

Livestock depredation is also seasonal, with the greatest peak in June at the end of the dry season / start of the south-west monsoon, with smaller peaks in April, before the monsoon, and during August/Sept at the end of the monsoon (Figure 10). However, the peaks correspond primarily with losses from village land. Forest losses peak in April and September, just before the south-west and north-east monsoon during the dry season, when cattle graze further into the forests (Madhusudan 2003).

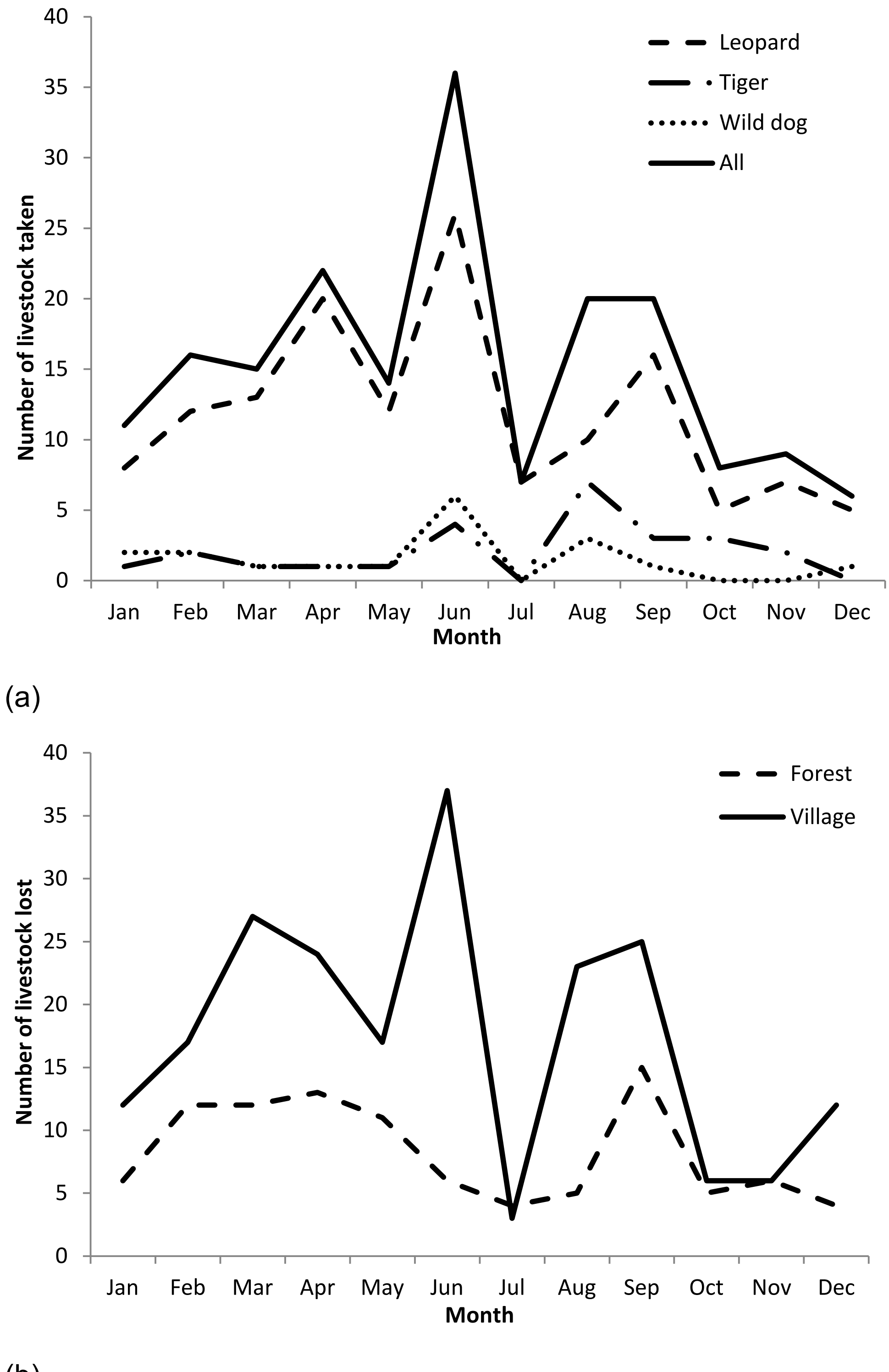


Figure 10: Seasonality in livestock depredation by (a) wildlife species (leopard, tiger, wild dog) and (b) depredation location (forest or village) across the NBR

Of all the responses given when asked if livestock depredation had changed over time, a majority of 59.4% claimed that it had actually decreased, whereas 40.6% claimed it had increased.

2.4.3 Government awarded compensation for livestock depredation

State managed interventions that consist of electric fences and trenches around parks are often broken to permit livestock to enter the park to graze. Thus the primary form of government mitigation is compensation for loss. With regards to compensation for livestock lost, the village level survey revealed that 88 households in 17 out of 62 villages had applied for compensation, and of those only three villages in Sathyamangalam and one village in Wayanad received any money, for a total value of R27,500 against the claimed-for loss in those three villages of R59,500 (Figure 11).

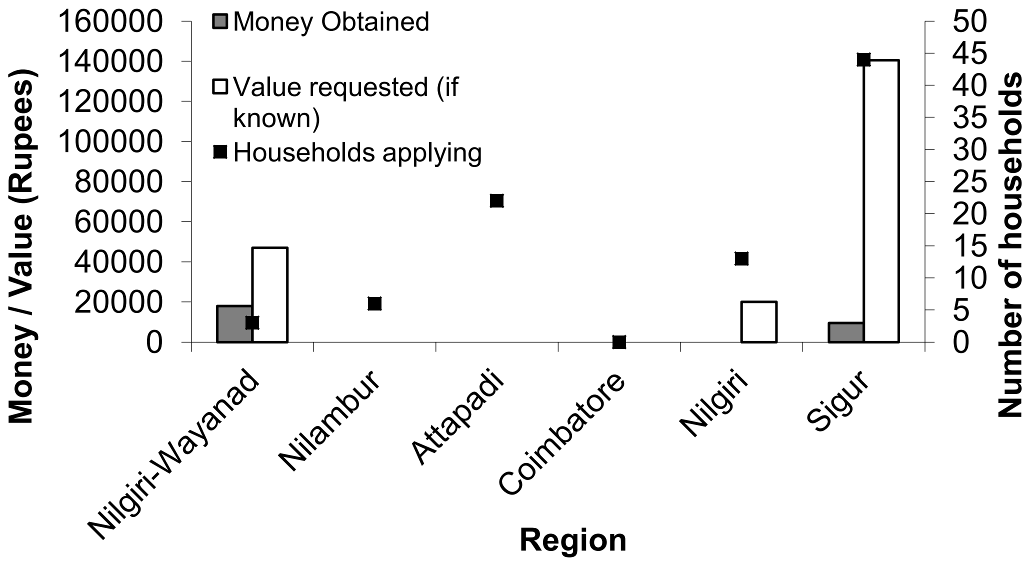


Figure 11: The number of households applying for compensation, the total money obtained, compared against the value applied for (where known) for different regions of the NBR

During the household level survey, only 9 households in three villages, out of a total of 478 households, reported applying for compensation. Of these, four households received compensation, one household receiving funds two years after the loss, totalling R15,460, although the losses were estimated to be worth at least twice as much.

2.5 Attacks on people by wildlife

In terms of wildlife attacks on people, minor injuries are more frequent than major injuries or death. Twenty-four of the sixty-two villages have reported some form of attack from 2007 - 2009 (Figure 12). Of concern is that 22 deaths and 33 major injuries have occurred in 15 of the 62 villages from 2007 - 2009, with the bulk of these happening in Chindakki in the Attapadi region (12 deaths; all due to elephant) and Nedungayam in the Nilambur region (24 major injuries; 20 due to elephant and 4 due to sloth bear). Five further deaths occurred during the monitoring period from 2010 – 2011, four due to elephant and one due to gaur, and one case of minor injuries due to elephant; in three villages including Nedungayam.

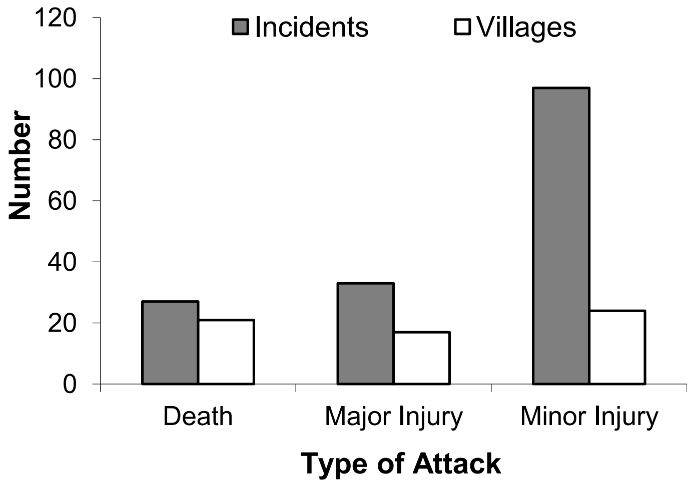


Figure 12: Wildlife attacks reported from sample villages across the NBR, numbers of incidents and numbers of villages reporting deaths, major injuries or minor injuries

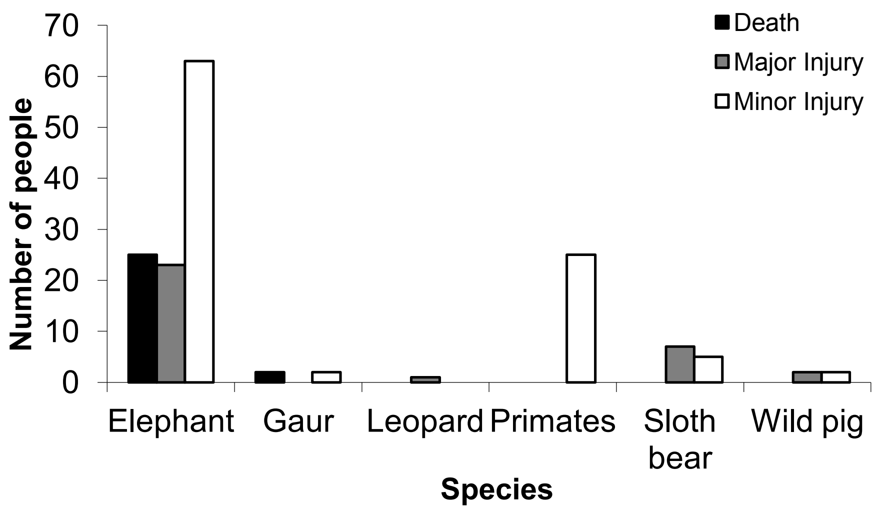


Figure 13: Wildlife attacks by species in villages across the NBR

Elephants are responsible for the majority of reported serious attacks, followed by sloth bear (Figure 13). Gaur, leopard, wild pig and primates have also been reported as causing injury but to a much lesser extent.

Where information on the location of the wildlife attack was supplied, the majority of attacks across the NBR occurred when people were in Reserve Forests (13 incidents, 52%), jointly followed by Protected Forest and village lands (each with 6 incidents, 24%). In Wayanad, Nilambur and Sigur reported attack locations were exclusively in protected or reserve forests, while in Silent Valley, Kotagiri and Sathyamangalam the majority of reported locations were protected or reserve forests (Figure 14). Reasons given for going into the reserve forest or protected area included for NTFP's such as honey, for firewood, and for grazing livestock. Some villages located in or close to forested lands linked attacks by wildlife to lack of electricity at night, and the need to return from work after dark.

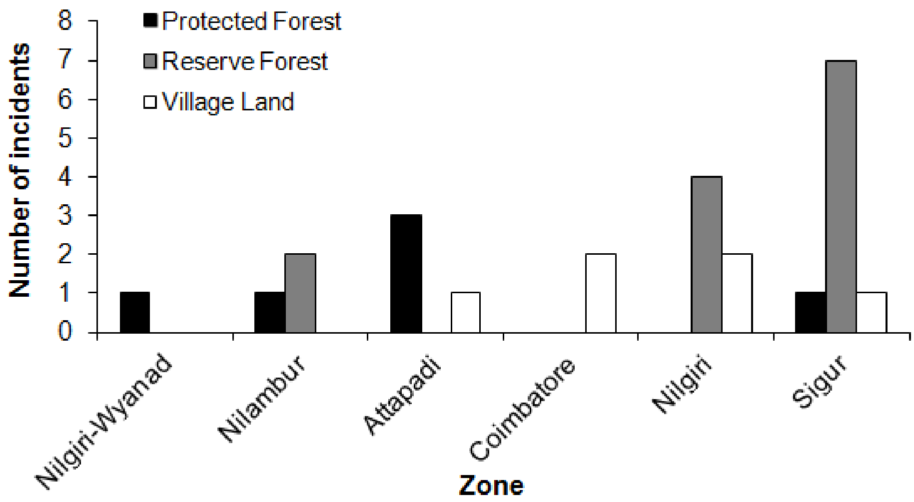


Figure 14: Location of wildlife attacks (protected forest, reserve forest, village land) by region in the NBR

2.5.1 Property damage

Damage to property or infrastructure was slightly more common than attacks on people, with 67 incidences in 19 out of 62 villages from 2007 - 2009, and 28 incidences in 7 out of 18 villages from 2010 – 2011 valued at R102,760. The villages suffering from the most incidents were located in the Attapadi region. Villagers believed that damage was usually a result of animals passing through, such as to raid crops or visit water sources. Elephants were responsible for the majority of incidents, with gaur, wild pig and sloth bear also reported but to a much lesser extent. In terms of compensation, 110 households in 5 villages (from 1 village in Nilambur, 2 in Attapadi and 2 in Sigur) applied for compensation. Only the two villages in Sigur received a total of R3000 as compensation.

2.6 Major problems facing villages

Villages were asked what they believed were the major problems facing their village. Overall, villages listed water availability (both drinking and for agriculture) and transport as problems more often than wildlife (Figure 15). Healthcare and livelihoods were listed as problems as frequently as conflicts with wildlife. Livelihood related problems encompassed access to seeds, cattle for ploughing, grazing areas for livestock, technology for agriculture, and drainage. Of the rest, electricity provision was the most important.

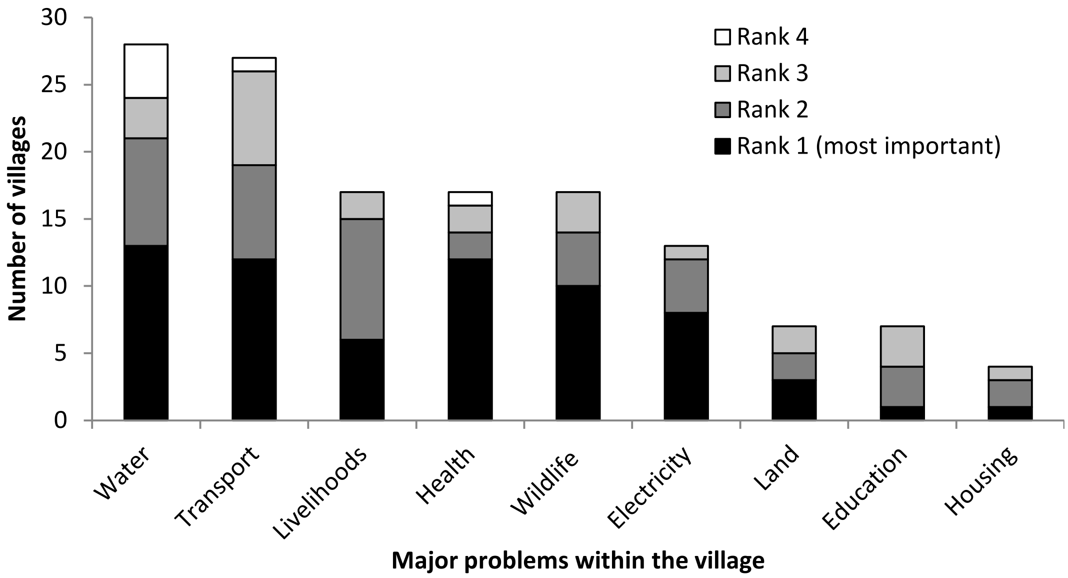


Figure 15: Ranking of most common major problems for villages across the NBR

At a zone level, wildlife was cited in a major proportion of responses in Nilgiri Wayanad, Coimbatore and Nilgiri (Figure 16). Villages in Nilambur and Attapadi did not consider wildlife to be one of the major problems at all, while Sigur cited it in only a small proportion of responses. Other major problems included lack of transport, commonly cited in all zones; access to water, common to all zones, the need for medical facilities mostly in Attapadi and Sigur, and the lack of electricity in Nilambur.

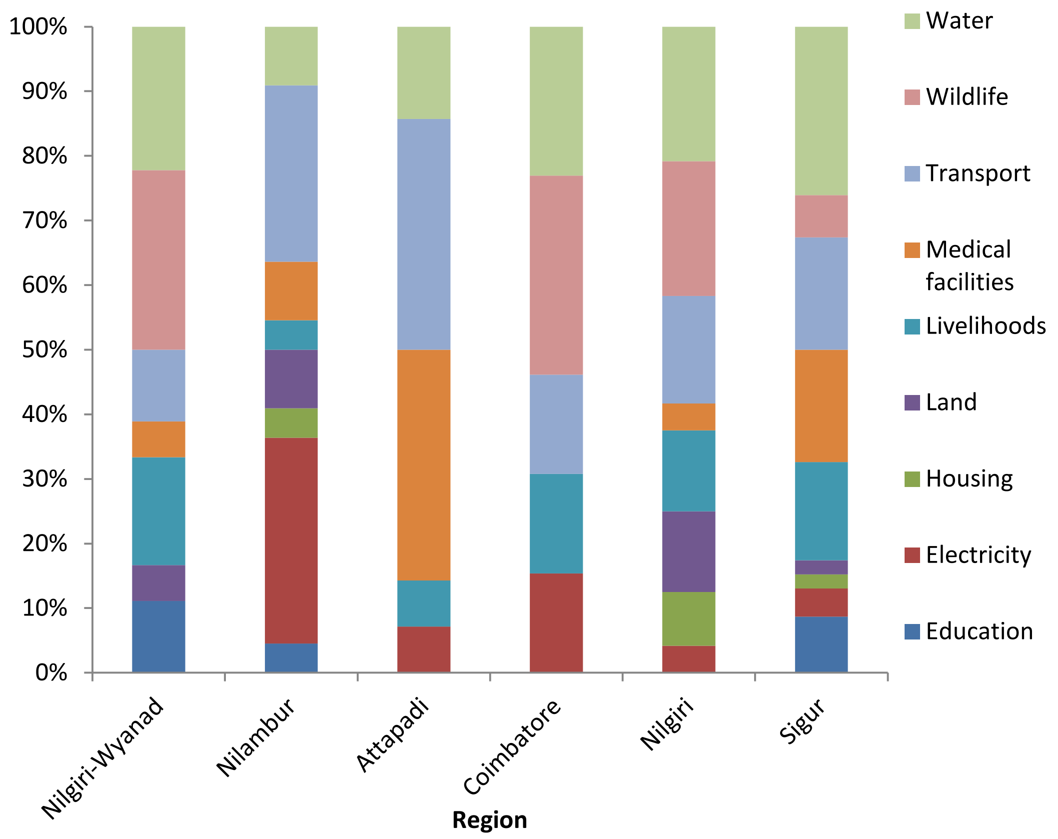


Figure 16: Percentage contribution of issues to village-generated lists of major problems by zone

All of these major problems (water, transport, livelihoods, health) that relate directly to the ability to live and make a living were considered more important than issues such as lack of access to education and disputes over land. Land disputes mentioned included needing more land for agriculture or issues over ownership due to the exclusionary nature of protected areas or the limited rights of rural communities. These two latter problems are frequently associated in the literature as either being negatively affected by, or triggering conflicts (Dickman 2010, Nagendra et al. 2013), but were not cited as problems as frequently as might have been expected. This is most likely due to the more pressing nature of other problems, which diminish the importance of biodiversity conservation in the face of social injustices. There may therefore be the opportunity for zone level management of conflict to focus on addressing some of these issues as conservation linked incentives (Sachs et al. 2009).

Chapter 3
(Mis-)understanding conflicts: ecological and socio-economic drivers of loss and perception at a landscape scale

3.1 Introduction

Human-wildlife conflict continues to pose one of the greatest threats to the conservation of large mammals and to the sustainable development of rural communities, despite the ever-increasing resources committed to research and mitigation (Redpath et al. in press). Conflicts with and over wildlife are most severe in biodiversity-rich and fragmented landscapes with high human densities, which exemplify both problems of habitat and species loss along with the marginalisation of rural communities (Balmford and Whitten 2003). Many of these conflicts manifest as livestock depredation, crop raiding, and threats to human life or property, often resulting in high costs for local communities (Thirgood et al. 2005b) and retaliation against wildlife which endangers conservation efforts (Woodroffe et al. 2005b).

The identification of both ecological and socio-economic drivers of conflict is an essential pre-requisite to establishing successful mitigation efforts (Graham et al. 2005, Dickman 2010, Linnell 2011). This is particularly pertinent considering that conflict mitigation efforts rarely provide long-term solutions, even where damage is successfully reduced (Webber et al. 2007, Dickman 2010). As yet, few conflict studies specifically identify common drivers or predicates of damage caused by wildlife, and typically often focus on ecological drivers (Dublin and Hoare 2004a, Treves et al. 2004, Graham et al. 2005, Sitati et al. 2005, Gubbi 2012).

Conflict situations have a number of aspects, such as the presence/absence of conflict, the intensity of conflict, the economic value of conflict and the perception of conflict. Each aspect can be driven by different sets of factors. Often, studies and mitigation efforts do not include all of these aspects, or there are differences in assessments between studies, which may explain difficulties in effectively identifying drivers of conflict or in drawing conclusions across sites. It is important to consider all aspects of a conflict situation in order to design appropriate mitigation measures. For example, apparent disparities have been noted between measures of conflict such as intensity or value, and the perception of conflict (Woodroffe et al. 2005a, Dickman 2010), leading to beliefs that perceptions of conflict by local communities can be illogical and therefore difficult to address (Woodroffe et al. 2005a). Consequently, failing to understand or address drivers of perception can undermine mitigation attempts since negative perceptions are often linked to behaviours such as retaliation or persecution (Dickman 2010).

One of the world's biodiversity hotspots (Myers et al. 2000), the Western Ghats is a mosaic of protected areas embedded in a human-dominated landscape, with high levels of biodiversity found alongside high human densities (Das et al. 2006). Within the Western Ghats, the Nilgiri Biosphere Reserve (NBR) exemplifies many of conservation management problems found throughout the wider area. In an area of *c.*7,500km^2, of which *c.*4 500 km^2 is protected, the NBR encompasses all the topographic and climatic variation, all major forest types and much of the species diversity found across the Western Ghats. Economic activities and land ownership range from subsistence holdings and corporate-owned commercial plantations to state-owned reserves, supporting a human population with a diverse demographic, economic and socio-cultural history. The NBR hosts some of the largest wildlife populations in Asia (Karanth and Sunquist 1992, Kumar 1999, Karanth and Sunquist 2000), including significant populations of elephant *Elephas maximus* and tiger *Panthera tigris,* with significant populations of wildlife persisting outside of protected areas (Bhagwat et al. 2005, Bali et al. 2007).

Given the extensive remaining populations of large mammals, human-wildlife conflict is prevalent across India, where nearly 500,000 households suffer from crop damage by elephants, which also kill almost 400 people per year, while up to 100 elephants are killed per year due to conflict (Rangarajan et al. 2010). Of the several species of large carnivores, leopards *Panthera pardus* are responsible for the most attacks on humans, with 902 injuries and 201 deaths attributed to leopards in the state of Maharashtra alone between 1999 and 2005 (Athreya et al. 2011), and 45 leopard deaths due to conflict across India reported in 2011 (WPSI 2012).

The high densities of both humans and large mammals in the NBR and changing land uses within and around the network of protected areas inevitably leads to particularly high levels of human-wildlife conflict in this region (Sukumar 1994, Madhusudan and Mishra 2003). Livestock predation and crop-raiding cause significant economic costs to local communities, such as losses of 11% of annual grain production to elephants and 12% of livestock holdings to felines (Madhusudan 2003), leading to destructive reprisals such as poaching, electrocution, and poisoning of livestock carcasses (Karanth and Madhusudan 2002, Rahmani 2003); and an associated negative change in human attitudes (Madhusudan and Mishra 2003, Ogra and Badola 2008a). These economic costs of conflict and the incentives for illegal exploitation mean that many local communities may not view biodiversity conservation as economically viable; especially when investment in damage control strategies (such as husbandry, guarding, deterrents or barriers), can be time-consuming, expensive, and involve opportunity costs limiting education or other income generating activities (Haule et al. 2002, Osborn and Parker 2003, Sitati and Walpole 2006). In India, state managed mitigation efforts include electric fences and / or trenches around parts of protected areas, with varying degrees of maintenance and hence effectiveness (Rangarajan et al. 2010); and compensation, a potential source of further conflicts (Bulte and Rondeau 2007), with problems such as inadequate remuneration, delays, and corruption (Madhusudan 2003, Ogra and Badola 2008a, Rangarajan et al. 2010).

With the shortcomings of existing mitigation measures (Sukumar 1993, Sukumar 1994, Karanth and Madhusudan 2002, Madhusudan 2003), there is an urgent need to identify the primary drivers of conflict in an integrated ecological and socio-economic context, to enable the development of effective conflict management strategies as part of conservation management and policy. Prevention and effective management of future conflicts depends on identifying the conditions promoting conflicts in order to focus outreach and interventions accordingly (Karanth and Chellam 2009, Dickman 2010).

This study used an interdisciplinary approach to identify ecological, social and economic drivers of two common manifestations of human-wildlife conflict, crop raiding and livestock depredation, in a large and geographically, climatically, ecologically and culturally variable landscape. By identifying drivers common to a range of communities subject to negative interactions with wildlife, the purpose was to define a set of 'generic' drivers of loss and perception likely to be involved in human-wildlife conflict situations at a landscape level. Knowledge of the general factors likely to promote conflict, and the linkages between different aspects of conflict, can facilitate mitigation efforts at other conflict sites and contribute towards understanding the dynamics of conflict.

3.2 Methods

3.2.1 Study Site

The Nilgiri Biosphere Reserve lies within the Western Ghats in south India, in the states of Kerala, Karnataka and Tamil Nadu, between 11°36′N and

12°00′N latitude and 76°00′E to 77°15′E longitude. The main protected areas are Wayanad Wildlife Sanctuary, Nagarhole National Park, Bandipur National Park, Mudumalai Wildlife Sanctuary, Silent Valley National Park, Mukurthi National Park, BRT Wildlife Sanctuary, and Sathyamangalam Wildlife Sanctuary. Several other areas are designated as reserve forests under lesser protection. Climate and habitats range from tropical moist semi-evergreen and deciduous forests on the western slopes of the Ghats, and montane forests and grasslands at higher altitudes, receiving up to 7000mm of rainfall per year; to dry deciduous and thorn or scrub forests on the eastern slopes receiving only 500mm of rainfall. The climate follows the tropical monsoon, with the south-west monsoon heavy rains from July to September, and the north-east monsoon light rains from October to November. Several major rivers thread through the NBR. Anthropogenic activities include forestry for teak *Tectona grandis* and timber, shade and open coffee, tea, rice paddies, subsistence farmers, pastoralists keeping cattle, buffalo, goats and sheep, and indigenous people reliant on non-timber forest products such as honey. Approximately 705,000 people live in the NBR (Das et al. 2006).

3.2.2 Methodology

Sixty-two villages were surveyed across the NBR, sampling across a range of ecological and socio-economic gradients. Surveys were conducted between May 2009 to August 2009, and followed a standardised semi-structured questionnaire posed to a group comprising members of the village. At each village, preliminary visits invited representatives to attend a meeting to obtain this data on behalf of all village occupants. Demographic data were taken for those who attended and contributed to the village level meeting, which typically lasted for a couple of hours. Questionnaires (appendix B) were undertaken by a small group which included a local language speaker, after a period of training in survey implementation and pilot surveys to minimise inter-observer bias and problems such as leading questions.

Detailed data were collected on a number of socio-economic village/household attributes, livelihoods, and on the ecological attributes of the surrounding landscape (summarised in Table 6). Reported losses due to conflicts with wildlife from 2007 - 2009 were recorded in terms of extent, value and perception of crop or livestock loss (Table 7). Perception of conflict was quantified in this study as the threat to life or livelihood. To assess perceptions, groups were asked to generate and self-rank a list of threats facing crop production, livestock production, and their village. Their identification and ranking of wildlife as a problem was then used as a contextual representation of perception of conflict.

Several ecological variables were obtained through remote sensing and compilation of existing data. Mean NDVI (Normalised Difference Vegetation Index) for a 5km zone around each surveyed village was used as a proxy for productivity, derived from MODIS Terra 16day 250m NDVI remote sensed images of the region. Changes in productivity were calculated using change in mean NDVI from images over a four year period before surveys were undertaken. Monthly precipitation logs[3] for the states of Kerala, Karnataka and Tamil Nadu (Hijmans et al. 2005) corresponding to the date of the images were analysed to identify images from the same month with similar rainfall patterns four years apart. This minimised effects due to vegetation changes that may have occurred under within-year climate variation. Nov 2004 and Nov 2008 were chosen as the comparable years, giving a 2008 proxy value for productivity, and a differential representing changes in productivity, i.e. negative changes indicated relative levels of degradation. MODIS assessments of the accuracy of each satellite image were also studied to ensure that there was minimal pixel unreliability (e.g. due to cloud cover) for the regions of interest. Altitude and precipitation records were taken from the online Data Pool at the NASA Land Processes Distributed Active Archive Center (LPDAAC 2012)[4]. The major habitat type in the surrounding landscape for each village was classified using a combination of ground observations and classifications from standardised vegetation maps of the region (Prabhakar and Pascal 1996), as evergreen forest, semi-evergreen forest, shola (high-altitude) forest, moist deciduous forest, dry deciduous forest, scrub/thorn forest, and non-native plantations, as per the dominant vegetation categories in the Western Ghats (CEPF 2004). Proximity to the protected area was recorded as the distance from the village location to a digitised GIS layer of the protected area boundary.

Population estimates at the landscape scale for the mammal species involved in conflicts were obtained using data from occupancy models developed for large mammals in the Western Ghats region (Pillay et al.

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[3] http://www.worldclim.org/ accessed Jan 2012

[4] https://lpdaac.usgs.gov/get_data accessed Jan 2012. ASTER GDEM is a product of METI and NASA

2011). Their data collection gave an index of reported encounter rates for each species in each forest range in the NBR, which was categorised for this study as proxies of low, medium and high density for herbivores, carnivores and carnivore prey species, and assigned to villages for their respective forest range.

Table 6: Ecological, social, and economic explanatory variables used in baseline candidate models for (1) presence of loss; (2) intensity of loss; (3) value of loss; (4) perception of loss

Ecological	**Social**	**Economic**
General Altitude Precipitation Degradation Productivity Protected area distance Forest refuge distance Wildlife densities Abandoned land Encroached land	*General* Number of households Family size Community composition	*General* Primary livelihood dependency *Crop specific* Farmland Households practicing agriculture Land ownership (owned, leased, shared) Irrigation Commercial/subsistence crops (acreage and percentage) Crop types Crop monetary values in Rupees Crop holding extent *Livestock specific* Households keeping livestock Livestock types Livestock monetary values in Rupees Livestock holding extent

Table 7: Response variables measured for each model type

Conflict Aspect	**Crops**	**Livestock**
Presence of loss	Presence / absence of raiding	Presence / absence of depredation
Intensity of loss	Reported area damaged due to crop raiding in last 2 years	Numbers of livestock reported lost to depredation in last 2 years
Value lost	Estimated value of crops lost (market value & investment)	Estimated value of livestock lost (market value)
Perception of conflict	Ranked perception of crop raiding as a threat	Ranked perception of livestock depredation as a threat

Models were generated for (1) the presence or absence of conflict; (2) the intensity of conflict (measured in terms of crop area or livestock number lost from those villages suffering from conflict); (3) the value of loss (in Rupees, for those villages suffering from conflict); (4) the perception of wildlife as a problem for crop or livestock production (for all villages sampled, regardless of whether actual loss was present).

For each response variable, a best fit explanatory model was selected (details provided in Table 8). Independent variables were tested for collinearity to refine and reduce the number of variables used in candidate model generation. This was combined with *a priori* selection of variables based on knowledge of likely variables associated with conflict. Generalised Linear Models were used to test for explanatory variables, choosing appropriate distributions for each response variable (presence/absence, intensity, value). Ordered Logit Models were used for the ranked perception data. All response variables were tested for outliers which were removed where necessary; and for over-dispersion which affected the choice of distribution. Mantel tests indicated that no spatial autocorrelation was present. All analyses were carried out using the R programming environment (R 2010).

Non-significant individual explanatory variables were dropped using backwards step-wise selection, and model selection criteria based on AIC was used to decide on the optimal model for each response variable explored. Models for each response variable were validated by testing the homogeneity of the residuals, normality of the residuals, residuals against variables, and testing for the presence of influential observations.

3.3 Results

Table 8 presents the significant explanatory variables associated with each aspect of conflict, and full details of the fitted models. Increased levels of habitat degradation, closer proximity to forest patches, and greater extents of farmland increased the probability that a village would suffer from crop raiding. Where crop raiding was present, the intensity of crop raiding (measured in acres lost to wildlife) was correlated with increasing acreage of abandoned land within a village, increasing acreage of encroached land within the adjacent protected area, and increasing extent of farmland.

Livestock depredation followed a similar pattern. Presence of livestock depredation is predicted by proximity to forest patches and the numbers of households keeping livestock. Intensity of depredation (numbers of livestock lost) is linked to proximity to forest patches, the total numbers of livestock held by the village, and increasing densities of carnivores.

The influence of protection or mitigation measures at a landscape level could not be ascertained, given that villages tended to employ a multitude of measures, hence it was impossible to include it as an explanatory variable in any of the models.

The economic costs of conflict are solely driven by socio-economic variables. The value of crop losses are determined by the extent of commercial crops, the level of ownership present in a village (as opposed to leasing or sharecropping), and the availability of water through investment in irrigation. Likewise, for livestock the economic value is simply determined by the types and numbers of livestock lost. No ecological variables were linked to value lost to conflict.

Finally, in terms of perceptions, the data suggests that this is predominantly driven by proportional loss (loss as a percentage of the overall extent of crop or livestock holding), for both types of conflict. Villages that experience larger proportional losses to wildlife hold a correspondingly increased perception of the threat posed by wildlife. For crop raiding, this is moderated by the level of commercialisation of a village: the higher the percentage of commercial crops grown in a village, the greater the perception of threat posed by wildlife.

Table 8: Significant ecological and socio-economic drivers of conflict: presence/absence of conflict damage, intensity of damage, economic value lost, and perception of conflict as a threat to livelihood production.

Type of conflict	**Presence of Loss**	**Intensity of Loss**	**Value Lost**	**Perception of Conflict**
Crop raiding	(1) - Degradation* - Forest distance* + Farmland*	(2) + Abandoned*** + Farmland*** + Encroached***	(3) + Commercial crop %** + Farmland ownership** Irrigation level (high)*	(4) + Proportion*** + Commercial crop %***
Livestock depredation	(5) - Forest distance* + Numbers of households keeping livestock **	(6) - Forest distance*** + Total livestock kept*** Carnivore density (medium)*	(7) + Total livestock lost*** Livestock type kept (large)*	(8) + Proportion**

(1) *Generalised Linear Model (GLM) fitted with a binomial distribution; model terms: degradation $p = 0.013$, farmland $p = 0.027$, forest distance = 0.029, percentage irrigation 0.187, df = 58, n = 62;*

(2) *GLM fitted with a gamma distribution; model terms: abandoned $p < 0.001$, encroached $p < 0.001$, farmland $p < 0.001$, df = 44, n = 48;*

(3) *GLM fitted with a quasipoisson distribution; model terms: commercialisation $p = 0.048$, irrigation high $p = 0.008$, df = 44, n = 48;*

(4) *Ordered Logit Model; model terms: proportion crop lost $p < 0.001$, commercialisation $p < 0.001$, n = 62;*

(5) *GLM fitted with a binomial distribution; model terms: forest distance $p = 0.045$, numbers of households keeping livestock $p = 0.002$, df = 59, n = 62;*

(6) *GLM fitted with a quasipoisson distribution; model terms: forest distance $p < 0.001$, carnivore density medium $p < 0.033$, total livestock $p < 0.001$, encroached land $p = 0.071$, df = 42, n = 45;*

(7) *GLM fitted with a quasipoisson distribution; model terms: total livestock lost $p < 0.001$, livestock type kept (large) $p = 0.019$, df = 42, n = 45;*

(8) *Ordered Logit Model; model terms: proportion livestock lost $p = 0.005$, n = 62;*

3.4 Discussion

Several key socio-ecological factors emerged as significant explanatory variables for different measures of conflict. The data showed that as measures of conflict move from absolute (presence/absence and the intensity of damage) to human interpretations of loss (economic value and perception), it is quite clear that ecological drivers give way to socio-economic factors.

The greater the level of habitat degradation in the vicinity of a village, the closer it is to forest patches, and the more cropland it has to attract wildlife, the more likely it is that crop raiding will be present. Although degradation in habitat quality is often cited as a possible driver for conflict, there are few other studies statistically linking measures of degraded habitat with increased conflict (Chartier et al. 2011). Proximity is however a strong predictor of crop loss in other conflict studies (Rao et al. 2002, Sitati et al. 2003, Naughton-Treves and Treves 2005, Woodroffe et al. 2005a). Intensity of crop raiding increased with increasing levels of farmland, abandoned land (land no longer used by the village), and illegally encroached land (land that villagers do not own but that they cultivate from nearby forests). The significance of farmland extent in both predicting presence and intensity of conflict indicates that a greater crop area is an attractant to wildlife, especially as cropland extent has also been strongly linked to levels of crop loss in other conflict studies (Woodroffe et al. 2005a). The presence of abandoned land in a village is likely to act as a local refuge for wildlife, resulting in increased numbers or lengths of crop raiding visits. Encroached lands that are illegally cultivated within the forest also indicate increased levels of forest disturbance as well as cropland that is likely to be more vulnerable to crop raiding as it is usually located within or adjacent to forest refuges. Although not significant in the final model, it is worth noting that moderate (not high) densities of herbivores were associated with increased levels of crop-raiding. This may suggest that conflict is not simply a function of the population density of the problem species, as higher densities would have been expected to correlate with more crop-raiding. Instead, medium densities may be linked to more conflicts due to the reasons behind the lowered population size, such as habitat disturbance and an associated decrease in habitat quality. However, the data were limited to categories of low, medium and high densities and so more detailed analyses of densities would permit this effect to be explored.

For livestock depredation, the data also indicated that the closer a village was to a forest, the more likely depredation was to occur. Proximity is particularly important in this case as many villages send their livestock each day to graze within forest lands where livestock is vulnerable to large carnivores, due to a lack of grazing lands in the village. However, some incidents also occur within villages and in these cases proximity is also important. Intensity was further predicted by the number of households keeping livestock, rather than the total number of livestock. This is likely to indicate an underlying combination of the total number of livestock in the village and the size of the grazing herd taken to forest areas, as small numbers of households may supervise their livestock independently, whereas large numbers of households often send all livestock to graze under the supervision of a couple of villagers. This is an important distinction, as a larger grouping of livestock is more likely to attract predators.

The model also indicated that increasing densities of carnivores are linked to increased levels of depredation, although there was no correlation with prey densities. These explanatory variables are similar to the findings of previous conflict studies which associated proximity, livestock density, predator and prey density with depredation intensity (Treves et al. 2004, Woodroffe et al. 2005a).

For both crop raiding and livestock depredation, presence or intensity was only linked with proximity to forest patches, with no link to proximity to a protected area. Sampled villages were surveyed along a spatial gradient that ranged from directly within, to 35km away, from a protected area. Given that this had no effect on measures of loss, the implication is that large mammals are utilising forest patches outside of protected areas and can be found throughout the entire landscape, hence risk from conflict in this area is strongly linked to proximity to a forest refuge.

The economic value of losses to conflict as manifested by crop raiding or livestock depredation can be seen to have a solely socio-economic context – the value of loss (measured in Rupees) is dictated by what people can afford to invest in their livelihood production system, and not by the foraging preferences of wildlife or ecology of the landscape. There is no statistically significant preference by problem wildlife species for more or less expensive crop or livestock types. Instead, the value of loss is linked to economic investment drivers: the percentage of commercial crops, farmland ownership, and levels of irrigation for crop raiding; and livestock types kept and numbers lost for livestock depredation. This indicates that the economic value of damage alone, although often used as a typical measure of conflict particularly when comparing across sites, is not appropriate when the underlying ecological and social drivers need to be understood and integrated into mitigation measures. It is also evidently not a suitable means for prioritising conflict interventions or assessing losses unless comparisons are made between similar holdings, as otherwise richer landholders will always be considered as suffering from a greater degree of loss than poorer landholders. For example, an acre of commercial crops lost to wildlife would be valued higher than an acre of subsistence crops lost, although the intensity of the crop raiding conflict remains the same.

Finally, perception of the threats wildlife pose is also driven by the socio-economic context of loss. That is, loss in the context of people's existing holdings - the proportional loss suffered. This bears no immediate relation to the intensity of conflict as measured in terms of absolute loss, such as acres of crops damaged or numbers of livestock lost, and can explain why perceptions often seem to be disconnected from absolute loss and from economic loss. Hence, if the socio-economic context of loss is not accounted for in conflict studies or mitigation, perception can seem to be arbitrary and mitigation measures will often fail to change it. In particular, schemes such as compensation that currently exist in India, which address only absolute economic loss often do not change perceptions of conflict. Furthermore, for crop raiding conflicts, perception is moderated by the degree of commercialisation of a village – the more the village economy is based on money rather than subsistence, the higher the perception of threat posed by wildlife for the same level of proportional loss. This implies a consistent increase in conflict as communities become more dependent on crops for income rather than subsistence.

Table 9: Generic factors driving crop raiding and livestock depredation conflicts

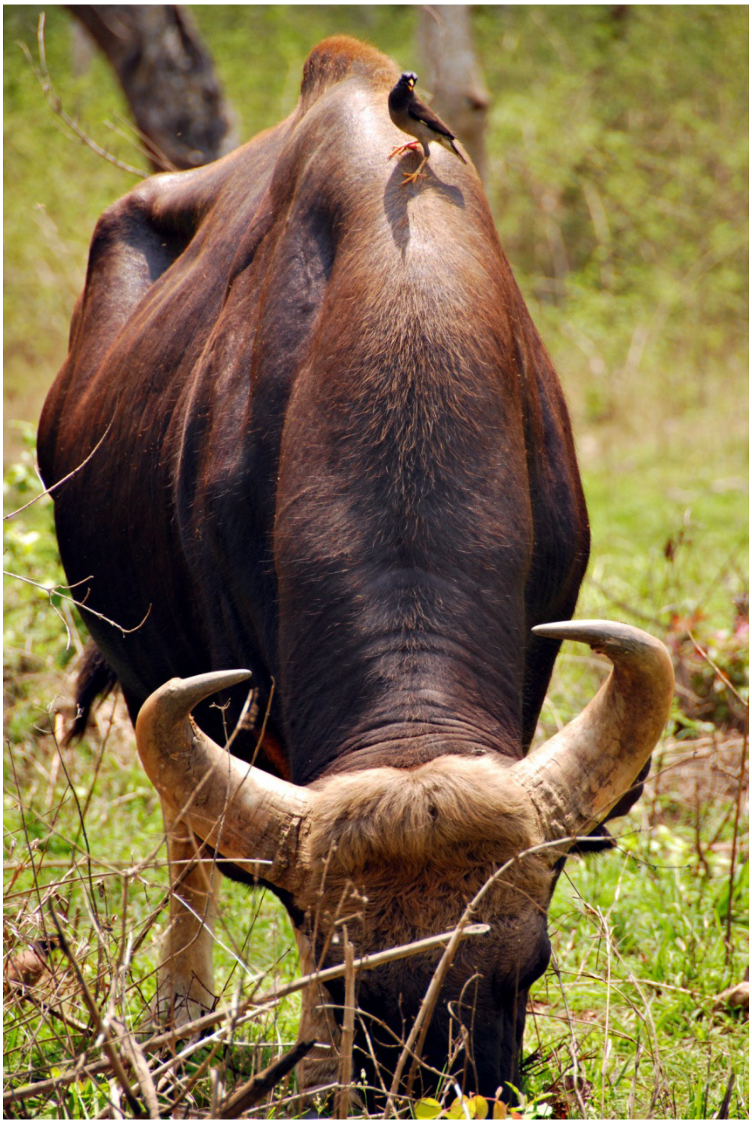
Likelihood of conflict & intensity of occurrence	**Value lost to conflict**	**Perception of Conflict**
- Habitat quality - Habitat proximity - Holding extent	- Economic investment	- Proportional loss - Economic investment

At a general level, these results (Table 9) indicate over-arching generic variables likely to play a part in any given conflict situation. For crop raiding, variables driving presence and intensity of conflict broadly represent ecological measures of habitat quality (degradation, abandoned land, encroached land), and proximity to a wildlife refuge, combined with the socio-economic variable of holding extent (farmland). Similarly, for livestock depredation, variables driving presence and intensity of conflict broadly represent ecological measures of habitat quality (wildlife densities), and proximity to a wildlife refuge, combined with the socio-economic variable of holding extent (livestock density). Economic losses for both crop raiding and livestock depredation are determined solely by economic investment (commercialisation, farmland ownership and irrigation for crops; livestock types kept and numbers lost for livestock depredation). Finally, perception is driven by the socio-economic context of proportional loss, which is exacerbated by increasing economic investment in the case of crop raiding. Hence, while the loss that people suffer may be driven by a combination of ecological variables and the human context, economic valuation of loss is a solely anthropogenic construct, with very little ecological basis. Most importantly, it is apparent that perceptions have no correlation with either loss or the ecological context of conflict; instead they are influenced by the impact of that loss, measured as proportion of holding lost to wildlife.

3.5 Conclusions

It is clear that conflict is a product of a complex inter-weaving of both ecological and socio-economic drivers, which play different parts depending on which aspect of conflict is being assessed. Versions of these generic variables may be drivers in any conflict situation, therefore studies of conflict should attempt to assess each of these aspects to understand the dynamics of a given situation, where best to target mitigation efforts, and how to prioritise vulnerable areas. Mitigation measures should also be clear about which aspect of conflict they intend to address, whether it is by reducing the probability of conflict occurring, reducing intensity when it does occur, reducing the value of loss, or by changing people’s perceptions, as different factors drive each of these aspects. This is a fundamental consideration, as it explains why schemes such as monetary compensation which only address the economic value of loss, without any effect on reducing actual losses, cannot influence perception as it does not address the impact of high proportional loss. The data also suggests that increasing economic development is likely to result in a decreased tolerance of conflict; hence the problems of human-wildlife conflict are only likely to become more intense. Mitigation efforts should therefore take steps to reduce or compensate for loss more effectively, accounting for high impact losses in order to address negative perceptions, as well as including measures to improve tolerance in more commercialised communities.

Chapter 4
A question of protection: how householders choose and use livelihood protection strategies to mitigate human-wildlife conflicts



4.1 Introduction

In landscapes shared between people and wildlife, conflicts can manifest as negative interactions with wildlife or between different groups of people over wildlife management. At a landscape level conflict that results in losses to people (livestock depredation and crop raiding) can have multiple ecological and socio-economic drivers, depending on the aspect of conflict being measured (chapter 3). However, conflicts can also be intensely localised throughout a landscape (Treves et al. 2004, Woodroffe et al. 2005a, Guerbois et al. 2012). Understanding the process and outcomes of local decision-making over conflict mitigation is fundamental (Young et al. 2010), as landscape-level management may not recognise local individuality or intensity, while local schemes may not be effective or able to sufficiently contextualise conflicts for stakeholder acceptance.

Furthermore, while several ecological drivers of conflict may be considered to operate at regional scales, at smaller scales the socio-economic context of individual behaviours becomes of integral importance in understanding conflicts and how they can be managed (Manfredo and Dayer 2004a, Young et al. 2010). For example, there are significant differences between individuals in their actions in response to conflict, such as the decision-making underlying interventions chosen to protect livelihoods or consequential behaviours such as retaliation (Manfredo and Dayer 2004a); and in the attitudes towards conflict, wildlife, and other stakeholder groups responsible for managing wildlife (Dickman 2010). These socio-economic nuances behind the trade-offs of coexisting with wildlife can only be adequately explored at the household level, but often have major impacts on tolerance for wildlife conservation which can have landscape scale consequences, and for the effectiveness and uptake of existing and new mitigation measures (Dickman 2010).

It is vital to be able to assess not only the efficacy but also the reasoning behind choices of existing intervention measures to recognise which are sufficiently effective at reducing losses and which are likely to be most accepted by stakeholders given the context of conflicts. Measures that meet both these criteria have improved chances of long-term sustainability, reducing conflict and promoting both wildlife conservation and permitting economic development (Messmer 2000). Measures that meet only one criterion are much more likely to fail: effective measures may not be utilised or maintained if they are not acceptable to communities, while ineffective but widely used measures will do little to reduce conflicts. Hence, community participation in management decisions is integral to human-wildlife conflict resolution (Western 1994, Redpath et al. 2004, Redpath and Thirgood 2009), particularly in the context of exclusionary protected areas (Horwich and Lyon 2007).

Many intervention measures are utilised globally to protect crops and livestock from loss to wildlife, broadly classified into early-warning systems, barriers, deterrents, guarding, husbandry, problem animal control, and financial recompense, but studies on the effectiveness of these systems have so far been limited (Osborn and Parker 2003, Graham and Ochieng 2008, Ogra and Badola 2008b, Inskip and Zimmermann 2009a). Some interventions such as compensation have been cited as exacerbating conflicts (Bulte and Rondeau 2005), and as yet few studies have attempted to quantify and include stakeholder decision-making (Redpath et al. 2004) in intervention choices.

This study builds on an interdisciplinary survey methodology (described in chapter 3) to investigate the effectiveness of different mitigation measures currently employed at the local level in a subset of villages across the Nilgiri Biosphere Reserve, India, and to understand at a preliminary level how householders consider and choose mitigation schemes, which potential schemes might be most favoured, and which institutions should be responsible for implementation. These are key mechanisms that must be understood in any landscape prior to the establishment of any conflict mitigation scheme to improve the potential for uptake and success.

4.2 Methods

Socio-ecological variables associated with losses to wildlife and perception of threat from wildlife were investigated at a household level within the Nilgiri Biosphere Reserve. Full details of the study sites and villages are given in Chapters 2 and 3. A sub-sample of 18 villages out of the original 62 villages surveyed were chosen to represent the range of conflicts experienced across different geo-climatic regions of the NBR, based on livelihood vulnerability to conflict, perceptions and loss, and with a focus on conflicts caused by large mammals of conservation concern.

At the local household scale, 478 household interviews (in a sub-sample of 18 villages taken from the 62 villages surveyed in Chapter 3), were conducted from May 2009 to January 2011. Surveys followed a standardised semi-structured questionnaire posed to adults in each household.

Questionnaires were undertaken by a single local language speaker, and several villages were covered by one interviewer, after a period of training in survey implementation and pilot surveys to minimise inter-observer bias and problems such as leading questions. This socio-economic dataset was coupled with a conflict monitoring scheme managed by each interviewer, that recorded actual losses to wildlife for all sampled households in the 18 survey villages from January 2010 to December 2011 using standardised questionnaires.

Detailed data were collected on a number of socio-economic household attributes, following the survey methodology described in Chapter 3 but applied at a household level. Additional data specific to the household interviews were collected as follows. Economic status was assessed as an index represented by a combination of income group, presence of children in education, cable television, a vehicle, a phone, and a tiled roof, given that typical measures of income are inappropriate for many subsistence based livelihoods. Past losses to wildlife and details of existing protection measures, livestock and crop holdings, compensation, actions taken in response to loss, and losses to other causes were also recorded. Household decision-making was assessed through self-ranked listings for several key decisions (Table 10). The lists of criteria for each decision were generated through pilot discussions and surveys with householders that elicited sets of relevant options. Further, to restrict choices to familiar measures, the options presented as potential intervention measures were based on those used in South India by communities and governments. Households were asked to rank criteria in an ideal mitigation scheme, rank potential mitigation measures for crop protection and livestock protection, and to rank stakeholder groups in order of responsibility for managing conflicts.

The conflict monitoring scheme collected information from households reporting conflict incidents, which was verified by the interviewer; and included the date, the GPS location and the household which was affected. For crops, details were collected on irrigation, fence type, deterrents used, distance from nearest forest refuge, crop type, area cultivated, area damaged, and wildlife species suspected of causing the damage. Interventions were classed as follows: no fence; natural fences made of brush or natural vegetation; wire fences made of several strands of plain or barbed wire; solar-powered electric fences; guarding/patrolling crops at night; noise generated by firecrackers, drums, or shouting; fires lit to protect crops or use of fire torches; the presence of dogs guarding crops; and lights from torches. For livestock, details included the location of the loss, guarding measures present, distance from nearest forest refuge, livestock type, number owned, number lost, age/sex of livestock lost, and predator suspected. Interventions were classed as no protection; guarding; the use of sheds / corrals at night.

Table 10: Key questions and criteria choices posed to householders in the NBR regarding mitigation scheme decision-making

Key question	**Criteria**
Rank the factors most important in your ideal mitigation scheme	Proven effectiveness; low start-up costs; low maintenance costs; low labour effort; household control of scheme; potential for negative effects on wildlife; high level of community acceptability; fair compensation;
Rank these mitigation measures in your order of preference for crop protection	Insurance; compensation; natural fencing; wire fencing; electric fencing around fields; electric fencing around parks; trenches around fields; trenches around parks; deterrents; stop livestock grazing in the protected area; improved habitats within the protected area;
Rank these mitigation measures in your order of preference for livestock protection	Guarding; fencing; compensation; insurance; government control of problem animals; stopping livestock grazing in the park; stopping illegal hunting; improved habitats within the protected area;
Rank the stakeholder groups in the order in which they should assume responsibility for managing conflict	Communities; NGOs; Forest Department; other government institution; tourists; resorts; urban citizens;

A best-fit Generalised Linear Mixed Model fit by the Laplace approximation was constructed to predict the intensity of conflict (measured in terms of number of incidents from those households suffering from crop raiding or from livestock depredation in a particular locality). Variables included in the initial candidate model are listed in Table 11, without interaction terms. Independent variables were tested for collinearity, and the response variables were tested for outliers, removed where necessary, and for over-dispersion. All analyses were carried out using the R programming environment (R 2010). Village was included as a random effect to account for spatial variation in the location and intensity of conflict incidents. Non-significant individual explanatory variables were dropped using backwards step-wise selection, coupled with model selection criteria based on AIC to decide the minimal adequate model. Models were checked for homogeneity and normality of the residuals and the presence of influential observations.

Table 11: Response and independent variables included in the baseline generalised linear mixed models of the number of conflict incidents

Variable type	**Variable name**
Response variable	Number of incidents of crop raiding per household per field Number of incidents of livestock depredation per household per locality (village vs. forest)
Independent variables (socio-economic)	Community, primary livelihood, economic status, forest resource use measured as level of firewood harvested;
Independent variables (crop raiding)	Type of protection: no fence, natural fence, wire fence, electric fence, guarding, noise, fire, dogs, and lights; Distance from nearest forest refuge, distance from protected area, cultivated land, presence of irrigation, crop type (paddy, fruit trees, cash crops, vegetables, non-timber forest products, sugar cane, livestock fodder crops;
Independent variables (livestock depredation)	Type of protection: none, guarding, shed / corral; Distance from nearest forest refuge, distance from protected area, total number of livestock of that type kept, livestock type;

4.3 Results

Between Jan 2010 and Dec 2011 there were 1753 incidents of crop-raiding reported by 376 households in 696 separate field locations, and 258 incidents of livestock depredation reported by 85 households, across the 18 survey villages.

4.3.1 Crop protection strategies

A total of 1721 incidents were attributable to larger mammals, while a further 32 incidents were ascribed to smaller mammals and birds, and excluded from the model analysis. Crop protection strategies fell into two main categories, barrier methods and deterrents. The majority of incidents were associated with no fence (35.5%) or with a natural fence (35.8%), followed by wire fencing (22.5%), and finally solar-powered electric fencing (6.3%). Deterrents were used in 65.6% of incidents, as one or more of the following: noise (48.2%), guarding (11.3%), fire (5.2%), dogs (0.7%), and lights (0.2%). The crops that were damaged were predominantly paddy fields (27.2%) and fruit trees such as banana or jackfruit (27%), followed by cash crops such as coffee, tea and spices (21.2%) and vegetables (21.3%). Cultivated non-timber forest products (2.2%), sugar cane (0.7%) and livestock fodder crops (0.5%) made up the remainder. Elephants *Elephas maximus* were responsible for the majority of incidents (44.2%), closely followed by wild boar *Sus scrofa* (34.8%). The minority of incidents were attributed to deer (sambar *Rusa unicolor*, chital *Axis axis* and muntjac *Muntiacus muntjak*; 9.6%), gaur *Bos gaurus* (0.6%), sloth bear *Melursus ursinus* (0.2%); with small mammals (porcupines *Hystrix indica*, black naped hare; 5.5%), primates (primarily *Macaca radiata*; 3.1%), birds and rats (0.9%) making up the remainder of incidents which were excluded from the model analysis.

The number of incidents experienced per field per household gave a measure of frequency of incursion to that particular locality. The best fitting generalised linear mixed model included distance from the nearest forest refuge ($p = 0.0393$) and fencing type as the significant explanatory variables influencing the number of incidents occurring (against no fencing: natural $p < 0.001$, wire $p < 0.001$, electric $p = 0.0162$), with village as a random effect (Table 12). The number of incidents decreased with distance from forest refuges. In terms of fencing type, electric fencing was associated with the least number of incidents, followed by wire, natural and no fencing. Notably, the presence or absence of deterrents did not have any significant effect on the number of incidents occurring, and neither did crop type.

Table 12: Generalised Linear Mixed Model details for incidents of crop raiding and livestock depredation across the NBR

Model variables	**Estimate**	**Standard Error**	**Z**	**Probability**
Crop raiding incidents ~ distance from forest + fence type + (1|village), n = 696				
Intercept[1]	1.038	0.126	8.206	< 0.001
Distance from forest	-0.077	0.037	-2.061	0.039
Natural fence	-0.312	0.067	-4.641	< 0.001
Wire fence	-0.424	0.072	-5.913	< 0.001
Electric fence	-0.350	0.146	-2.404	0.016
Livestock depredation incidents ~ number of livestock kept + protection type + (1|village), n = 143				
Intercept[2]	0.934	0.110	8.499	< 0.001
Number of livestock kept	0.011	0.001	10.920	< 0.001
Shed / corral	-0.583	0.256	-2.279	0.023
Guarding	-0.572	0.184	-3.199	0.002

[1] *Corresponds to the factor of no fence type;*

[2] *Corresponds to the factor of no protection;*

Figure 17 shows the actual number of incidents plotted against distance to the forest refuge, with predicted line values for each fence type as generated by a version of the model without village as a random effect. There is a lot of variability in incident number at close proximity to the forest refuge, and this is likely to be a consequence of factors that drive conflict at a larger spatial scale, such as those identified in Chapter 3 (degradation, farmland, abandoned and encroached land), variation which is accounted for to some extent in the final model by including village as a random variable.

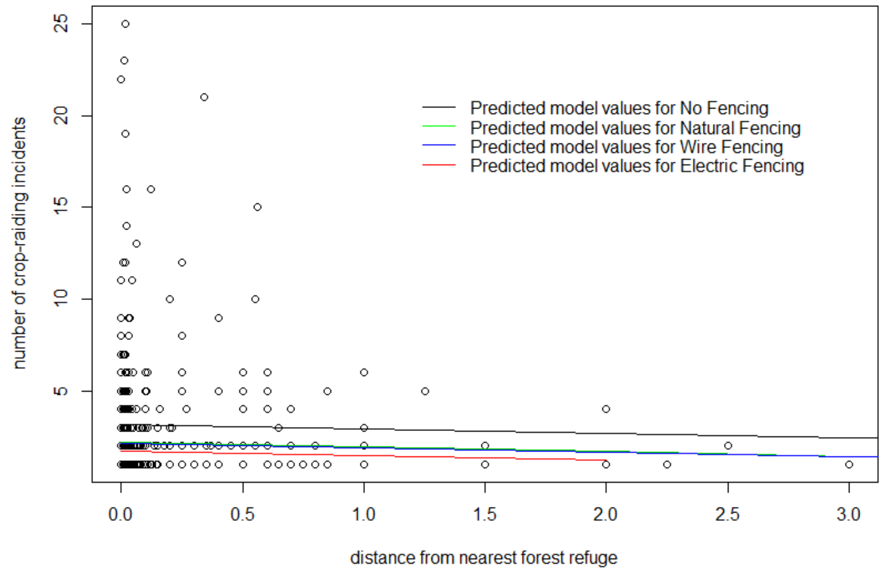


Figure 17: Number of crop raiding incidents as a function of distance from nearest forest refuge. Lines represent predicted values for each fence type, from a generalised linear model of incident as a function of fence type and distance

4.3.2 Livestock protection strategies

A total of 184 incidents of livestock depredation attributed to large mammals were recorded across all study villages. A further 120 incidents of losses of poultry to small carnivores (such as jungle cat *Felis chaus*, small Indian civet *Viverricula indica*, mongoose *Herpestes spp.*) and raptors within village property were also recorded but not included in the analysis. Incidents were classified based on household, locality of loss and livestock type. Leopard *Panthera pardus* were primarily responsible for depredation incidents (46.4%), followed by tiger *Panthera tigris* (8.2%) and wild dog *Cuon alpinus* (5.9%).

Livestock protection strategies in the study region were limited to no protection, where stock were left to forage unattended, and to personal guarding where a herder was present with the stock. Both protection methods were used for grazing livestock within village lands and within nearby forested areas. Within village lands livestock were also sometimes protected by being kept in a corral or shed. Incidents occurred both within village lands (48%) and within the forest (52%). The majority of incidents were associated with no protection (58.2%), followed by guarding (30.9%) and lastly by the use of sheds or corrals (10.9%). Cattle were most commonly depredated (38.3%), followed by goats (31.4%), dogs (12.6%), chickens (8.6%), buffalo (8%) and sheep (1.1%). Although not technically livestock, the taking of dogs by leopards was included as a loss.

The best fitting generalised linear mixed model included number of livestock of that type kept ($p < 0.001$) and protection type as the significant explanatory variables influencing the number of incidents occurring (against no protection: shed/corral $p = 0.023$, guarding $p = 0.002$), with village as a random effect. The number of other livestock of that type kept was the main predictor of the number of incidents, while guarding or using sheds or corrals was associated with reduced numbers of depredation incidents. Notably, location (whether taken from the village or from in the forest), distance from nearest forest refuge, and livestock type were not retained as significant predictors in the final model.

Figure 18 shows the number of incidents plotted against the number of livestock kept, with predicted line values for each protection type as generated by a version of the model without village as a random effect. Once again there is some variability which is accounted for to some extent in the final model by including village as a random variable.

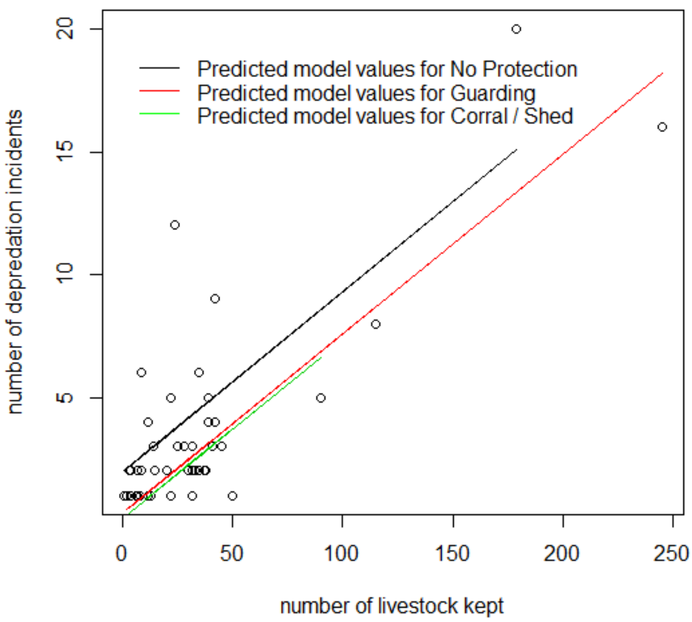


Figure 18: Number of livestock depredation incidents as a function of number of livestock kept. Lines represent predicted values for each protection type, from a generalised linear model of incident as a function of protection type and number of livestock

4.3.3 Household decision-making

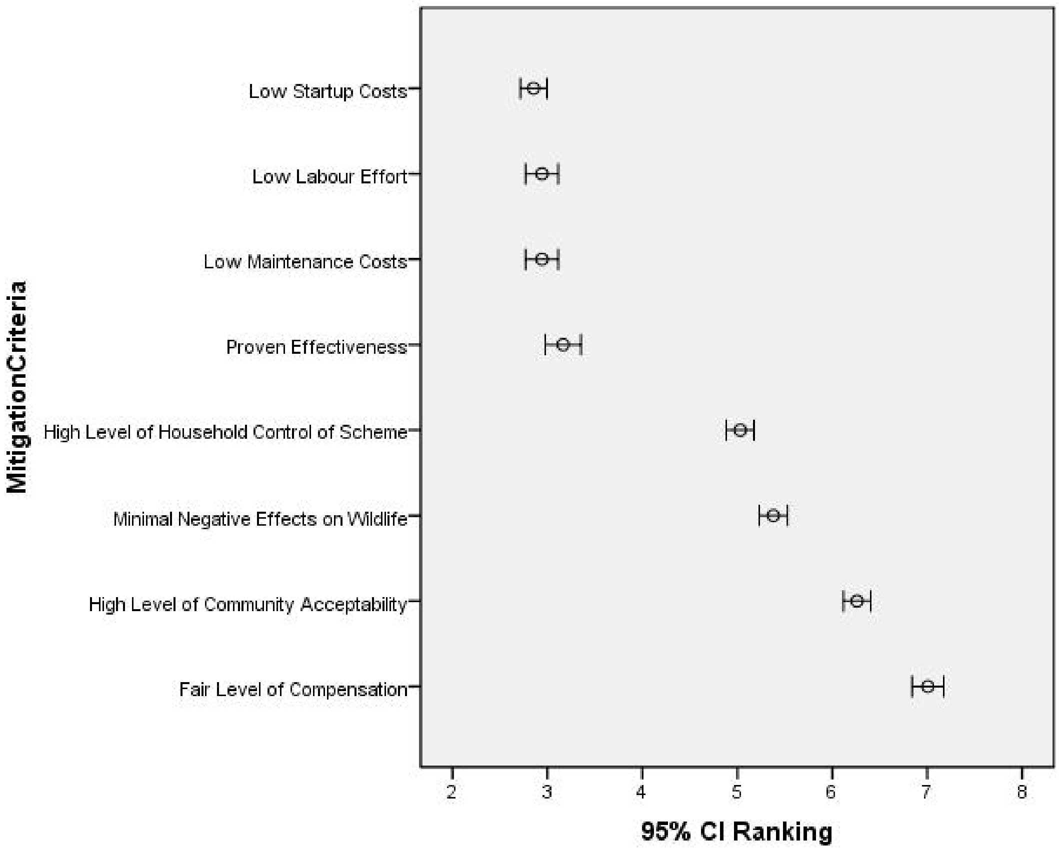
When asked which factors were most important in an ideal mitigation scheme, householders expressed clear preferences for certain criteria, with a significant difference in mean preferences overall (Independent-samples Kruskal-Wallis test, $p < 0.001$, $n = 478$; Figure 19a). Four key criteria relating to costs and benefits were most preferred: low startup costs, low maintenance costs, low labour effort, and proven effectiveness. The three criteria relating to costs were considered as important as the effectiveness of the scheme, with no significant difference between them in mean rankings. A high level of household control of the scheme, minimal negative effects on wildlife, community acceptability and fair compensation were ranked as much less important, with a significant difference in the order of preference between proven effectiveness and household control (Mann-Whitney U test, $Z = -13.741$, $p < 0.001$, $n = 478$), between household control and negative effects on wildlife ($Z = -4.990$, $p < 0.001$, $n = 478$), between negative effects and community acceptability ($Z = -10.686$, $p < 0.001$, $n = 478$), and between community acceptability and fair compensation ($Z = -12.167$, $p < 0.001$, $n = 478$).

Regarding preferred mitigation schemes to protect against crop-raiding, householders again expressed a strong preference for certain options (Independent-samples Kruskal-Wallis test, $p < 0.001$, $n = 478$; Figure 19bi). The most preferred option was electric fencing surrounding fields, with a mean ranking significantly higher than the second option of trenches around fields (Mann-Whitney U test, $Z = -12.589$, $p < 0.001$, $n = 478$). The choice of trenches around fields was significantly different from the third most popular option of electric fences around the park ($Z = -3.983$, $p < 0.001$, $n = 478$), which differed from the fourth most popular set of options ($Z = -19.103$, $p < 0.001$, $n = 478$). This set of options, which included better compensation, trenches around parks, more deterrents, wire fences around fields, and insurance, showed no significant difference in their mean preference ranking. These were all considered significantly better than natural fences around fields ($Z = -2.953$, $p = 0.003$, $n = 478$), followed by improving habitat within the park ($Z = -5.427$, $p < 0.001$, $n = 478$), and government control of problem animals, and finally the least preferred option was to stop grazing livestock in the park ($Z = -2.970$, $p = 0.003$, $n = 478$).

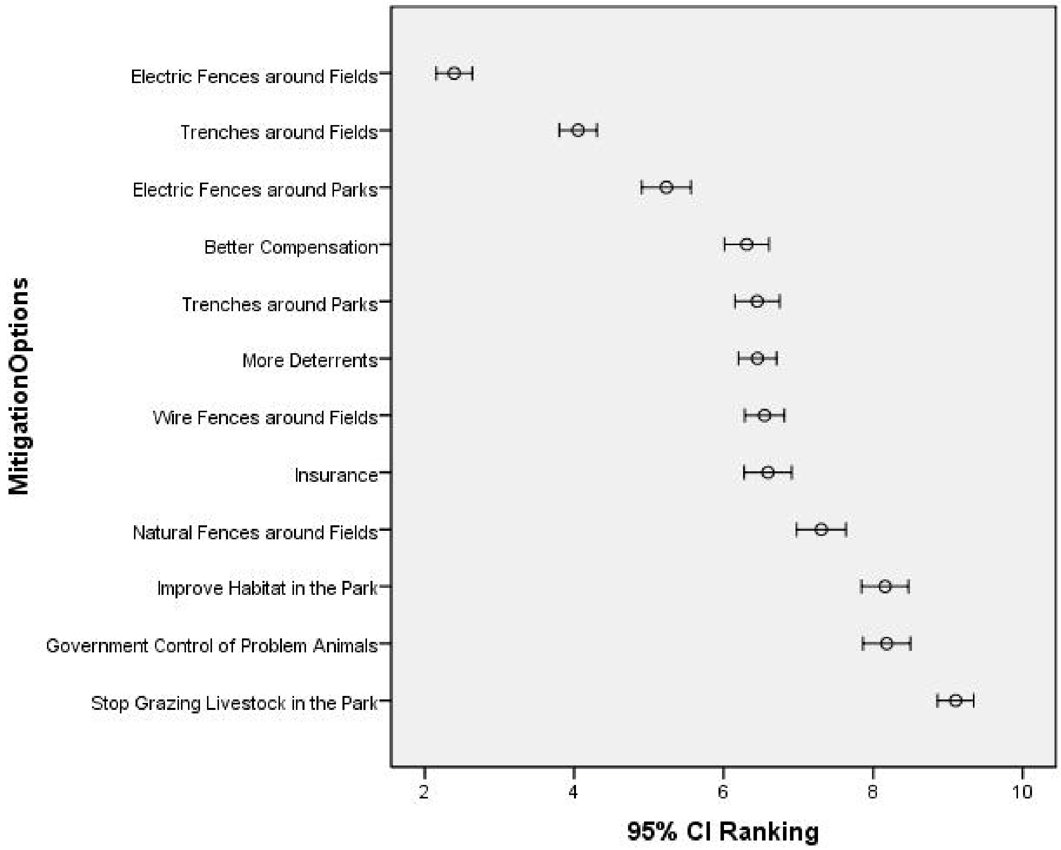
For preferred mitigation schemes to protect against livestock depredation, householders again expressed significant differences in preferences between options (Independent-samples Kruskal-Wallis test, $p < 0.001$, $n =$

478; Figure 19bii). Guarding was consistently ranked as the most preferred mitigation measure, followed by fencing of livestock corrals (Mann-Whitney U test, Z = -3.752, $p < 0.001$, n = 478). This was significantly preferred over the third option of compensation (Z = -6.292, $p < 0.001$, n = 478), which was preferred over insurance (Z = -3.669, $p < 0.001$, n = 478). Four criteria ranked last in preference (Z = -5.771, $p < 0.001$, n = 478), but with no difference between them: government control of problem animals, stopping livestock grazing in the park, stopping illegal hunting, and improving habitat in the park.

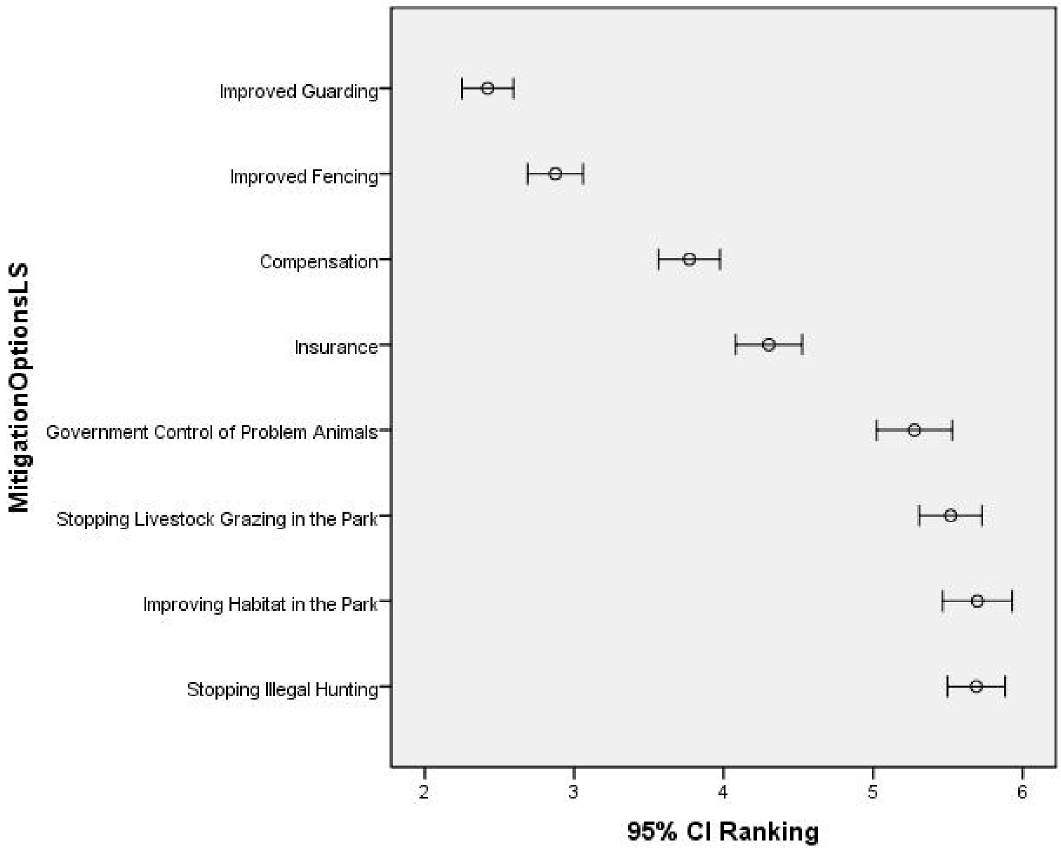
There was an obvious difference in preferred rankings for those most responsible for conflict (Independent-samples Kruskal-Wallis test, $p < 0.001$, n = 478; Figure 19c). Householders considered conflict management to be primarily the responsibility of the Forest Department, followed by other government institutions (Mann-Whitney U test, Z = -19.649, $p < 0.001$, n = 478), local communities (Z = -11.722, $p < 0.001$, n = 478), and independent conservation and development NGOs (Z = -5.114, $p < 0.001$, n = 478). Finally, tourists (Z = -20.150, $p < 0.001$, n = 478), tourist resorts (Z = -18.051, $p < 0.001$, n = 478), and urban citizens (Z = -19.308, $p < 0.001$, n = 478) were consistently ranked as being least responsible for managing or helping solve problems with conflict.



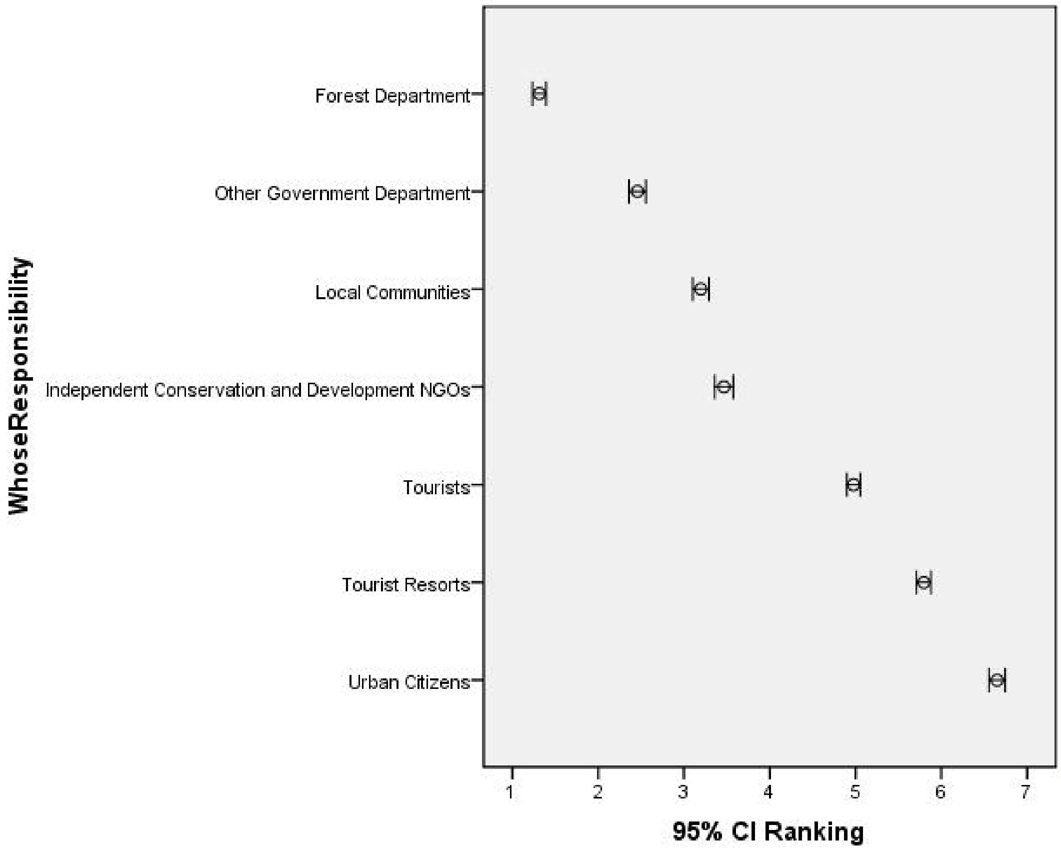
(a)


MitigationOptions
Electric Fences around Fields
Trenches around Fields
Electric Fences around Parks
Better Compensation
Trenches around Parks
More Deterrents
Wire Fences around Fields
Insurance
Natural Fences around Fields
Improve Habitat in the Park
Government Control of Problem Animals
Stop Grazing Livestock in the Park
2
4
6
8
10
95% CI Ranking

(b) (i)


MitigationOptionsLS
Improved Guarding
Improved Fencing
Compensation
Insurance
Government Control of Problem Animals
Stopping Livestock Grazing in the Park
Improving Habitat in the Park
Stopping Illegal Hunting
2
3
4
5
6
95% CI Ranking

(b) (ii)



(c)

Figure 19: Mean ranking with 95% confidence interval bars for (a) preferred criteria in a householder’s ideal mitigation scheme; (b) preferred mitigation schemes for (i) crop raiding and (ii) livestock depredation; (c) stakeholder groups considered to be most responsible for managing conflict (where 1 = most preferred/responsible)

4.4 Discussion

4.4.1 Livelihood protection strategies

The type of barrier and proximity to a forest refuge were the primary predictors for the number of crop raiding incidents. The closer fields were located to forest refuges, the higher the number of incidents, regardless of fence type. However, the most effective intervention associated with the lowest numbers of incidents was found to be electric fences, followed by wire fences, natural fences, and lack of fencing. This is in accordance with previous studies which consider electric fences best able to reduce both the likelihood of crop-raiding and loss (Davies et al. 2011), and which found proximity to forest to influence the extent of crop-raiding (Linkie et al. 2007).

However, in this study there was no indication that the use of particular deterrents in combination with fencing affected the number of incidents, although other studies have reported the use of spotlights and fire to effectively reduce damage while noise increases damage (Sitati and Walpole 2006, Davies et al. 2011).

Livestock loss was most associated with the numbers of livestock kept, most likely because this can be an attractant for predators, both when out grazing and when kept at night. Previous studies have similarly cited livestock density as a key predictor of depredation intensity (Treves et al. 2004, Woodroffe et al. 2005a). However, loss to predation was moderated by protection type: no protection was associated with a much higher frequency of predation than the use of guardians or sheds / corrals to house livestock at night. Other studies have also found the use of guarding and husbandry to effectively decrease depredation by large carnivores (Ogada et al. 2003, Marker and Dickman 2004, Woodroffe et al. 2007, Inskip and Zimmermann 2009a). However, there was a very low diversity of protection strategies employed to protect livestock from depredation in this particular study area, when compared to other carnivore conflict studies (Inskip and Zimmermann 2009a). Unexpectedly, for livestock there was no clear association with depredation and location. Grazing livestock in forest areas has previously been considered to be one of the main reasons for livestock losses to wildlife in the region (Madhusudan 2005) ; although results from the two years of monitoring in this study indicated no significant difference in the number of depredation incidents on village lands or within forests.

4.4.2 Household decision making

Rankings of the different criteria for each key question relating to conflict mitigation schemes were quite clear and consistently ordered across the 478 households sampled in the region. Although these questions were very broad and quite simplistic, this indicates that a majority of rural households have consistent views concerning livelihood protection from wildlife loss at this broad level, despite differences in livelihoods, economic status, community, and other socio-economic attributes. The revealed homogeneity of this particular stakeholder group of rural communities indicates some consistent preferences for important criteria that could realistically be incorporated into management plans implemented by government or other stakeholder groups.

The primary criteria used by householders in deciding on a protection strategy related to the direct costs and benefits of that measure: low startup costs, low maintenance costs, low labour effort, coupled with proven effectiveness. This explains the use of less effective barrier methods such as natural and wire fencing, the use of deterrents, and why there are still a majority of householders that continue to use no protection methods at all for either crops or livestock.

Given the choice however, householders considered electric fencing surrounding fields to be the best mitigation strategy out of those currently available to protect crops, followed by trenches surrounding fields. The focus on field-based protection is in contrast to the currently commonly practiced Indian method of placing trenches and fences around parks. For livestock, guarding was recognised as the most preferred mitigation measure, followed by fencing of livestock corrals. This indicates that the effectiveness of these measures is clearly recognised by householders, considering that they were associated with significantly reduced incidents, but that there are underlying factors that must inhibit their more widespread use. For electric fences, these are likely to be the costs of start-up and maintenance, and for livestock guarding to be the high labour effort involved.

Government awarded compensation is the most prevalent form of mitigation in India for all types of conflicts, with many associated problems and complaints (Bulte and Rondeau 2005, Nyhus et al. 2005b, Ogra and Badola 2008b, Rangarajan et al. 2010). Despite this, fair compensation was considered the least important criteria when it came to choosing a mitigation scheme. Better compensation was also only ranked as a middle option from the list of potential measures to protect against crop raiding, although it was ranked third for livestock, indicating that it is considered more acceptable for addressing livestock losses than for crop losses. This is most likely because it is easier to assess and claim the market value for an animal than for a certain area of crop damage. Insurance was not considered as a particularly important option for crop-raiding or livestock-depredation. Mitigation measures that concentrated on the protected area for both crop-raiding and livestock-depredation were least popular, including improving habitat or reducing hunting, control of problem animals, or restricting livestock access to grazing.

4.4.3 Responsibility for managing conflicts

There was a strong belief that the Forest Department should be responsible for conflict mitigation, followed by other government institutions. Local communities viewed themselves as being less responsible for these problems than the government, though more responsible than NGOs. This is in opposition to some of the preferred scheme criteria which showed that households clearly prefer mitigation measures to be field rather than park based, and understand the problems of existing measures such as park fences, trenches and compensation, which should reflect a greater acceptance of responsibility. However, they still strongly believe responsibility lies with the government, despite ongoing mitigation failures. This is reflected in householders' responses to being asked if they were prepared to take personal or collective responsibilities for managing conflict, where 31.8% were not prepared, 21.9% were prepared, and 53.7% were non-committal. Community reluctance to collaborate in mitigation efforts has been highlighted as a major factor in conflict mitigation failures (Ogra 2009, Rangarajan et al. 2010). Thus, empowering local communities to take responsibility for conflict may be the only sustainable solution (Osborn and Parker 2003), and hence any initiatives should attempt to reduce conflicts between the local communities and the Forest Department to drive a mutual sense of responsibility in parallel with establishing protection measures. Tourists, tourist resorts and urban citizens were considered to be those least responsible for dealing with conflicts. This suggests that schemes that attempt to link tourism incomes to conflict mitigation may need to be undertaken with care to ensure that local communities are accepting of the assistance provided by outsiders without assuming that this will be the case.

4.5 Conclusions

It is clear that the closer fields are to forest refuges, the higher the number of incidents of crop-raiding. Raiding can be reduced with more effective barriers, with the greatest reductions achieved by the use of electric fences. Deterrents do not appear to have any significant effect on incident reduction. Elephants and wild boar are responsible for the majority of crop raiding incidents, while leopard are primarily responsible for livestock depredation. Livestock depredation appears to be associated primarily with livestock density, and incidents are significantly reduced with guarding or with sheds / corrals. Given the low diversity of livestock protection methods employed, it may be that trials of other methods or further investigation into effective ways of improving guarding and husbandry may result in decreased depredation incidents (Inskip and Zimmermann 2009a).

However, it is not sufficient to implement or promote intervention measures solely on effectiveness if the mechanisms by which people choose to protect their livelihoods are not understood. Electric fences are shown in these circumstances to be the most effective at reducing crop-raiding incidents, but only if maintained, and a common criticism of electric fences in India is poor maintenance by the Forest Department leading to failures (Ogra and Badola 2008b, Rangarajan et al. 2010). This is a problem of institutional implementation, which has been recognised in a recent governmental inquiry that recommended a moratorium on further trenches and fences around Indian protected areas until universal performance standards are established (Rangarajan et al. 2010). These institutional problems however, may be avoided if decision-making by communities can be understood and tied to the establishment and use of effective measures. When given the choice communities would prefer to utilise electric fences surrounding fields, or improve their guarding practices, but are obviously hampered by their main criteria for implementing such strategies, which are issues of start-up and maintenance costs and labour effort. Results also indicate that many households continue to use no or extremely ineffective protection strategies, due to the associated costs or effort, which will inevitably perpetuate conflicts and undermine any conservation initiatives.

Given that the choice rankings revealed a large and diverse stakeholder group to have clear and consistent preferences, this indicates scope for more in-depth analyses of decision-making, which can be undertaken using economic valuation techniques such as conjoint analysis (Alriksson and Öberg 2008) and multi-criteria decision making (Kiker et al. 2005). This would yield further understanding of household preferences, particularly relating to the continued absence of protection strategies as well as identifying barriers to the adoption of more effective strategies.

The problem of conflict is also overwhelmingly attributed to the Forest Department and the government, despite government-managed mitigation schemes being less favoured. Creating a sense of responsibility and empowerment at a community level may be a mechanism by which more community based schemes can be implemented (Kellert et al. 2000, Berkes 2004, Ogra 2009), to overcome the challenges of cost and effort associated with more effective measures.

Chapter 5
"No man is an island[5]": challenges and opportunities for co-operative human-wildlife conflict mitigation

[5] John Donne (1624) Meditation 17: Devotions upon Emergent Occasions

5.1 Introduction

5.1.1 Human wildlife conflict and mitigation needs

Human-wildlife conflict undermines the conservation of large mammals and inhibits the sustainable development of rural communities in shared landscapes. Livestock depredation, crop raiding, and threats to human life or property are major causes of conflicts adjacent to protected areas, often resulting in retaliation against already threatened wildlife populations (Thirgood et al. 2005b). In biodiversity-rich landscapes with high human densities, conflicts can be most severe, impacting on impoverished local communities who bear a high cost for conservation (Balmford and Whitten 2003).

Crop raiding in particular can be a source of debilitating loss, e.g., in southern India village households lost 11% of annual grain production to elephants (Madhusudan 2003), with a total of 0.8 – 1million ha of crops lost across India (Bist 2006), while investment in damage control strategies can even exceed the cost of damage (Osborn 2005, Thirgood et al. 2005b). Compensation is often hampered by implementation problems which can be a source of further conflicts (Bulte and Rondeau 2005, Nyhus et al. 2005b) and does nothing to reduce the risks of future crop loss. Out of the growing body of mitigation techniques, improved crop protection strategies may be most cost-effective (Thouless and Sakwa 1995, Sitati and Walpole 2006). Methods include manual guarding; deterrents such as noise, fire and chilli; and barriers such as natural or wire fences, electric fences, and trenches (Osborn and Parker 2003). Guarding varies in effectiveness and often involves opportunity costs such as restricted participation in other income generating activities or education (Haule et al. 2002, Osborn and Parker 2003). Deterrents and non-electrified fences are usually of low efficacy (Osborn and Parker 2003, Sitati and Walpole 2006), while the most effective methods are electric fences and trenches which are the most expensive to install and maintain (Hayward and Kerley 2009), as reported in Chapter 4. These latter methods must rely on economies of scale, therefore are often implemented by external agencies or at a community level (Osborn and Parker 2003, Hayward and Kerley 2009).

Community-based conservation, development and natural resource management is an increasingly common practice, based on the involvement of community members and local institutions in the control of natural resources, devolving power from government, and linking development with conservation (Kellert et al. 2000, Berkes 2004). However, many co-operative projects have reported failures for a variety of reasons, whether initiated internally or by external agencies providing financial assistance, which often relate to intrinsic community heterogeneity. These include a lack of interest (Barrett and Arcese 1995, Songorwa 1999); failing to recognise different stakeholder motives and required incentives (or penalties), particularly over illegal hunting (Keane et al. 2008) and fisheries (Byers and Noonburg 2007); or failings in conceptualising and implementing community participation (Agrawal and Gibson 1999, Berkes 2004). One Indian study recommended community level electric fencing combined with a co-operative conflict management institution as a potential approach for mitigation, yet found that only 27.4% of respondents would actively support this institution due to the opinion that conflict resolution is solely a government responsibility (Ogra 2009). However, given consistent failures and criticisms of government-managed conflict mitigation schemes, from inadequate compensation measures (Nyhus et al. 2005b, Ogra and Badola 2008a) to failures to maintain electric fences or trenches (Rangarajan et al. 2010), conflict can seriously challenge agricultural livelihoods particularly in developing world contexts. Thus, there is a real need to understand how to increase the success of community-based conservation and development projects using interdisciplinary analyses of coupled socio-ecological systems (Berkes 2004, Ostrom 2009, Poteete et al. 2010), particularly regarding conflict mitigation.

5.1.2 Integrated ecological economic modeling and game theory

The use of integrated ecological-economic models for biodiversity conservation and environmental management is growing (Watzold et al. 2006, Drechsler et al. 2007, Cooke et al. 2009). Agent-based modeling explores individual decision-making in many social and policy contexts (Poteete et al. 2010), including conservation management settings such as land use (Parker et al. 2003) or ecosystem management (Bousquet and Le Page 2004), deer management (Touza et al. in press), bushmeat hunting (Bousquet et al. 2001), and in market-based conservation actions (Hartig and Drechsler 2009).

One mechanism for understanding conflict and co-operation in individual decision-making is evolutionary game theory (Myerson 1991). Game theory has been used to integrate biological and economic processes in environmental decision-making; e.g. in deforestation (Rodrigues et al. 2009), in transboundary protected areas (Busch 2008), protected area cost-benefit analysis (Albers and Robinson 2007), and in group decision-making over biodiversity conservation (Frank and Sarkar 2010), and can be a potential tool for adaptive management in conservation settings (Colyvan et al. 2011).

5.1.3 The stag hunt

The stag hunt (also known as the assurance game) is one game that illustrates the problems inherent in social co-operation (Skyrms 2004). In its basic form, two individuals go hunting, and each has a choice of stag or hare, without knowing the other's choice. If one chooses stag, the other must co-operate in order to succeed, while hare can be hunted alone. However, hare is worth less than a stag. There are two stable states, termed Nash equilibria: both players co-operate (payoff dominant) or both defect (risk averse but sub-optimal as the payoff is less). Co-operation results in the maximum payoff, while defection results in some payoff to the defector and nothing to the co-operator (Figure 20), so if one party defects the other is better off defecting as well. Hare-hare can therefore be considered the status quo as the safest strategy is to defect and not rely on others to co-operate, while stag-stag is the social contract. Choosing to establish a social contract always carries the risk of defection. This game can be applied at larger scales using an n-person stag hunt, where co-operation benefits can scale with increasing numbers of co-operators (Pacheco et al. 2009). The stag hunt may be more suited to describe problems of co-operation over natural resources than the oft-cited prisoner's dilemma which differs in that the best payoff comes from defecting against a co-operator (Myerson 1991). Stag hunt appropriate examples include any situation where success requires a minimum level of co-operation for socially and individually beneficial outcomes to be realised, such as in land-use management (Skyrms 2004, Colyvan et al. 2011).

		Player 2	
		Stag	Hare
Player 1	Stag	A, A	C, B
	Hare	B, C	D, D

		Player 2	
		Stag	Hare
Player 1	Stag	2, 2	0, 1
	Hare	1, 0	1, 1

Figure 20: The stag hunt payoff matrix, where payoffs follow $A > B \geq D > C$, as illustrated in the example payoffs

The n-person stag hunt game can therefore be effectively applied in a conflict mitigation context. Here, people can choose whether to establish a co-operatively based crop protection scheme, such as a community electric fence or trench surrounding a group of landholdings. This technology is typically more expensive to install and maintain than currently practiced individual strategies, such as guarding or non-electrified fences, but is significantly more effective in reducing crop losses when maintained (Hayward and Kerley 2009), as reported in Chapter 4. Successful co-operation results in a better payoff to co-operators in terms of crop protection, which increases as more co-operators reduce the costs of participating. However, acting individually is the status quo, as it is a known cost investment, and to some extent a predictable although lower level of risk reduction. Investing in a higher cost co-operative scheme is risky if other people defect and the scheme fails – the co-operator has paid the costs but has no risk reduction in place. Establishing the social contract requires moving from a known lower risk individual equilibrium to a more rewarding but risky co-operative equilibrium. Typically, game theory is pessimistic about the transition to social co-operation, claiming that social norms evolve slowly and often regress to the status quo (Skyrms 2004). Despite this, many well-intentioned community-based schemes have optimistically assumed that co-operation will always be beneficial and that people will participate if offered the opportunity (Barrett and Arcese 1995, Songorwa 1999, Kellert et al. 2000, Berkes 2004).

This study used a game theoretic approach in an agent-based simulation model of a virtual human-wildlife conflict situation centred on crop raiding, combining a spatially explicit landscape ecological model with a household based economic model, to explore factors that may influence crop protection decision-making. Here, conflict was considered in terms of the economic value of crop loss. Parameters influencing conflict risk (proximity and stochasticity) and economic productivity (landholding size and crop value) were chosen to represent key drivers identified from the literature. The model assumes that landowners cannot calculate their optimal decision given incomplete knowledge of mitigation effectiveness, but instead base their decisions on the outcomes of neighbouring landowners' decisions, choosing to follow the strategy of the neighbour with the highest payoff. The purpose of this study was to understand some of the underlying mechanisms for the observed difficulty in achieving sufficient investment in community-based conflict mitigation schemes, and to use this insight to suggest alternative designs to enhance participation and reduce problems generated by conflict.

5.2 Methods

The model consisted of two sub-models: a spatially explicit ecological model that determined the risk from conflict and impact on productivity based on the attributes of individual landholdings; and an economic model determining whether each landholder will pursue an individual or co-operative strategy of crop protection based on payoff calculations formulated as a 'stag hunt' game (Skyrms 2004) (full details of model variables are given in Table 13 & Table 14). The model was set in an agricultural landscape on the border of a protected area, where risk from conflict is a function of proximity to the protected area and stochasticity. Landholding productivity is a function of crop value and landholding size, and this productivity can be diminished by the risk of conflict. The factors parameterised in the model are conceptualised in Figure 21, illustrating the interaction between community-level, landholder-level and strategy choice attributes. Each landholder seeks to maximise utility by choosing one of the mitigation options based on incomplete information. The drivers for the configuration of strategies in the landscape at equilibrium are the economic costs and benefits of each choice given a variable degree of risk from conflict, combined with the ability to learn from the success of neighbouring landholders.

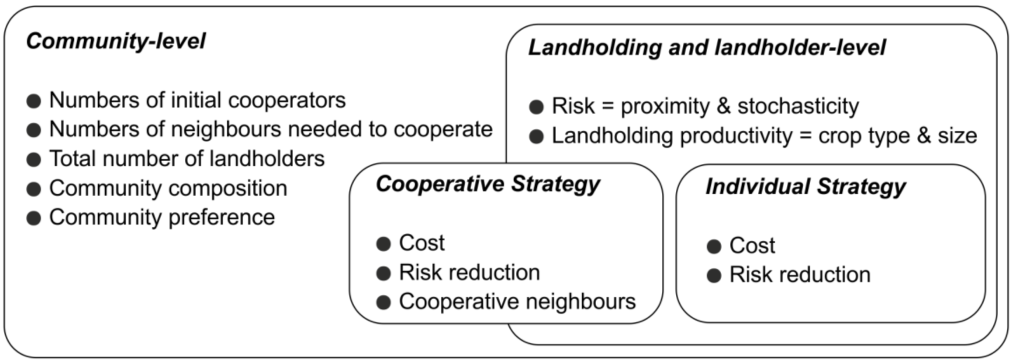


Figure 21. Conceptual framework for ecological and socio-economic parameters at community, landholding and strategy level that influence the landholder decision-making process.

Diffusion of each strategy throughout the landscape is mediated further by community-level demographics. The model was constructed in Netlogo

(Wilensky 1999), presented following model protocols (Grimm et al. 2010), and data outputs were generated in R (R 2010).

5.2.1 State variables and scales

The model is a 20 x 21 grid, with periodic boundaries creating a vertical cylindrical shape. A single row along one horizontal edge of the model represents the border of the protected area (PA). Each of the remaining $n = 20^2$ grid cells represent a landholding managed by a landholder ($n = 400$), each with variable ecological and economic attributes. The model can be applied to any spatial or temporal scale, but in this case the modeled grid is of sufficient size to represent a large grouping of landholders along a gradient of PA proximity. As each landholder may have a differently sized property, each grid cell is a representative landholding rather than real geographical extent. Each time step represents progress towards equilibrium rather than a measure of real time, as the percentage of co-operators at equilibrium is the simulation outcome. The landholder strategy x_i exists in one of two states: for grid cells where landholders pursue a co-operative strategy $x_i = s_{co\text{-}op}$; where landholders pursue an individual strategy $x_i = s_{ind}$. The variables of the two sub-models are presented in Table 13.

5.2.2 Ecological / spatial model

The ecological model sets the attributes of the spatial landscape (Table 13). Crop value, vc_i, is assigned to each landholding, representing a scale from low value subsistence crops to high value commercial crops as an index of $1 \leq vc_i \leq 10$; and landholding size a_i, representing a scale from smaller landholdings up to larger landholdings as an index of $1 \leq a_i \leq 10$. Each of these values are drawn from scenario-specified distributions. The total value of each landholding vf_i is thus assigned as a function of the crop value and the size:

$$(1) \qquad vf_i = vc_i * a_i$$

This represents an index of landholding productivity where $1 \leq vf_i \leq 100$, which can be diminished according to the extent from which a particular landholding suffers from crop-raiding conflict.

In order to model the different effects that crop-raiding conflict (measured as percentage loss in productivity) has on each landholding, the risk r_i of crop loss posed to each landholding from conflict was modeled as a function of proximity to the PA boundary p_i and a stochastic risk element se_i:

$$(2) \qquad r_i = p_i * se_i$$

To obtain this, the model describes the proximity of each landholding from the PA boundary, standardised to a continuous $0 < p_i < 1$ index, where 1 is closest to the boundary. Many studies show that one of the primary drivers for conflict is that wildlife are attracted to cultivated areas closer to protected area boundaries or refuge areas (Sitati et al. 2003, Naughton-Treves and Treves 2005, Woodroffe et al. 2005a). Stochasticity was set as a randomly drawn index of $0.5 \leq se_i \leq 1.5$, drawn from the specified part of a normal distribution with a mean of 1. Risk is often locally spatially variable between landholdings for different (and not always identified) site-specific reasons (Sitati et al. 2003, Woodroffe et al. 2005a) sometimes producing severe idiosyncratic events (Dickman et al. 2011). This simple measure combines proximity with inherent stochasticity that can increase or decrease overall risk. The resulting risk measure is used to calculate the value of losses to conflict for each landholding, as a proportion of the overall productivity of the holding. This risk measure is reduced by different extents according to each landholder's strategy choice.

These indices reflect a small selection of key conflict drivers from the literature (Sitati et al. 2003, Naughton-Treves and Treves 2005, Woodroffe et al. 2005a), centering on risk as a function of proximity and stochasticity, and on economic losses as a function of the variation in productive capacity of landholdings as a result of crop value and landholding size.

5.2.3 Economic / decision-making model

The economic model determines the decision-making process of the landholders (autonomous agents) who reside on each landholding. Each landholder decides whether to pursue the co-operative crop protection strategy, or the individual strategy, following a 'stag hunt' definition of payoffs. Fixed model parameters are listed in Table 13 and manipulated scenario parameters in Table 14.

Firstly, a given percentage of initial co-operators is randomly distributed throughout the landscape, in order to initiate the learning and evolution process. Co-operation cannot arise in a solely individual-based landscape unless some participants change their strategy, so it was projected that a certain number of landholders decide from the outset that they would co-operate. Then, at each subsequent time step, landholders change strategy through imitating the strategy of their immediate neighbour with the best payoff.

Table 13: Ecological and economic model variables parameterized in the agent-based model of decision-making in a conflict situation

Symbol	Connotation	Model Range
Ecological (spatial) model variables:		
p_i	Proximity: the standardised inverse position of the i*th* landholding from the PA boundary = *(max distance + 1 – distance) / (max distance + 1)*	0 – 1
se_i	Stochastic element of risk to the i*th* landholding as a randomly drawn value from part of a normal distribution with μ = 1	0.5 – 1.5
r_i	Risk to the i*th* landholding from conflict i.e. proportion of productivity that will be lost as a function of proximity and stochasticity $= p_i * se_i$	0 – 1.5
a_i	Size of the i*th* landholding	1 – 10
vc_i	Value of crops grown on the i*th* landholding	1 – 10
vf_i	Productivity of the i*th* landholding $= vc_i * a_i$	1 – 100
cc	Community composition as a percentage of community A over community B	0 – 100
Economic (decision-making) model variables:		
s_i	Strategy of the landholder of the i*th* landholding	Co-operative or Individual
ss	Percentage of landholders who choose to co-operate at the outset	0 – 100
$c_{co\text{-}op}$	Co-operative strategy cost per size unit a_i	1 – 10
n_i	Number of co-operating neighbours surrounding the i*th* landholding	0 – 8
cn_i	Proportion reduction in $c_{co\text{-}op}$ due to co-operating neighbours $= 1 – (n_i / 10)$	0.2 – 0.9
c_{ind}	Individual strategy cost per size unit a_i	2
$m_{co\text{-}op}$	Co-operative strategy risk reduction	0 – 1
m_{ind}	Individual strategy risk reduction	0.25

To obtain payoffs for each landholder (equation 3), the chosen strategy cost is subtracted from the productivity of the landholding vf_i (equation 1), where the cost of their chosen strategy $c_{strategy}$ is calculated as a scenario-defined cost per size unit a_i. This cost is further reduced in the co-operative strategy by a certain proportion depending on the number of co-operating neighbours cn_i in the immediate vicinity (where 1 neighbour = 10% decrease and a cn_i value of 0.9; 2 = 20% and 0.8 etc). Finally, the loss due to conflict is also subtracted, derived from the risk to a landholding r_i, (equation 2) multiplied by the chosen strategy $m_{strategy}$ risk reduction, producing a proportional loss of landholding productivity to conflict. This final value is the economic payoff as a result of each landholders chosen strategy. If a landholder chooses a co-operative strategy but is surrounded by non-co-operators (defectors), he receives no co-operative reduction in the cost of the co-operating strategy, and no risk reduction at all, hence receives the poorest payoff.

The economic payoff for each landholder is thus calculated based on the following variables: (1) the productivity of the landholding, (2) the cost of their chosen strategy per size unit, and (3) the risk and losses to conflict as reduced by their chosen strategy, as follows:

(3) Payoff for individual strategy =

$$[vf_i] – [a_i * c_{ind}] – [vf_i * (r_i * (1 – m_{ind}))]$$

Payoff for co-operative strategy with neighbouring co-operators =

$$[vf_i] – [a_i * (c_{co\text{-}op} * cn_i)] – [vf_i * (r_i * (1 – m_{co\text{-}op}))]$$

Payoff for co-operative strategy with no neighbouring co-operators =

$$[vf_i] – [a_i * c_{co\text{-}op}] – [vf_i * r_i]$$

The influence of heterogenous communities was also considered, where different segments within a community landscape would prefer to interact with neighbours of the same community, or choose not to co-operate with members of a different community. Community composition *cc* sets the percentage of community A over community B, and trust *t* is set as a community-level probability that landholders of different communities choose to learn from and co-operate with neighbours of different communities.

5.2.4 Parameterisation and analysis

The model can therefore be divided into parameterisations of attributes at the community, landholdings, and landholder mitigation strategies level (Figure 21), varied according to a number of different scenarios. For all scenarios, the outcome was measured as the percentage of co-operators established once the model reached equilibrium (i.e. once landholder strategy choice settled to an unchanging state, or time steps reached 100 to account for any continuous small scale changes).

Table 14: Ranges for parameters varied by landholder and community level scenarios in the agent-based model

Variable	**Scenario values**	
	Landholder-level & co-operative attributes scenarios	**Community level Scenarios**
Landholding size a_i	Small, medium & large farms; Normal dist: σ = 2.5, μ = 1, 5, 10, bounds 0.1 – 10.	5
Landholding crop values vc_i	Low (subsistence), moderate (mixed), high (commercial) value crops; Nomal dist: σ = 2.5, μ = 1, 5, 10, bounds 0.1 – 10.	5
Community Composition (% community A) *cc*	NA	50 – 100
Initial co-operators *ss*	25% or 100 landowners	0 – 100
Co-operative costs $c_{co\text{-}op}$	1 – 10	5
Co-operative risk reduction $m_{co\text{-}op}$	0 – 1	0.75

Co-operative cost-benefit tradeoffs under different landholder economies

Nine scenarios were generated representing example patterns of landholdings subject to conflict, based on combinations of landholding size a_i and crop value vc_i (value ranges are given in Table 14). Landscapes were defined as predominantly small, medium, or large landholdings, landholding size being randomly drawn from part of a normal distribution where $1 \leq a_i \leq 10$, with the distribution mean size varying across scenarios. A distribution mean size of 1 represented predominantly small scale landholdings, 5 -

medium landholdings, and 10 - large landholdings. Crop value was defined as predominantly crops of low economic value (e.g. subsistence crops), moderate value, and high value (e.g. commercial crops) per size unit a_i. Value was randomly drawn from part of a normal distribution where $1 \le vc_i \le 10$, with a distribution mean set to represent the primary crop value type (1 representing low, 5 - moderate, 10 - high value).

These scenario parameters hence influence the total productivity vf_i of each landholding; and so also the potential percentage losses occurring due to conflict. Note that 'large' sized landholdings and 'high' value crops in these scenarios represent the upper bound of richer landholders who still cannot afford expensive protection strategies at the individual level.

In these size-value scenarios other parameters were kept constant (listed in Table 14). An initial 25% *ss* of randomly distributed landholders were set as choosing to co-operate. Individual strategy costs c_{ind} were set at 2 and individual risk reduction m_{ind} set at 0.25, since individual crop protection strategies tend to be of lower cost with a lower level of risk reduction, also in keeping with the definition of the 'stag hunt' payoff.

Then, for each landholding size/value combination scenario the 'costs' of co-operation $c_{co\text{-}op}$ were varied along an index of 1 to 10, representing low to high cost; along with the proportional risk reduction produced by co-operative strategies $m_{co\text{-}op}$, from a scale of 0 to 1, representing zero to full protection effectiveness. Varying the costs and benefits of the co-operative strategy against a fixed individual cost/benefit explored the importance of the relative differential between the strategies given other variations in parameters, and shows the same results as varying the individual parameters against fixed co-operative parameters. The model was run 108,900 times (12,100 runs per scenario, 100 runs per permutation).

Variations in community-level and external factors

In order to explore some of the community-level factors, the landholder-level and co-operative strategy attributes were kept constant. These were set at medium sized landholders, moderate crop values, moderate co-operative strategy costs and moderate co-operative risk reduction benefits (listed in Table 14). The community-level factors could be considered as being set by government or NGOs assisting in implementation of such a community-based scheme, or by inherent aspects of the community itself.

The model was run with variations in the initial percentage of co-operators (from 0 – 100%; 10,100 model runs, 100 runs per permutation). Different world sizes were used to vary the total number of landowners (over 1,500 model runs, 250 per permutation), but using the same initial number of co-operators (100); and explored variation in the numbers of neighbouring co-operators needed (from 1 – 4; 1,000 model runs, 250 runs per permutation).

Finally, the possible influence of community heterogeneity was considered. Heterogeneity could potentially influence either the diffusion of the co-operative strategy through learning, or through an increased likelihood of defection against a different community member, and the effect of the former was investigated. Each landholder was randomly assigned to one of two different communities, varying the percentage of one community in the population (from 50-100%). As before, landholders choose their strategy based on the best strategy of their neighbours, but followed a rule of preference for following the successful strategy of a neighbour of your own community, rather than a neighbour from a different community.

The assumption is that they trust and have insight into the decision making of their community over and above decisions made by those outside. If they were surrounded by members of both communities, they chose to follow the neighbour of their own community with the maximum payoff. If they were surrounded by only members of the opposite community, they would then choose to follow a neighbour of the opposing community with the maximum payoff. The model was run 6,050 times (250 times per permutation).

Strategy payoffs at the community and individual level

An ‘average’ model scenario (with fixed parameters of moderate landholding size and value, co-operative costs of 5 and benefits of 0.75, and initial co-operators set at 25%, for 500 runs), was used to investigate the total and per capita payoffs at both a community and individual level for the two strategies at equilibrium.

5.3 Results

Varying degrees of co-operation emerged, dependent on the economic parameters of each landholder strategy, landholding-level attributes, and community-level attributes. The coupled model identified key determinants of the emergence of co-operative outcomes by comparing a number of different conceptual scenarios. Maximising the percentage of co-operators at equilibrium was considered to be the optimal outcome for conflict mitigation.

Two sets of scenarios were explored: one set investigated how variations in the attributes of the co-operative strategy (the cost-benefit trade-off) might impact on the evolution of co-operation, given certain typical combinations of landholder demographics. These scenarios permitted the evaluation of the core criteria of the co-operative strategy and whether these might change if a community is economically better or worse off. The other set of scenarios investigated how variations in external factors dictated by the community or scheme implementer could impact the evolution of co-operation, as this can enable suggestions for potentially beneficial changes in implementation procedures.

The strategy landscape (co-operative vs individual crop protection) that emerged for all scenarios displayed clusterings of co-operators, with a tendency for co-operation to increase with proximity to the PA, corresponding to a general increase in the risk of loss. This validated the model settings, in that co-operative mitigation schemes rely on spatial proximity of landholdings, and that the co-operative payoff increases as risk from conflict increases, as does the cost from risk of defection.

5.3.1 Co-operative cost-benefit tradeoffs under different landholder economies

The first set of scenarios investigated how variations in the cost and benefit (risk reduction) attributes of the co-operative strategy might impact on the evolution of co-operation, given certain typical combinations of landholding demographics, where landholding varied by size and by value (Table 14). The model showed that within the co-operative strategy, cost is the main constraint to the evolution of co-operation, rather than the level of risk reduction (Figure 22). Changes in cost produced sharper and greater changes in percentage of co-operators than changes in the level of risk reduction, for all landholder demographics. Concurrently, landholding crop value had a greater influence on the evolution of co-operation than landholding size (Figure 22). Increasing crop value for a given size supports a greater cost of co-operating, while there was little variation in the evolution of co-operation across size, for a given crop value. Increasing crop value and size was also associated with the increased importance of risk reduction.

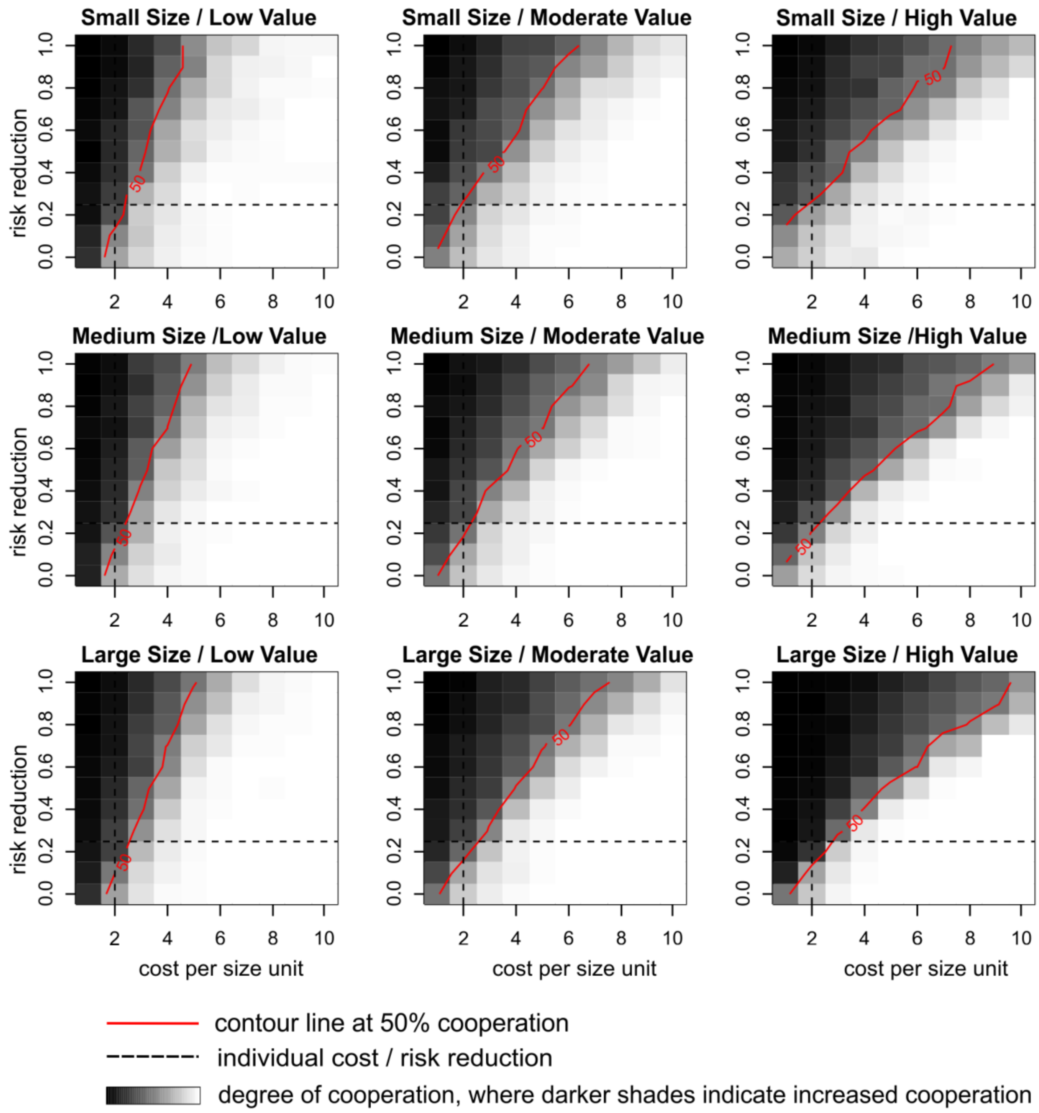


Figure 22. The percentage of co-operators at equilibrium, as a function of variations in co-operative strategy cost and benefits, across nine landholding scenarios varying in landholding size and crop value, for a fixed individual strategy cost and benefit.

5.3.2 Community-level contexts

The second set of scenarios investigated how variations in external factors dictated by the community or scheme implementer could impact the evolution of co-operation (Table 14). Variations of the following were tested: the initial percentage of co-operators, the total number of landowners, the number of neighbouring co-operators required for scheme implementation, and the influence of community heterogeneity.

When initial numbers of co-operators are varied (Figure 23), a threshold of approximately 20% needs to be exceeded for there to be a strong likelihood of co-operation developing, as below this the chances of completely reverting to the status quo of individuality are very high due to the pull towards this equilibrium. Points above the *xy* line indicate the uptake of co-operation, while those below indicate the reduction of co-operation from the initial numbers of co-operators. This is also because the randomly distributed initial co-operators are more likely to be clustered at higher levels, which enhances the retaining and diffusion of the co-operative strategy. Once initial interest increases past this threshold the likelihood of co-operation also increases, and past initial levels of approximately 60% the equilibrium is pulled towards full co-operation.

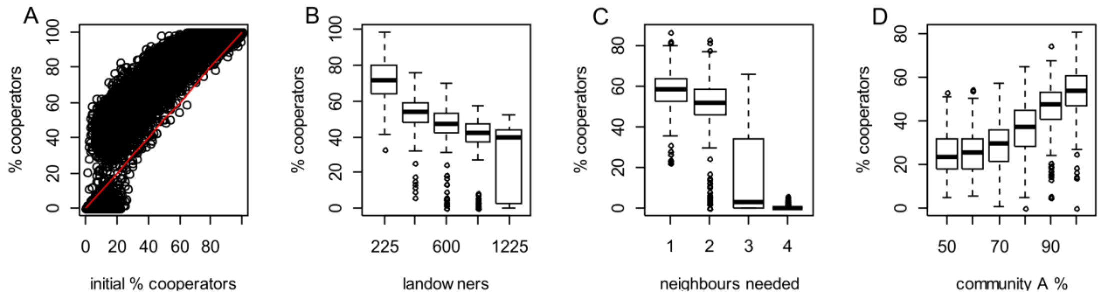


Figure 23. The percentage of co-operators at equilibrium, as a function of A. percentage of initial co-operators; B. number of landowners; C. number of neighbours needed; D. community heterogeneity as a percentage composition of two community types.

When there are more landholders in a community but a fixed number of initial co-operators, there is a corresponding decrease in the percentage of co-operators evolving (Figure 23). Increasing the numbers of participants makes co-operation more difficult to achieve and lower levels of co-operation becomes a more predictable outcome.

Establishing initial constraints on co-operation, in that it can only be successful with a certain number of neighbours, results in a dramatic decrease in the degree of co-operation (Figure 23). The need for 2 neighbours results in a reduction in the number of final co-operators, whilst increasing it to 3 or 4 neighbours means that the average percentage of final co-operators drops to near zero.

The potential effects of community heterogeneity were investigated, by varying percentages of community A over community B. A rule of preference was constructed for following the successful strategy of a neighbour of your own community, rather than a neighbour from a different community. A simple rule such as this only assumes a preference, not that there is an active distrust or increased likelihood of defection towards others. Community heterogeneity under the circumstances tested has a strong effect on diminishing the degree of co-operation that evolves (Figure 23). A community that is homogenous or mostly homogenous has a greater likelihood of co-operation evolving than a mixed community. The more mixed the community, i.e. when there is no clear majority, the smaller the probability of co-operation.

5.3.3 Community level payoffs of social co-operation versus individuality

The relationship between payoff and strategy was also assessed using the 'average' model scenario. The per capita payoff of all landholders in a community increases as the final number of co-operators within the community at equilibrium increases (Figure 24). Further, co-operators receive a better payoff than individuals, which increases as the final number of co-operators increases (Figure 24) above a threshold of approximately 25% co-operators.

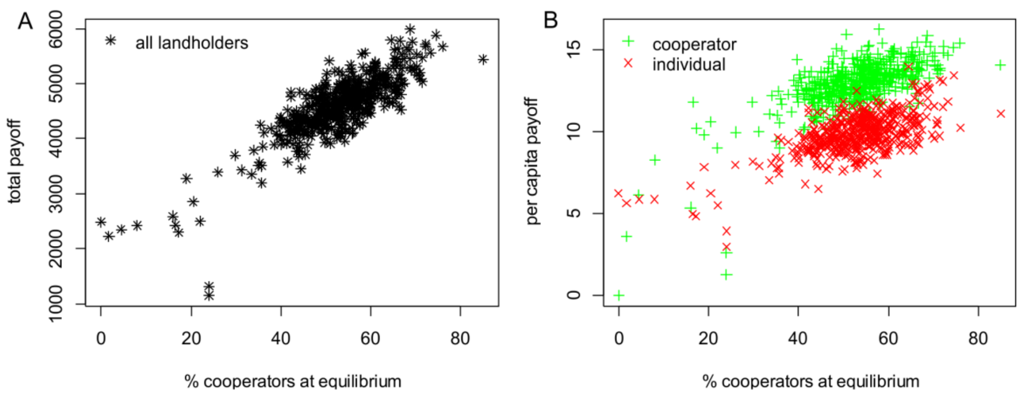


Figure 24. Payoffs by the percentage of co-operators at equilibrium, for (a) total payoff for all landholders; (b) per capita payoff for co-operating/individual landholders.

5.4 Discussion

5.4.1 Model findings and applicability to community-based mitigation schemes

Social contracts require a measure of trust between co-operators that the others will not defect. In this case, a modeled community-based co-operative scheme, such as electric fencing, improves the chances of maximising loss reduction due to conflict. Individual methods of protection, the status quo, are relatively ineffective, but carry a known cost and a known risk, and success is independent of other people's actions. Those who invest in the co-operative strategy stand to lose when others defect, which in real-life could be either in refusal to participate, failing to contribute to set up costs, or failing to contribute to maintenance – all with economic consequences for other participants. Variation in parameters at the strategy-level, landholder-level and community-level produces different effects on the evolution of co-operation. Results show that (1) variation in individual risk has a significant effect on likelihood of co-operation; (2) co-operative risk reduction is more important for more affluent landowners whilst cost is more important for poorer landowners; (3) limited initial interest, more landowners, pre-defined constraints and community heterogeneity all hinder the evolution of co-operation; (4) co-operation can dramatically increase the productivity of a landscape if risks from conflict are high.

The importance of individual risk for co-operation

The cost of the co-operative strategy is the main constraint to the evolution of co-operation (Figure 22), rather than the effectiveness of risk reduction. This happens in the model because the cost of participating in a community-based scheme has been set according to a particular single attribute of the landholder, to reflect real-world situations. People are usually required to contribute according to their means, often measured in terms of land area to be protected, in the interests of establishing a 'fair' scheme. However, this is unexpectedly problematic because the model clearly reveals that the benefits of the co-operative scheme are variable, not according solely to an individual's demographic but also according to the spatial variability of risk. Risk may be random or driven by socio-ecological factors, but it is not usually related to the measures typically ascribed to establish cost. Therefore, people may pay costs according to a particular landholder attribute, such as land, but actually receive benefits in a more stochastic fashion related to risk. So, when deciding on a strategy, for an individual the cost becomes a much more important factor than how much more effective that strategy might be, due to risk being variable and often unpredictable.

In situations where cost is linked to means rather than risk, when full co-operation is needed it would therefore be necessary to bring the cost of co-operating down in line with the risk faced by the member of the group *who faces the smallest risk of conflict,* or accept that these members will often defect to an individual strategy as their co-operative payoff is less. If the scheme aims to provide poorer farmers with improved protection, defection can have grave implications and so the most important outcome would be for many to participate to benefit from reduced costs due to economies of scale. For example, in a group where smaller landholders lie in closer proximity to the PA than larger landholders, the larger landholders may be at a lesser risk than the smaller but would be paying more to co-operate if contributions depended on area – hence subsidising the losses of those at greater risk. Even if landholding size is fairly constant, those at reduced risk will still be ultimately paying relatively ‘more’ to co-operate as their trade-off results in a smaller payoff, subsidising the losses of those at greater risk. A scheme designed to be ‘fair’ by basing contributions on area can actually be indirectly unfair if it results in a lower participation rate. This also has important implications for the maintenance of co-operative schemes, where continued payments or another form of ongoing cost is required – those who believe their progressive gains are less than other participants may become more likely to defect.

Ideally, to avoid these problems, contributions to a community scheme should be individually based on the level of risk each landholder is likely to face. This could follow actuarial models of insurance premiums, of which there are many crop insurance financial mechanisms applied on larger scales for other types of risk, e.g. in India (Clarke et al. 2012). In cases where risk can be strongly predicted by a small number of socio-ecological drivers (e.g. proximity) this may be feasible, but in more unpredictable conflict situations it may be impractical for communities or other local institutions to calculate individual risks. An alternative way of assessing costs, if risk is unknown, could be to means-test costs based on contributions proportional to multiple landholding values, as a more inclusive measure of economic productivity (e.g. with both crop type and landholding size). This is important because the model results also show that variations in crop value actually have a greater influence on the level of co-operation for given costs/benefits than landholding size. This would enable those of a greater economic status to contribute more than those less able, providing a clearer association between cost and benefit, and can be a more immediately practical method of assessing contributions when the calculation of risk alone is not feasible.

When co-operative risk reduction becomes important

The model shows that economically better off communities with higher value crops and larger landholdings are more able to support paying an increased cost for participating in co-operative schemes (Figure 22). For these higher costs the model shows that there is actually a demand for a consequentially much more effective risk reduction strategy. Economically poorer communities, with extremely small or low value landholdings, simply cannot afford a co-operative cost much greater than their individual strategy, regardless of the increased benefits, hence in groupings of poorer landholders costs must be low in order for co-operation to develop. Consequently, and counter-intuitively, for these communities and at these costs effectiveness does not actually need to be much higher than the individual strategy.

Estimating the costs of co-operation

Costs can be translated into real terms by comparing the cost of co-operation to the cost of acting individually. The lower the cost differential between these two activities, the more likely co-operation is to evolve. As can be seen from the model results, for poorer landholders a scheme that focuses solely on the benefits of co-operating – i.e. the effectiveness of the strategy – is unexpectedly less likely to promote co-operation if improved benefits come at greater cost.

Governments or NGOs assisting in the implementation of co-operative schemes should therefore focus on reducing the cost of co-operating as much as possible to encourage inclusiveness, rather than focusing on effectiveness which often comes at greater expense. This is not a suggestion that these schemes should be free, as lack of ownership or expectations of subsidies may bring their own problems of sustainability, but that as previously stated, determining the cost of participation must bring it in line with those in the group that *suffer the least risk* if it is necessary for them to be involved. This runs counter to conventional strategies which often focus on helping the individuals suffering the greatest risk, but in these cases help should be granted at an individual level or in much smaller co-operative groups. Larger co-operative schemes will be forced to follow the lowest common denominator of risk to achieve the greatest participation.

Community level factors driving co-operation

At a community level, the model showed that initial interest in co-operation is an important factor, because it is difficult to pull away from the natural equilibria of all acting individually or all co-operating. Interest needs to be at or above a natural threshold of approximately 20% for there to be a reasonable likelihood of co-operation developing (Figure 23). This could be a useful gauge to judge whether initial interest is sufficient before embarking on such a scheme. This follows previous analyses of the stag hunt, which found that because of the difficult transition from individuality to co-operation, if a community is very individualistic the chances of instituting a social contract are poor (Skyrms 2004).

The model also showed that when the initial number of co-operators is fixed, more participants hinder the evolution of co-operation (Figure 23). This is one avenue for further research to compare the impacts of varying the initial numbers versus percentage of co-operators, and in determining where the co-operation threshold (Figure 23) might lie for different community sizes. This result does indicate caution in the frequently occurring drive to make community-based schemes bigger and more inclusive for economies of scale. Game theory also posits that there may be an upper limit for a self-contained and sustaining commons, and that in fact multiple small-scale co-operative schemes may be more successful than fewer large-scale schemes (Santos and Pacheco 2011). However, there is ongoing debate on the effect of group size given that evidence from empirical studies on collective action is conflicting (Poteete and Ostrom 2004).

Establishing a constraint on co-operation, in that it must include a certain number of neighbours, results in a dramatic decrease in the final degree of co-operation (Figure 23). This means that co-operative schemes which formally require a set number of participants or minimum area to be included in the scheme may be reducing their chances of success. These constraints are usually important from an economic or ecological perspective e.g. for economies of scale or simplifying management, but unexpectedly may not be socially desirable. However, even without these constraints, the evolution of co-operation often subsequently meets these criteria as the model showed a strong tendency to form fairly large clusters, so these pre-requirements can be self-defeating.

Community heterogeneity is a major obstacle to co-operation

Community differentiation as considered here could represent any means by which people might differentiate themselves from one another resulting in a difference in the likelihood of imitation or co-operation, such as religion, caste, income stratification or land use differences. Increasing community heterogeneity diminishes the evolution of co-operation (Figure 23), under the simple rule that the diffusion of co-operation is influenced by a preference for your own community. This alone has a strong effect on co-operation, without incorporating any theoretical potential for increased defection between communities. Failed community-based approaches have been criticised as having misunderstood communities as being “a small spatial unit, as a homogenous social structure, and as shared norms” (Agrawal and Gibson 1999). Co-operation can prosper in a community with already established co-operatives, because people learn to interact with others who wish to co-operate, hence schemes that force inclusivity with new or different groups are unlikely to be successful due to a lack of knowledge or trust in other participants’ likely choices (Skyrms 2004). The mechanism by which heterogeneity influences co-operation, and its effect under different circumstances is another divisive debate (Poteete and Ostrom 2004). The model does, however, support the general view that in heterogenous communities, external agencies wishing to promote co-operation need to actively engage with each faction to encourage trust and positive interactions. Communities should not be expected to overcome these issues independently, and external support of local decision-making institutions in this respect has been identified as an important criteria for community-based conservation and development projects (Agrawal and Gibson 1999, Balint and Mashinya 2006).

Co-operation can benefit both conservation and development

Both the community and landholders can benefit from co-operation, as according to the model the economic productivity of a landscape can potentially be improved once significant risks of conflict are minimised (Figure 24), particularly once co-operation becomes more mainstream, above approximately 25%. This threshold also indicates that very small co-operative schemes, or schemes in areas where conflict risks are small, may not be worthwhile investments, either to individuals, communities, or to implementing agencies. It is more beneficial at a landholder level to be a co-operator unless your level of risk is particularly low (Figure 24).

This potential for increased productivity can be considered a form of conservation incentive, through reducing dependency on PA resources with the stabilisation of agricultural productivity as a profitable livelihood option. Reduced conflict can also lead to improved attitudes towards wildlife and reduced retaliation. Facilitating the use of more effective but more expensive mitigation technologies at a community level avoids the multiple problems of implementation of these methods at higher levels, which include poor maintenance, lack of ownership, and stakeholder conflicts.

5.4.2 Model generality

This model has been used to illustrate a community co-operative scheme such as electric fencing, but could equally be applied to intangible co-operative schemes such as insurance, where the cost is fixed but the individual benefits are variable. As a concept, this type of model can be used to study any form of community-based conservation and development scheme that meets the requirements of the stag hunt game, where the greatest payoffs are delivered through co-operation, but at the risk of gaining nothing when others defect. This is in opposition to the Prisoner's Dilemma, where the best payoff is to defect against a co-operator, which explains the exploitation of common pool resources, rather than situations where co-operation is necessary for success.

The model can be expanded to accommodate more detailed parameters in site-specific case studies. For example the current indices used can be changed to real values in a real-world spatial context. Further, this model used risk as a function of proximity and a measure of stochasticity, which could be altered to incorporate one or more known drivers affecting risk for particular sites. It is also possible to expand these models to include more comprehensive ecological functions for conflict-causing species, or to include other types of stakeholders.

This model solely focuses on the means to reduce risks from conflict, not to improve tolerance, although both activities should be part of effective mitigation approaches (Dickman 2010). Debates over the particular method proposed as a basis for community co-operation, e.g. electric fences, are beyond the scope of this paper, but see (Hayward and Kerley 2009).

5.4.3 Game theory and community co-operation

The stag hunt and other games of co-operation show that social norms evolve slowly even when co-operation is obviously beneficial, and that the risks of co-operation can cause the social contract to spontaneously degenerate. In order to co-operate, participants must believe that others will co-operate rather than defect. Analyses of the stag hunt have shown that other factors can influence co-operation, which can also be related to the implementation of community-based co-operatives, as described in (Skyrms 2004). Reputation is important, in that people learn to co-operate with co-operators and not with known defectors, and these people will naturally be excluded. People will usually follow a key person or group in the community, and identifying and enlisting their participation from the outset can facilitate co-operation. This also leads on to the imitation of other co-operators, hence if people can view working schemes they are more likely to want to imitate them.

Often, natural resource and conservation management may require consensus decisions among and within stakeholder groups, but this has been highlighted as inappropriate or even futile when there are major conflicts of interest (Berkes 2004, Colyvan et al. 2011). This study demonstrates the difficulties inherent in obtaining full co-operation within only one stakeholder group where the conflicts of interest are much less than between groups. This study supports Colyvan et al.'s (2011) claim that understanding the underlying structure of conservation decisions using game theory can provide management insights, indicate likely outcomes, and suggest actions to improve conservation outcomes; and Berkes' (2004) perspective that community-based conservation can be better informed by interdisciplinary studies of socio-ecological systems.

5.5 Conclusions

In summary, a game theory approach can be used effectively to assess the management of conflict mitigation, in particular the likelihood of persistence of co-operative strategies that enable individuals to benefit from typically expensive but more effective technologies usually restricted to use by government or external agencies.

Here, results suggest that for poorer landholders the most important factor influencing degree of co-operation is the cost of the co-operative strategy, while effectiveness becomes more important as the economic status of landholdings increases. Contributions to a community scheme should ideally be based on an assessment of risk to ensure the greatest levels of participation, or acknowledging that this may be unattainable in some situations, on a wider measure of means testing than simply area, for example. There needs to be a sufficient level of initial interest in co-operation in the target community landscape, otherwise co-operative initiatives cannot succeed, and schemes should not be too ambitious in large community landscapes. External agencies devising co-operative schemes are discouraged from setting too many official constraints from the outset, such as the minimum numbers of people required, as this increases the likelihood of defection. Greater community heterogeneity must be recognised as a factor that can impede co-operation and external action will need to be taken to assist in overcoming this.

Co-operative mitigation schemes can benefit both landholders and the wider community and significantly increase the productivity of landscapes even with the additional cost of installation and maintenance of such technology. The benefits to conservation that such mitigation schemes can bring include reduced reliance on PA resources, improved attitudes to wildlife and reduced retaliation, and hence could be considered a potential form of conservation incentive.

6. Conservation, conflicts and costs: conclusions

It is clear that human wildlife conflicts are one of the greatest threats to biodiversity conservation and sustainable development in today's world. Threats to human life, livelihoods and property are major causes of conflicts in fragmented landscapes surrounding protected areas, undermining conservation efforts and reinforcing the social inequalities of those who bear the costs (Redpath et al. in press).

In the geo-climatically and culturally diverse landscapes of the Nilgiri Biosphere Reserve in the Western Ghats, South India, people and wildlife live cheek by jowl in a mosaic of protected areas interspersed with anthropogenic land uses that range from subsistence agriculture and pastoralism to corporate plantations and hydropower developments. Here, conflicts are inevitable despite a long history of religious tolerance and reverence for wildlife in India (Rangarajan 1998).

6.1 Stakeholder relations in the Nilgiri Biosphere Reserve

The main stakeholder group focused on in this study were local communities who bear the costs of conflict. It is important to recognise that this group is not homogenous, despite some clear consensus in their decision-making over mitigation measures. A combination of settlers and Adivasi groups, there is a disparity in economic wealth and social status, some of which is a consequence of India's caste system although Government instituted positive discrimination efforts are in place.

However, other major groups include the Forest Department, responsible for managing protected areas. They implement mitigation measures such as electric fences and trenches around parks and manage the compensation scheme, providing recompense to those suffering crop and livestock losses, property damage, and ex-gratia payments for injuries and deaths.

Independent conservation and development NGOs also work in this area, and while there are notable exceptions in many cases they operate as advocates for their causes rather than as neutral organisations. This colours the beliefs of other stakeholders, who often assume that there is an agenda of wildlife protection in the case of conservation NGOs and that their needs must come second.

Tourists and tourist resorts also play a role, given that they receive the financial and other benefits from wildlife while paying very little of the costs. There are also issues of land displacement and employment between resorts and local communities, and accusations of unsustainable exploitation of wildlife or natural resources from both sides. Furthermore, implementation of the Forest Rights Act permitting the reinstatement of traditional access and rights over forest resources continues to be disputed by conservationists and tourist operators[6], while the presence of tourist operators in core parts of protected areas is under legal investigation[7], adding to already strained relations. However, despite this the unanimous view from communities was that tourists and resorts were least responsible of all for managing conflicts.

The primary stakeholder conflict lies between communities and the Forest Department, held responsible for curtailing traditional forest uses, displacing indigenous communities outside of parks, and maintaining exclusive property rights over wildlife. Communities believe the Forest Department should be primarily responsible for managing conflict, diminishing their own responsibility and actions over protecting themselves and their livelihoods.

6.2 Predicting vulnerability to conflict

In the NBR, key predictors of the likelihood and intensity of conflict in terms of crop raiding and livestock depredation were forest degradation, forest proximity, cropland extent and livestock numbers. Species primarily responsible for crop raiding were elephant and wild boar, while leopard was the main predator on livestock. Seasonal peaks correspond with particular growing seasons for crops, and availability of forage for livestock in the dry season.

The risk conflict poses to livelihoods can therefore be broadly assessed at a landscape scale given knowledge of village locations and holdings as well as the quality and locations of remaining forest fragments. Knowledge of where depredation is likely to occur and to what level is important for planning and implementing mitigation measures at a regional level. This is useful when considering how and where to reduce or compensate for actual losses. Mitigation measures can be timed to target reductions around typical seasonal peaks in loss.

However, this study found that perceptions were actually associated with the proportion of loss suffered rather than any absolute measures of loss. This

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[6] http://www.conservationindia.org/articles/whose-forest-is-it-anyway

[7] The interim order of the Supreme Court in Writ Petition 12351/2010 (Ajay Dubey vs the National Tiger Conservation Authority)

has particular importance for the appropriate targeting of conflict mitigation measures; and implications for measures such as compensation which cannot change perceptions as they fail to address the impact of high percentage losses. It also explains why perceptions often seem to be counter-intuitive to losses, if the context of loss is not accounted for, and mitigation measures will often fail to achieve changes in perceptions. Furthermore, there is a link between perception of conflict and commercialisation, where villages that grew more commercial crops and less subsistence crops perceived wildlife as being a greater threat to livelihood productions. This can and does confuse priorities in conflict management, where the focus is often on those who lose the greatest economic value, not those most impacted by the loss. The results indicated that the economic value of damage alone, although often used as a typical measure of conflict particularly when comparing across sites, is not a suitable means for prioritising conflict interventions or assessing losses unless comparisons are only made between similar holdings. In general, the emphasis placed on value disadvantages some of the poorer communities in this study, who often lose less to wildlife in terms of value, but typically lose a larger percentage of their holding.

This information can be of use to practitioners and managers, for example the livelihoods NGO the Keystone Foundation works closely with the Indian Forest Department to produce regional recommendations for managing these issues, while the conservation NGO the Nature Conservation Foundation implements conflict mitigation measures at a village level. Unfortunately, the drivers identified mean that a consistent increase in conflict is likely as agricultural and pastoral livelihoods in these fragmented landscapes continue to increase, placing further demands on forest resources. This, coupled with a move from subsistence to commercial livelihoods will inevitably result in greater losses to wildlife and a corresponding increase in the perception of threat.

6.3 Effectively managing conflicts

Investigations of conflict and proposed mitigation measures must be clear about which aspect of conflict they intend to address, whether it is by reducing the probability of conflict occurring, reducing intensity when it does occur, reducing the value of loss, or by changing people’s perceptions, as results show that different factors drive each of these aspects. It explains why schemes such as monetary compensation which only address the economic value of loss, without any effect on reducing actual losses, cannot influence perception as it does not address the impact of high proportional loss.

The Forest Department is evidently not managing conflict in a way that reduces losses or provides adequate compensation. The electric fences and trenches around parks are not effectively maintained, often breached by those taking livestock into the park, and the recent Elephant Task Force report recommended a moratorium on further barriers until regulatory standards can be introduced (Rangarajan et al. 2010). The state-awarded compensation scheme is little better, with problems of inadequate remuneration, delays and corruption (Madhusudan 2003, Ogra and Badola 2008a, Rangarajan et al. 2010). In this study, for crop–raiding, only 18% of households experiencing loss applied for compensation, and of those only 47% of households applying received monies that amounted to only 9.6% of the loss they claimed for. For livestock only 16.5% of households that experienced loss applied, with only 24.5% of these receiving funds worth less than half of the loss they claimed. This indicates that compensation is either not available to the majority that suffer from loss, or for those who do apply, it only covers a small fraction of the loss suffered. Despite this, fair compensation was considered the least important criteria when it came to choosing a mitigation scheme, although better compensation was considered to be slightly more acceptable for addressing livestock losses than for crop losses.

Mitigation measures therefore need to be not only effective at reducing losses, but acceptable to stakeholders to improve the chances for sustainable conflict resolution (Messmer 2000). The most effective interventions were found to be electric fences around fields, as has been found in other parts of India (Davies et al. 2011), and the use of guarding and sheds / corrals to keep livestock, consistent with other studies (Ogada et al. 2003, Marker and Dickman 2004, Woodroffe et al. 2007, Inskip and Zimmermann 2009a). The assumption that all or the majority of losses occur on forest lands is also controversial given that there was no significant differences in the number of incidents in the forest and the village. Hence improved guarding and husbandry methods are likely to yield reduced losses regardless of where households continue to graze livestock, an important consideration as although grazing in protected areas is illegal, many households have no alternative source of fodder.

In terms of acceptability to stakeholders, clear consensus was reached despite the economic and social diversity within the household sample, indicating consistent views on livelihood protection which could be incorporated into management planning for conflict. Households considered the direct costs and benefits of mitigation measures to be of primary importance, which explains the continued use of less effective methods or no protection given comparatively high monetary costs and labour effort. Households preferred to utilise electric fences surrounding fields, or improve their guarding practices, but are obviously hampered by the issues of start-up and maintenance costs and labour effort.

Community participation in management decisions is vital (Western 1994, Redpath et al. 2004, Redpath and Thirgood 2009), but in this case there is some reluctance to assume responsibility for conflict on the part of local communities, which has been highlighted as a factor in conflict mitigation failures (Ogra 2009, Rangarajan et al. 2010). Creating a sense of responsibility and empowerment at a community level can be a mechanism for implementing community-based schemes (Kellert et al. 2000, Berkes 2004, Ogra 2009) that can overcome the challenges of cost and effort associated with more effective measures.

It was therefore possible to construct a model of crop-raiding conflicts using the predictors of conflict and knowledge of household decision-making, to explore how co-operative community strategies to mitigate conflict can be facilitated by scheme managers. Landholder demographics play a key role in the cost-benefit trade-off of co-operation, with costs most important for poorer landholders and benefits most important for richer landholders. Co-operation can be maximised by basing contributions on risk rather than simplistic measures of means testing. Co-operation cannot be imposed by external agencies or subject to too many pre-constraints, community interest must be genuine and participation allowed to develop freely. Community heterogeneity is likely to be the main obstacle to co-operative schemes and communities cannot be expected to resolve this issue alone. However, co-operative mitigation schemes can have the potential to increase the productivity of landscapes even with the additional cost of installation and maintenance of such technology, benefiting both individuals and the wider community. As a consequence, improved agricultural productivity can lead to reduced reliance on forest resources, and clearly implementing such schemes as conservation incentives may help to improve attitudes to wildlife.

6.4 Issues of interdisciplinarity

"To see the whole is to see it in breadth, but without access to the particular vision; to see the part is to see it in depth, but in the absence of the general overview"

- (Becher 1989)

Although human wildlife conflict is an interdisciplinary problem in conservation biology, it is only recently that mitigation efforts and the literature have begun to effectively take an interdisciplinary approach. Problems of definition, terminology, and consistency have resulted in a disparate and diverse literature and slow progress towards unifying concepts and themes that permit a more standardised and comparable approach towards understanding and managing conflicts.

Since many existing conflict mitigation measures have so far failed to successfully address conflict issues and resolve the situation, exploration and utilisation of interdisciplinary approaches and methodologies can facilitate better understanding of conflict situations and enable the emergence of mitigation measures with greater chances for success.

In this study, an interdisciplinary approach was taken from the outset to incorporate ecological, social and economic contexts to explore the problem of conflict and suggest potential solutions. In each research piece, the terminology and measurement of conflict was clearly defined, but there were obvious restrictions to the depth and breadth of interdisciplinarity that can be achieved in a single thesis study. However, this serves to show that further studies that build on these results would be productive lines of research. Ecological surveys of wildlife movements, habitat use, and density in the forests and protected areas surrounding villages prone to conflicts would generate a deeper understanding of the consequences of problems such as habitat degradation, and the strong seasonality of crop and livestock depredation. More detailed social and attitudinal surveys using techniques such as conjoint analysis (Alriksson and Öberg 2008) or multi-criteria decision analysis (Kiker et al. 2005) would elicit more detail on the decision-making process behind choosing and using mitigation measures. Finally, the agent based model of co-operative crop protection schemes can be broadly expanded to model different types of livelihood production systems subject to conflict to evaluate mitigation measures in different situations, both using theoretical parameters and empirical data. Additionally, the benefits of interdisciplinarity have been clearly demonstrated through the use of the game theoretic agent-based model to evaluate co-operative crop protection strategies. This supports the claims that game theory can provide insights into conservation decision-making (Colyvan et al. 2011) and that interdisciplinary studies of socio-ecological systems can improve community-based conservation (Berkes 2004).

6.5 Contexts to conflicts

It is important to consider conflict in the context of other problems to livelihoods and the dangers of wildlife. Although livestock depredation was the main cause of livestock loss, disease was a close second, and the weather caused more problems to crop production than was lost to crop raiding. Perceptions of threats to wildlife production can also be influenced by general fears, for example during the study period 27 deaths and 33 major injuries were recorded from encounters with wildlife, mostly due to elephants. Reasons for venturing into the forest included for NTFP collection, firewood collection, and guarding grazing livestock; while attacks on village lands were linked to the lack of electricity at night and walking home after dark. Clearly safety is a major concern for those living in these areas and measures to reduce risks are socially necessary.

These latter issues of electricity provision and transport correspond to some of the major problems identified by villagers as facing their village. Conflict with wildlife was considered one of the least important problems, overtaken by issues of water availability, transport, healthcare and livelihoods, and as important as electricity provision. Wildlife conflicts, land disputes, and access to education were last, these three being the issues most focused on by conservationists aiming to reduce environmental conflicts and promote tolerance (Dickman 2010, Nagendra et al. 2013). The main problems cited are the true indicators of social inequality demonstrated by these marginalised communities, and emphasise that the ‘pressing’ problem of wildlife conflicts may simply be the imposition of conservationist privilege. However, this could be viewed as an opportunity for conservation interventions to link issues of economic development and social justice to the conservation of wildlife (Sachs et al. 2009).

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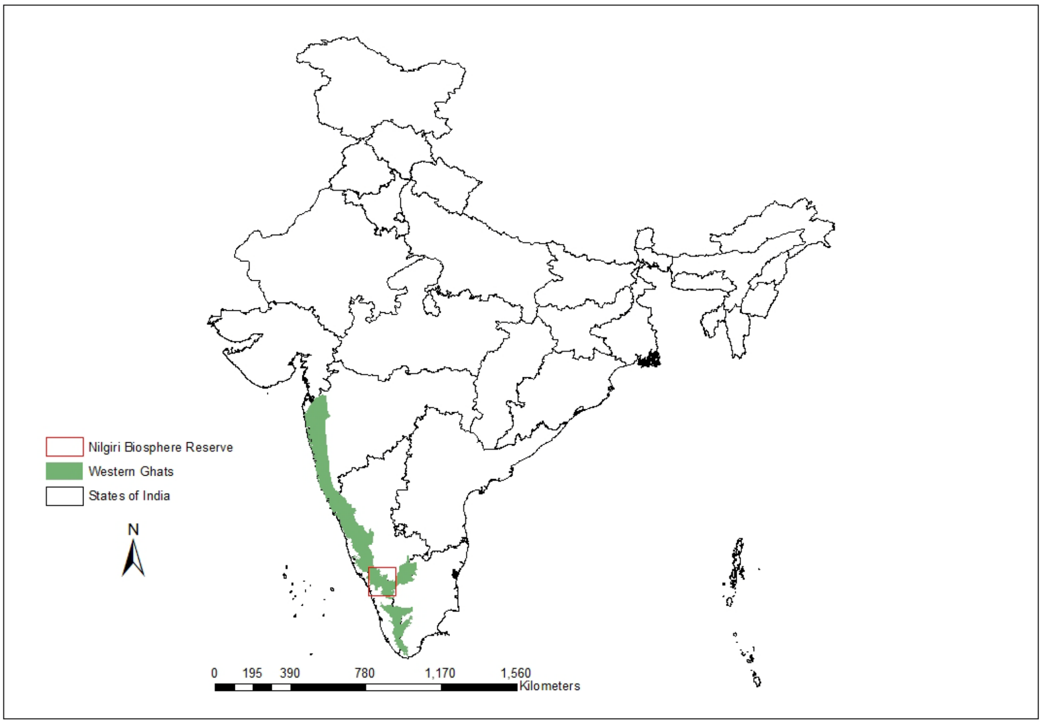
List of Abbreviations

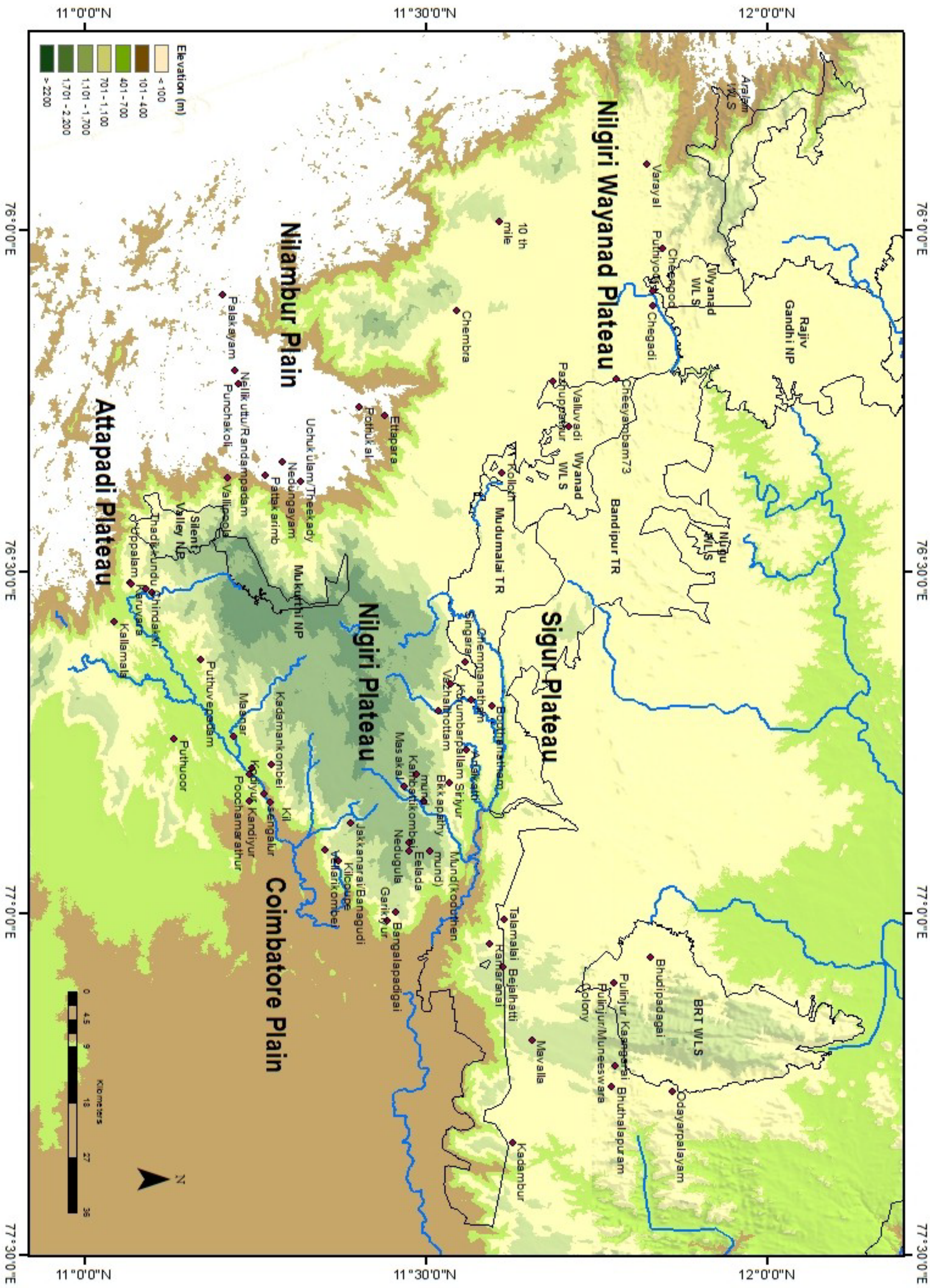
HWC	Human wildlife conflict
NBR	Nilgiri Biosphere Reserve
NP	National Park
NTFP	Non-timber forest products
PA	Protected Area
TR	Tiger Reserve
WLS	Wildlife Sanctuary

Appendix A
Maps

A.1 Map of the Nilgiri Biosphere Reserve and the Western Ghats in India



A.2 Map of the Nilgiri Biosphere Reserve, showing protected areas and 62 sampled villages



Appendix B
Village-level Perception Survey

1.
    a. Village name b. Zone c. District d. State
2.
    a. Altitude b. Aspect
3. Description of ecological region and locality, with reference to major topographic features
4.
    a. Annual rainfall b. Pre-monsoon season rainfall c. Monsoon season rainfall
    d. Post-monsoon season rainfall e. The monsoon normally falls in which months?
    f. Information source
5. Description of natural habitat in the area, details of vegetation, including extent/size remaining, dominant species present, level of human disturbance and encroachment into the natural habitat.
6. Village proximity to the forest (to the nearest km).
7. Description of water sources in the area (including name, type, size, whether seasonal/permanent).
8.
    a. Large mammal species present
    b. Historical records of large mammal species no longer present.
9. Published information sources on the area (ecological & social).
10. Length of time Keystone worked in village.
11.
    a. Date b. Name of village c. Names of communities d. Latitude/Longitude
    e. Size of group interviewed (aim for at least 4-5 main contributors with both men and women)
12. Particulars of people interviewed (mark with one or more * those who contributed to the answers most, you should allocate a minimum of 5 * to indicate level of contribution)

Name	*Age*	*M/F*	*Occupation*	*Status*

13.
    a. Village population size b. Total number of households
    c. Numbers of households per community
14. Main sources of livelihoods and numbers of households (per community)

a. What are the main sources of livelihood? b. How many households utilize each source?

Livelihood	*Numbers of households*	*Months practiced*
Agriculture		
Livestock		
Labour		
Forest Products		
Leasing of land		
Other		

Livestock

15.

a. What types of livestock do you keep?

b. How many households keep each type of livestock, by community?

c. How many of each livestock type are kept in total?

d. What is the value of an individual animal of each type?

e. What are the uses of each type of livestock?

Type	*Number of households*	*Total numbers of livestock kept*	*Value of animal*	*Uses*
Cattle				
Goat				
Sheep				
Buffalo				
Chickens				
Other				

16.

a. What are the main problems for livestock, ranked in order of seriousness (1 = most serious)?

b. How many households are affected by these problems, by community?

c. How many livestock have been lost in the past year in the village?

Problem	*Rank (1=most serious)*	*Number of households affected*	*Number of livestock lost in the past year*
Disease			
Fodder availability			

Drought			
Livestock depredation			
Other			

17. Where do most instances of livestock depredation occur?

Village land Protected Forest Reserve Forest

Forest Department Land (if difference between types of protection unknown)

Other:……………………………………………………………………………………………

18.

a. Which species of wildlife depredate livestock, ranked by most serious (1 = most serious)?
b. How many livestock were lost in the past 12 months to wildlife?
c. How many households are affected, by community?
d. Which months do these species depredate livestock?

Species	*Rank (1 = most serious)*	*Number of livestock lost in past year*	*Number of households affected*	*Months*
Tiger				
Leopard				
Dhole				
Other				

19. Has livestock depredation changed over time, and why do you think this is?

Increased Decreased Same

Timescale:………….……………

Why:………………………………………………………………………………………

20. How do your livestock losses compare with other villages, and why do you think this is?

Relatively low Similar levels Relatively high

Why:……………………………………………………………………………………………

Crops

21.

a. How much land is there in the village (acres)?
b. How much land has been abandoned by the village or given over to wildlife (acres)?

c. How much land is leased to other villages or communities outside the village (acres)?

d. How much farmland is there in the village (acres)?

e. How much farmland is irrigated (acres)?

f. How much farmland is rainfed (acres)?

22.

a. How many households own their own land and how many acres in total?

b. How many households lease their land and how many acres in total?

c. How many households sharecrop their land and how many acres in total?

d. How many households farm on unrecorded land and how many acres in total?

e. If none practice agriculture, why?

23.

a. What sources are there for investment in farming?

b. How many households per community have access to these different sources?

Type of crop grown by household	*Personal Savings in Banks*	*Personal Savings in other form*	*Loan from Banks*	*Loan from other sources*	*Investment from other person*	*Other*
Subsistence crops						
Commercial crops						

24. What is the interest rate for money lent:

a. From banks? b. From other sources?

25.

a. What types of crops are grown in the village?

b. How many households per community grow each type of crop?

c. What is the intended use of each crop (subsistence, commercial or both)?

d. How much land does each type cover (acres)?

e. What season is the crop grown in?

f. How much on average do villagers invest in Rupees in each crop per acre per growing season?

g. What is the maximum return villagers expect to gain in Rupees for each crop per acre per growing season?

h. What was their return in the last year, in Rupees for each crop per acre per growing season?

Type of crop	*Number of households*	*Use: S / C Both*	*Land cover (acres)*	*Months*	*Investment per acre per season*	*Max. return*	*Last year's return*
Millets							
Pulses							
Vegetables							
Beans							
Rice							
Cereals							
Tea							
Coffee							
Ginger							
Cotton							
Corn/Maize							
Other							

26.

a. What are the main problems for crops, ranked in order of seriousness (1 = most serious)
b. What proportion of all crops have been lost in the past year? (This does not need to add up to 100%)
c. How many households are affected by each problem, per community?
d. What times of the year does each problem occur?

Problem	*Rank (1=most serious)*	*Proportion of crops lost in past year*	*Number of households affected*	*Months*
Disease				
Insects/pest				
Rodents				
Crop raiding				

Drought				
Heavy rainfall				
Other				

27.

a. Which species of wildlife raid crops, ranked by most serious (1 = most serious)?
b. Which crops do each species raid (listing by names as in question 25)?
c. What proportion of crops have been lost in the past year to each species?
d. What is the area damaged (in acres) in the past year?
e. How many households have been affected by each species, per community?
f. Which months do each species raid crops?

Species	*Rank (1 = most serious)*	*Types of crops affected*	*Proportion of crops lost in the past year*	*Damaged area (in acres)*	*Number of households affected*	*Months*
Elephant						
Gaur						
Sambar						
Wild Pig						
Chital						
Birds						
Primates						
Porcupine						
Other						

28. Has crop depredation by wildlife changed over time, and why do you think this is?

Increased Decreased Same

Timescale:………….……………

Why:……………………………………………………………………………………

29. How do your crop losses compare with other villages, and why do you think this is?

Relatively low Similar levels Relatively high

Why:………………………………………………………………………………………

Attacks on people

30.

a. Which species of wildlife attack people, ranked according to the most serious (1=most serious)?

b. When was the last incident that occurred for each species?

c. How many incidences have there been in the last year for each species, and when do these occur?

d. What is the severity of these incidences (death, major injury, minor injury)?

e. Why do you think these incidents happen?

Species	*Rank (1 = most serious)*	*Date of last incident*	*Number of incidences in last year*	*Months*	*Severity (death, major injury, mild injury)*
Elephant					
Gaur					
Tiger					
Leopard					
Sloth bear					
Other					

31. Where do most instances of wildlife attacks occur?

Village land Protected Forest Reserve Forest

Forest Department Land (if difference between types of protection unknown)

Other:…………………………………………………………………………………………

32. Have the numbers of wildlife attacks changed over time, and why do you think this is?

Increased Decreased Same

Timescale:……………………….

Why:…………………………………………………………………………………

33. How does danger from wildlife compare with other villages, and why do you think this is?

Relatively low Similar levels Relatively high

Why:………………………………………………………………………………………

Damage to infrastructure

34.

a. Which species of wildlife damage infrastructure, ranked according to the most serious (1=most serious)?
b. When was the last incident that occurred for each species?
c. How many incidences have there been in the last year for each species, and when do these occur?
d. What is the total cost of these incidences in Rupees per species in the last year?
e. Why do you think these incidents happen?

Species	*Rank (1 = most serious)*	*Date of last incident*	*Number of incidences in last year*	*Months*	*Total cost of damage in last year (Rupees)*
Elephant					
Gaur					
Other					

35. Have the levels of damage to infrastructure changed over time, and why do you think this is?

Increased Decreased Same

Timescale:……….……………

Why:…………………………………………………………………………………

36. How does infrastructure damage from wildlife compare with other villages, and why do you think this is?

Relatively low Similar levels Relatively high

Why:……………………………………………………………………………………

Responses to conflict

37. What do people in your village do when they experience conflict with wildlife by species?

Actions can include: Complain to Forest Dept; Complain to elected representatives; Retaliatory actions; Compensation claim to Forest Dept; Increase in protection measures; Scare away or deter animals; Other

Species	*Village responses (e.g. Complain to Forest Dept; Complain to elected representatives; Retaliatory actions; Compensation claim to Forest Dept; Increase in protection measures)*
Elephant	
Gaur	
Sambar	
Wild Pig	

Chital	
Birds	
Primates	
Tiger	
Leopard	
Dhole	
Sloth Bear	

38.

a. What measures are currently available to prevent or reduce wildlife damage?
b. What level are these measures set up and managed at – household, community or government?
c. Rank the measures per type of protection by cost /year (1=most expensive)?
d. How many households per community use this measure?
e. What is the effectiveness in reducing conflict (1=most effective)?

Conflict prevention measures employed	*Management level (household, community, government)*	*Rank order of expense (1=most expensive)*	*Number of households using this measure*	*Rank effectiveness in reducing conflict* *1=most effective)*
LIVESTOCK PROTECTION				
Time accompanying livestock				
Stop keeping livestock				
Other…………				
CROP PROTECTION				
Electric fence				
Wire fence				
Trench				
Time personally protecting crops				
Deterrents (chilli, firecrackers, etc)				
Stopping				

agriculture				
Other…………				
INFRASTRUCTURE PROTECTION				
Other…………				
INJURY AVOIDANCE				
Not going to work				
Not going to school				
Moving away				
Other…………				

39.

a. What measures are currently in place to compensate for wildlife damage?

b. What level are these measures set up and managed at – household, community or government?

c. If benefits are obtained from compensation schemes, how much in Rupees is obtained per year by the village?

d. How many households apply for compensation measures per community?

e. How adequate are these compensation measures in compensating for conflict (very effective, somewhat effective, not effective), what is the value of the compensation compared to the value of the item lost?

f. Note down any relevant further details.

Compensation measures	*Management level (household, community, government)*	*Money (Rupees) obtained per year in village*	*Number of households applying for compensation*	*Value & adequacy of compensation*
Livestock compensation				
Crop compensation				
Personal injury compensation				
Infrastructure damage compensation				
Other				

40. Do you know whether any people from your village take action against wildlife that damage their crops or threaten their livestock or lives? If so, do you know what kind of actions have been taken against different species, and how many of each species have been killed in the past year? Interviewer should note the reliability of this information.

Species	*Actions (eg poison, guns, snares, electrocution)*	*Number killed in past year*
Elephant		
Gaur		
Sambar		
Wild Pig		
Chital		
Birds		
Primates		
Tiger		
Leopard		
Dhole		
Sloth Bear		

Attitudes

41. What is your opinion of wildlife?

It is a good thing It is a bad thing We don't care †

42. What do you think needs to be done to reduce conflict with wildlife? Which of these options do you agree with?

Better fencing Killing problem animals Killing all wildlife

Stop killing prey species Reduce forest degradation

More money in compensation Insurance schemes †

43. Who should take responsibility for reducing conflict with wildlife?

Local communities Forest Department Local NGOs †

Other:………………………………………………………………………………………

44. What are the major problems faced in your village, and rank these in order of importance to the village (1=most important), e.g. access to water, access to health care, access to education.

Problems faced by the village	*Ranking (1=most serious)*

45. Other notes the interviewer feels important to be documented and relevant to conflict.

Appendix C
Household-level Evaluation Surveys

C.1 Questionnaire

INTERVIEWERS:

SECTION 1: ALL HOUSEHOLDS

Interviewer Name:……………………………………………………………………………………

Household Particulars

1.

a. DATE	b. VILLAGE	c. Latitude: Longitude:
d. NAME OF PERSON INTERVIEWED (HEAD OF HOUSEHOLD IF POSSIBLE)	e. HOUSEHOLD MEMBERS ……..males ……..females ..….. children …………total members Names of other members of household………………………………………	
f. COMMUNITY	g. TIME RESIDENT IN VILLAGE	h. OCCUPATION
i. AGE	j. GENDER	k. STATUS

2. Level of income / possessions

a. ANNUAL CASH INCOME	b. NUMBER OF KIDS IN SCHOOL/COLLEGE	C. OWN WATERSOURCE & TYPE	d. CABLE TV (BOUGHT / GOVT)
d. VEHICLE (TYPE)	e. PHONE (LANDLINE/MOBILE & HOW MANY)		g. TYPE OF ROOF

3. Main sources of livelihood and months practiced

Livelihood	*Months practiced*
Agriculture	
Livestock	
Wage Labour	
Forest Products	
Leasing of land	

Other…………………………..	

4. Have your traditional livelihoods changed?

Over what timescale?...

Natural Resource Knowledge and Use

5. Do you think natural areas around your village have changed over the last 10, 20, or 30 years?
6. Do you think the climate has changed over the last 10, 20, or 30 years?
7. How do you use the forest?

Resources	*Type of forest (administrative)*	*How important is this activity/resource to you? Quantify if possible*
Honey		
Medicinal plants		
Firewood		
Wood for building		
Stone for building		
NTFP for subsistence		
NTFP for trade		
Water channels		
Religious ceremonies		
Burial grounds		
Cattle corrals/patties		
Other		

8. Use of fuels

Fuel	*Proportion (percentage)*
Firewood	
LPG	
Kerosene stoves	
Other:	

9. Firewood collection

Home: Distance……………… Amount (kg,headloads)………..

Sale: Distance……………… Amount (kg, headloads)………..
Value……………………………………

Attitudes to wildlife and conflict

10. Do you believe you have a problem with wild animals?

11. Attitudes to wildlife conservation

Statement	*Agree*	*Disagree*	*Neutral*
Wildlife should be conserved			
Protected areas are too large and should be reduced in size			
People who harm wildlife should be punished			
People who traditionally use natural resources in protected areas should be allowed to continue to use them			
Wildlife should be confined to protected areas			
It would not matter if large mammals were lost from the environment			

Further comments:……………………………………………………………………

12. Attitudes to human wildlife conflict

Statement	*Agree*	*Disagree*	*Neutral*
People who have problems with wildlife should be able to stop them with any methods.			
It is the fault of farmers and livestock herders that there are problems with wildlife.			
Wildlife should be controlled by the authorities using lethal methods to lower population numbers.			
Wildlife should be controlled using non-lethal methods such as barriers, deterrents and relocation.			
The Forest Department should manage wildlife to stop conflict.			
The Government should take a greater role in mitigating human wildlife conflict.			
Tourists coming to see wildlife should contribute to their conservation.			
Wildlife is valued over human livelihoods.			
Some losses from wildlife are to be expected and should be tolerated.			

Further comments:……………………………………………………………………

13. Who should take responsibility for reducing conflict with wildlife?

Stakeholder	*Ranking of responsibility (1=most responsible)*
Local communities	
Independent conservation and	

development groups	
Forest Department	
Government	
Tourists	
Tourist resorts	
Urban citizens	

14. Do you believe wildlife should be protected? Yes No

Value	*Ranking (1=strongest reason)*
They have as much right to live as we do	
Religious/cultural	
For future generations	
Education	
Tourist income	
Value of wildlife products to the economy	
Other reasons	

15. What factors do you believe are most important when choosing a conflict mitigation scheme?

Criteria	*Ranking (1=most important)*
Proven Effectiveness	
Low Startup Costs (Financial)	
Low Maintenance Costs (Financial)	
Low Labour Effort	
High level of Household control of scheme	
Minimal negative effects on wildlife	
High level of Acceptability to other people	
Fair level of Compensation	

Other factors:……………………………………………………………………

16. Do you have any traditions related to the wildlife or the forest?
17. Identify people/ positions/ institutions responsible for community decisions (who Keystone will need to work with if conflict resolution measures could be implemented)
18. Do you see a role for yourself in conflict resolution, if yes, what is that role?
19. Other notes the interviewer feels important to be documented and relevant to conflict.

SECTION 2: Households that experience Livestock Depredation

Village Name:…………………………Name of Person Interviewed:……………

20. Livestock kept now, and numbers bought/sold in the last two years

Type	*Total numbers of livestock kept*	*Value of individual animal*	*Number Bought (last 2 years)*	*Number Sold (last 2 years)*
Cattle				
Goat				
Sheep				
Buffalo				
Chickens				
Other				

If no livestock, why?...

21. Where do you obtain food for your livestock?

Personal land/fodder Unprotected common land

Reserve/Protected forest

Other:…………………………………………………………………………………

22. Livestock lost in the last 2 years to wildlife

Livestock: Animal-age-sex	*Time:month /season /year*	*Predator identity*	*Location: village/ forest*	*Distance from village*	*Value of animal (Rs)*	*Reason for loss*

23. Livestock protection measures

Livestock	*Protection measures*	*Management level: household /community /govt)*	*Cost (wage Rs or unpaid person-days)*	*Money lost through time spent protecting*	*Effectiveness: Little, Moderate, Very*
Cattle					
Goat					
Sheep					
Buffalo					
Chickens					
Other					

24. Other reasons livestock have been lost in the last 2 years

Other cause	*Livestock type (animal-age-sex)*	*Numbers lost*
Disease		
Drought		
Fodder availability		
Other		

25. Why does depredation occur?

Details:……………………………………………………………………………………

Statement	*Agree*	*Disagree*	*Neutral*
There are too many wild animals			
Livestock owners have been negligent			
There are too many livestock			
There is not enough wild prey in the forest			
Livestock are taken because they graze in the forest			
The government fails to keep wildlife in the Park			

26. How can human-wildlife conflict over livestock be reduced?

How:……………………………………………………………………………………

Scheme	*Preference Ranking (1=most preferred)*
Insurance	
Compensation	
Improved herding/livestock guarding	
Improved fencing for stock corralling	
Stopping hunting/poaching in the protected areas	
Stopping livestock grazing in the protected areas	
Improving the habitat within the protected areas	
Control of problem animals by the Forest Department	

27. What do you do when you lose livestock to wildlife?

Complain to Forest Dept

Complain to elected representatives

Retaliatory actions

Compensation claim to Forest Dept

Increase in protection measures

Scare away or deter animals

Nothing

Other:……………………………………………………………………………………

28. Compensation for loss

a. Have you ever sought compensation for livestock killed by wild animals? Yes ☐ No ☐

Livestock Animal-age-sex	*Compensation sought from*	*Date compensation claimed*	*Date received*	*Amount received*	*Satisfaction with compensation?*

b. If you have not sought compensation, why not?

SECTION 3: Households that experience Crop Raiding
Village Name:…………………………Name of Person Interviewed:……………

29.

a. LAND OWNED acres	b. LAND OWNED 10 YEARS AGO acres	c. LAND ABANDONED acres

d. Land bought/sold or received under Government schemes in the last 5 years

Land bought /sold /received (acres)	*Cost per acre*	*Within/outside village*	*Why bought/sold/received?*	*Plans for / Proceeds to?*

Further Details:…………………………………………………………

e. Land leased to someone else:……..acres and income per acre per year……………..……………

f. Land rented from someone else: ………..acres and cost per acre per year……………..…………

g. LAND CULTIVATED acres	h. LAND SHARECROPPED acres	i. UNRECORDED LAND CULTIVATED acres
j. LAND RAINFED acres	k. LAND IRRIGATED acres	l. IRRIGATION SYSTEM

m. If you do not practice agriculture, why not?......................................

30. Agricultural investment

a. ANNUAL CASH INVESTMENT	b. SOURCE bank/family/co-operative/money lender/other…………………………	c. INTEREST RATE ………………per month ………………per year

31. Crop loss to wildlife

Type of crop	*Acres*	*Investment per acre per season*	*Yield kg/ Season /acre*	*Proportion Used:Sold*	*Acres lost to wildlife in last 2 years*	*Value lost to wildlife in last 2 years (Rs & subsistence)*
Millets						
Pulses						
Vegetables						
Beans						
Rice						
Cereals						
Tea						
Coffee						
Ginger						
Cotton						
Corn/Maize						
Other						

32. Crop protection measures used

Species	*Methods used (guarding, barriers, deterrents)*	*Household unpaid time spent (person days)*	*Money lost through time spent protecting*	*Cost in Rs (on wages or materials*	*Management level: household /community /govt*
Elephant					
Gaur					
Deer (sambar /chital)					

Wild Pig					
Primates					
Porcupine					
Other					

33. What other reasons have caused crop loss in the past 2 years?

Other cause	*Crop types*	*Value lost in last 2 years (Rs & subsistence)*	*Acres lost in last 2 years*
Disease			
Insects/pests			
Rodents			
Drought			
Heavy rainfall			
Other			

34. Why does crop raiding occur?

Details:……………………………………………………………………………………

Statement	*Agree*	*Disagree*	*Neutral*
There are too many wild animals			
Farm owners have been negligent			
There is insufficient food in the forest			
Livestock that graze in the forest push the wildlife out			
The government fails to keep wildlife in the Park			

35. How can human-wildlife conflict over crops be reduced?

Scheme	*Preference Ranking (1=most preferred)*
Insurance	
Compensation	
Natural fencing (thorn bushes, stone walls)	
Wire fencing	
Electric fencing around fields	
Electric fencing around park	

boundaries	
Trenches around fields	
Trenches around park boundaries	
Deterrent techniques (firecrackers, noise)	
Stopping livestock grazing in the forest	
Improving the habitat within the protected areas	
Control of problem animals by the Forest Department	

36. What do you do when you lose crops to wildlife?

Complain to Forest Dept — Complain to elected representatives

Retaliatory actions — Compensation claim to Forest Dept

Increase in protection measures — Scare away or deter animals

Nothing

Other:……………………………………………………………………………………

37. Compensation for loss

a. Have you ever sought compensation for crops destroyed by wild animals? Yes†No†

Crop type and acres /value lost	*Date compensation claimed*	*Compensation sought from*	*Date received*	*Amount received*	*Satisfaction with compensation?*

b. If you have not sought compensation, why not?

SECTION 4: Households that experience Attacks on People

Village Name:…………………………Name of Person Interviewed:………

38. Attacks on members of household in the last two years

Month /season /year	*Wildlife Identity*	*Location (village/forest etc)*	*Distance from village*	*Severity (minor /major /death)*	*Reason*

39. Are you afraid of wildlife? Yes No

Why:……………………………………………………………………………………

40. Have you changed your behaviour because of this fear? Yes No

Details:…………………………………………………………………………………

41. Compensation for loss

a. Have you ever sought compensation for attacks by wild animals?
Yes No

Injury & wildlife responsible	*Date compensation claimed*	*Compensation sought from*	*Date received*	*Amount received*	*Adequacy of compensation*

b. If you have not sought compensation, why not?

SECTION 5: Households that experience Damage to infrastructure

Village Name:…………………………Name of Person Interviewed:……………

42. Attacks on property/infrastructure

Month /season /year	*Species*	*Property location*	*Property type*	*Value of damage (Rs)*	*Reason*

43. Compensation for loss

a. Have you ever sought compensation for attacks on property?

Yes No

Property description	*Date compensation claimed*	*Compensation sought from*	*Date received*	*Amount received*	*Adequacy of compensation?*

b. If you have not sought compensation, why not?

C.2 Monitoring Data

Sheet 1: Dates

Village	Keystone Staff	Village Informants	Start Date	End Date

Sheet 2: Livestock Depredation Incidents

Data Collector	Incident No.	Date	Householder	Wife/Husband Name
Village	Latitude	Longitude	Location of loss	Guarding measure
Dist. from Forest	Livestock species	Number owned	Number lost	Age/sex
Loss (Rs)	Total Monetary Loss	Predator responsible	Notes	Photo No

Sheet 3: Crop Raiding Incidents

Data Collector	Incident No.	Date	Householder	Wife/Husband Name
Village	Latitude	Longitude	Irrigation	Fence Type
Deterrents / Other protection used	Dist. from Forest	Crop	Area Cultivated	Crop Area Damaged
Loss (kg)	Loss (Rs)	Fodder Lost	Fuel Lost	Total Monetary Loss
Species responsible	Notes	Photo No		

Sheet 4: Attacks

Data Collector	Incident No.	Date	Householder	Wife/Husband Name
Village	Latitude	Longitude	Location of attack	Person / Property
Dist. from Forest	Severity of injury	Value of property damage (Rs)	Wildlife species	Notes
Photo No				