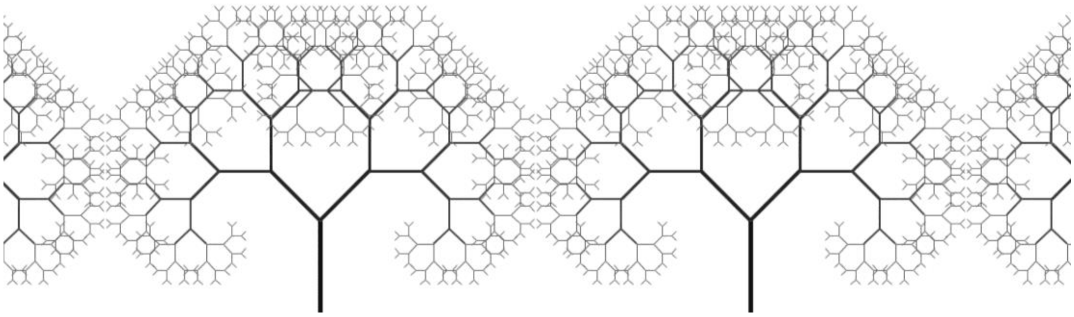
CONSERVATION CHALLENGES OF WET-TROPICAL NATURE RESERVES IN NORTH-EAST INDIA

A PH.D. THESIS



BY

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2015

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I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any University or other institution of tertiary education.

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DEDICATION

I dedicate this thesis to my grandmothers:

Bemvinda D'Costa Dias

&

Maria Blandina Coelho Velho

For the love when we were together.

For the perspective when we were apart.

STATEMENT OF CONTRIBUTION

Several people have contributed to this thesis in different capacities:

Chapter 1 in this thesis is a literature review on hunting in India. This was published as a manuscript in *Biological Conservation* (Velho, N., Karanth, K. & Laurance, W.F., 2012. Hunting: A serious and understudied threat in India, a globally significant conservation region. *Biological Conservation* 148:210-215). Nandini Velho conceived the main idea, analysed the data and wrote the manuscript. Krithi Karanth and William F. Laurance helped develop the idea and assisted with the writing. Anurag Ramchandra produced the map.

Chapter 2 deals with malaria and the downstream effects it has on anti-poaching efforts and rural communities around a tiger reserve in north-east India. This was also published in *Biological Conservation* (Velho, N., Srinivasan, U., Prashanth N.S. & Laurance, W.F., 2011. Human disease hinders anti-poaching efforts in Indian nature reserves. *Biological Conservation* 144:2382-2385). Nandini Velho developed the main idea, analysed and wrote this paper. Umesh Srinivasan helped with the analysis and the writing. Prashanth N.S. helped with the idea and the writing. William F. Laurance assisted with the analysis and writing. Tana Tapi and Kedar Bhide gave advice and supported the field implementation of malaria mitigation measures.

The first part of Chapter 3 was published in the journal *Oryx* (Velho, N. & Laurance, W.F., 2013. Hunting practices of an Indo-Tibetan Buddhist tribe in Arunachal Pradesh, north-east India. *Oryx* 47:389-392). Nandini Velho conceived the idea, analysed the data, and wrote the paper and this chapter. William F. Laurance helped develop the idea and with the writing. The second part of Chapter 3 is in press in the journal *Animal Conservation*. Nandini Velho and William F.

Laurance contributed in the same way as in the first part of Chapter 3. In addition, Priya Singh and Umesh Srinivasan assisted with data collection, analysis and the writing. Others who aided with data collection were: R. Kuotso, A. Kulkarni, B. Tamang, D. Pradhan, D. Subba, E. Soumya, G. Rana, I. Glow, J. Borah, K. Rai, K. Paneerselvan, M. Agarwala, M. Rai, N. Tsering and P. Munda.

Chapter 4 is being prepared for submission as: "Protection from poaching: use of protected areas and community lands by mammals and other hunted species", for *Conservation Biology*. Nandini Velho conceived the idea, collected and analysed the data, and wrote the chapter. William F. Laurance assisted with formulating the idea, analysis and also the writing. Umesh Srinivasan gave inputs on the analysis. People that helped with fieldwork were: P. Munda, K. Munda, T. Tapi, N. Nabam, R. Nabam and all the above mentioned names in Chapter 3.

Chapter 5 is being prepared for submission as: "The last hunters of Arunachal Pradesh: the past and present of wildlife hunting in north-east India", as a book chapter for *Orient Blackswan*. Ambika Aiyadurai and Nandini Velho conceived the idea and wrote the chapter. William F. Laurance and many others provided useful comments on the draft.

William F. Laurance guided all the work herein and read this entire thesis. Susan G. Laurance and Jeff Sayers helped with the initial drafts. My Ph.D. was supported by the Australian Laureate Scholarship that was awarded to William F. Laurance. I was also granted a tuition fee waiver from James Cook University. Funding for my research came from the Australian Research Council, the Rufford Small Grants Programme and James Cook University Graduate Research Scheme. This study received human research ethics approval from the JCU Human Research Ethics Committee (approval number H4243). A copy of my original data and metadata is stored in a Dropbox folder (another copy has been given to my adviser) and will be deposited with the James Cook University data management repository.

ACKNOWLEDGMENTS

I did not get here alone…

This Ph.D. has sometimes been filled with trying times, creating an ultimate collection of one-minute stories to share over beer, but the enduring bonds I've made with people will last a life-time. In many ways, the late Archana Bali's tenacious smile, lasting throughout far bigger trials, has provided an important perspective to me. While the acknowledgements here are long, thanking each and every one here would make this section even longer than my thesis.

I have to start off with my family members. The passion for life doesn't run, but gallops in them – it remains strength, a weakness and a jig-saw of sorts. I may not be able to thank each one of them for their support through this Ph.D. (and also for an enriched life) but I should mention a few examples of their all-round support and cheer. My aunts and uncles made small food hampers (sending Goan mangoes and bottles of home-made pickle for me to take into the field), and wrote recipes that I could teach to the nature-based tourism staff in my field site. My cousin, Aliya Abreu, provided last-minute help in editing and proof-reading my thesis. My dear uncle, Alvaro Pedro Dias, always kept me grounded; he always made me laugh with news from Goa, and never made me forget that I should come home to be a daughter, and his niece. Important members of our family, Piedade Cabral and Olimpio D'Souza, have been assistants and secretaries helping me to concentrate on writing my Ph.D. My cousin Anjora, aunt Lisa and father were part of a team that created a fantastic nature interpretation centre in one of my field sites. Only with their constant support was it possible to do this (and myriad other

things) with shoe-string budgets and limited time. As I complete my Ph.D., we now move on to help with another centre and with our other plans. My brothers, Sunith and Fernando, were supremely encouraging in their thoughts and deeds. Their words of encouragement were usually restricted to why I wasn't kicked out of university yet. As their only sister, the addition of Branca Pegado was a welcome relief to my Ph.D., and eased their focus off me. Still, my brothers critically and constructively evaluated my presentations and writings, created art-work for me, pitched in for the education and health problems of my assistants (and anyone I felt needed help). They never stopped being my childhood partners in exploring and discovering forests.

My mother made important days special: for me, and on my behalf. Her ways were information and effort based – sending Bill a thank you package with cards, poems and a collage of pictures of me since I was born! The cross-talk of thank you, discussions on parenting and surprise birthday cakes brought us closer, made me smile and increased the number of pillars I have.

I almost did not sign up for this. I came into this Ph.D. with an almost fundamentalist-type of conviction that nothing could beat the professional happiness and satisfaction I had in my previous job. I've been lucky to have a life-long mentor in Ajith Kumar (Swami Ajithananda) who said, explained, inspired, and demonstrated many things. I am thankful that he nudged me from my reluctance, kept track of my progress and lived vicariously through all my travels, experiences and stories. In the process, he has become my close friend and remains a mentor who did not become a tormentor.

I was ably supported by other teachers from my M.Sc. as well: Jagdish Krishnaswamy, Ullas and Krithi Karanth, Anindya Sinha, Ravi Chellam, Jayashree Ratnam and Mahesh Sankaran. I feel lucky to know Mahesh Rangarajan, one of the most brilliant scholars I have met, and my gratitude to him for making free-

time to be a friend. Thanks also to Elizabeth Bennett, Ramana Athreya and Romulus Whitaker who supported my work in different capacities.

The transition into a full-time Ph.D. student was made easier by Varad Pande, Cara Tejpal and Meghna Krishnadas who ensured that I was still included in a few exciting projects which spilled over into Ph.D. candidature. Over the years, I've enjoyed catching up with Meghna and Sachin to live and work on a different continent. Our travels in a campervan through the outback, rainforest and reef will remain unforgettable.

On deciding my Ph.D. topic, I went back to India to do a pilot study in Arunachal Pradesh, a place that I have come to love because of the amazing people there. The Arunachal Forest Department provided research permits and their support has been wide-ranging. Although far away from my field sites, Pekyom Ringu, Deputy Conservator of Forests, helped process my paperwork in the capital city of Itanagar in Arunachal Pradesh.

For my time in Eaglenest, I am grateful to Dinesh Subba, Bharath Tamang, Shambu Rai (Kami) and Gorey Rana, who have the unique ability to transform a rundown shed into a warm home. As I continued to do my fieldwork, the attractions changed every year: a basketball hoop, a French cricket field, and then indoors to play chess with each other. I thank Lobsang Murphew (Abu) for feeding myriad hungry mouths after long days of fieldwork and packed lunches (which included the cake recipes that we had tried out together). Bhayung Murphew and Chamu Rai (Saila Baje) made an unbeatable combination: one didn't know the terrain very well but had the enthusiasm to walk transects everywhere and the other knew the area like the back of his hand and didn't want to walk transects anywhere. The negotiations kept the peace and work chugged along, as it always does ultimately. I've been lucky that Baje and I could be friends off work and that I was part of many festivities in his beautiful house in Alubari. Dumbar Pradhan (Nocte) and Mangal Rai helped Priya Singh and me immensely while camera

trapping in the field. I thank Priya for spending time walking some of the most beautiful forests of India. There have been many people who've helped with logistics in Eaglenest: Ashok Moody, Rohan Pandit, Raju Sharma, Swaraj Srini, Angu Pradhan, Bicky Murphew, the principal and teachers of VKV Shergaon School. The person, who I always wanted to hear from miles away, came in a Bolero camper jeep with provisions and cheer: Nima Tsering has the unique ability to create sweet magic with just his presence. The evenings spent in his house, with his wife Sunthali and children: Passang, Gendan and Tenzing, are an important reason that I've returned to Eaglenest over the years. While my thesis draft was under review and doing rounds, Nima's car over-turned. While we waited and watched on different aspects, he showed me his amazing ability of being able to smile through anything. I've benefitted from many discussions on forest management with Millo Tasser, the Divisional Forest Officer of Eaglenest Wildlife Sanctuary. I would also like to thank him for the partnerships we have formed, working together on many conservation efforts with the residents and kids around Eaglenest. His openness and enthusiasm to implementing new ideas is not only a breath of fresh air but has made all of us be part of a very nice team in Eaglenest. It brings me the widest smile when I think about how the most difficult kids, who complained about coming to a forest for a camp, later cried bitterly to leave. I also thank Indi and Nima Glow for their support in organising these camps and their overall support during this Ph.D. They have not only extended steaming yak momos, piping hot tea and bags of walnuts from their fields, but also personal and familial warmth over the years. It is only thanks to the goodwill of Indi Glow and other Buguns, the Singchung Village Council and the residents of Ramalingam village that I was able to do camera trapping in human-dominated landscapes, where I lost more camera traps to elephants than theft.

The time I spent with the Shertukpen community and the village council members remains unforgettable. I especially remember their unparalleled hospitality while chatting and learning about their lives. I would specially like to thank Nana Khrimey, Chessang Khrimey, Rinchin Lama, Pema Mosobi, Nawang Norbu Khrimey, Sangay Sir and D.K. Thungdok for the wonderful times: snacking on home-grown apples from their fields, wriggling into caves on mountain tops (so narrow that only the honest could get in!), taking us to attend memorial functions of their loved ones and meeting the last traditional Tukpen honey collector.

While in Bana, the Degio clan (especially Maran and Madhu Degio) took time off to introduce us to people while also making time to walk through orange orchards. Sarchang Sopung helped tirelessly, showing us the forests around Bana. Miyali Sidisow taught us a lot about Aka culture while we were in Thrizino. I am enamoured by one of the brightest sparks I've met who continues to be my friend. Ten-year-old Jusman Das would come by in the evening to flip through my reading books. He would borrow my books and surprise me by returning them early next morning after having read them all night. I've enjoyed keeping in touch with him about the animals he has seen in zoos and in the wild. In Khuppi, I remember with how the Ranger T. Tali housed us and shared the one tin of canned fish he had. The nearest market was 40 km away and was open only once a week. Village chief (*gaon buddah*) Chewang Jebisow and Ram Netan and family helped us immensely with logistics in Khuppi and Ramda.

Over the course of my data collection, I've enjoyed shorter stints of fieldwork with Joli Borah, Elizabeth Soumya, Meghna Agarwala, Aditi Kulkarni, Rhea Ganguly, Binod Borah, Rohan Pandit, Rokohebi Kuotsu, Prachi Galange, P. Karthikeyan, Rohan Chakravarty, Sanjay Sondhi, Soujanyaa Boruah, Nupur Mathur, Dayani Chakravarty, Vishnupriya Sankararaman, Umang Bhattarcharya, Narendra Patil, Krishnapriya Tamma, Sartaj Ghuman, Mansi Mungee, Rohit Naniwadekar, Amruta Rane, Bikram Aditya Roy and Vineeta Rao. Some of them worked on this project directly, while I shared a common field site with others. Some who worked directly with me went on to create short films, worked with the Forest Department, developed websites, became resource people for education camps, or raised money for these study sites by helping to sell merchandise, among doing many other things.

In between field seasons, I spent short but memorable times in Bangalore and Goa with: Nisarg Prakash, Aathira Perincherry, Swapna N, Dipti Humraskar, Dharmaveer Shetty, Kulbhushansingh Suryawanshi, Viral Mistry, Praveen Muralidharan, Priya Singh, Chandni Gurusrikar, Nirmal and Assavri Kulkarni, Prashanth NS, Tanya Seshadri, Varun Goswami, Divya Vasudev, Werner Soors and Annie Philip. Special thanks to my girlfriends from my MSc batch and Annie Philip for their unwavering and core friendship. Special thanks to Varun Varma for all his help with GIS. Thanks also to Sadiq, from Printo, for his patience and the long hours he spent working on print files for different sites in Arunachal Pradesh. Renu and Satish Srinivasan, Radhika, Rhea and Bernard D'Costa, had the ability (and understanding) of being able to take off from where we last left. After these memorable yet short stints away from field, I always did look forward to going back.

Pakke Tiger Reserve has been an important site in my Ph.D. work but also a place where I have come to know people very closely. I've been helped tremendously by the Forest Department staff. Unfortunately, there are too many to name. The two Rangers (P.B. Rana and Kime Rambia), office staff (Yadav Sonar, G.C. Majumdar, M. Talukdar), cooks (Amar Das, Narayan Mogar, Montu Basumatary), elephant mahouts (Bikas Munda, Lal Babu Munda, Dharmeshwar Saikia, Julli Welly) and drivers (Binod Majhi, Mabe Kino, Talo Nabum) provided critical support. I am also grateful to Anish Andheria for the timely help that Wildlife Conservation Trust provided to the front-line staff of Pakke, all these years and hopefully for the years to come.

I've spent many midnights watching world cup matches with Kepu Riba and Oppo; explored my interest in craft with G.C. Majumdar and family; laughed around the fire with Suren Das, Wangta Ralongham, Loguna Welly, Kandra Brah and Sanjay Tissu. Sanjay was the person who had the most number of stories to tell us around the fire, and he never seemed to run out of them. In the mornings he would sometimes disguise his action-packed dreams of the previous night as stories he had heard or read somewhere. Apart from his passion for story-telling, he loved

art, music, dance, veterinary science and cooking; I learnt a lot and loved spending time with him. His superb knowledge on wild edible plants and cooking always kept all of us at the anti-poaching camps well fed and chirpy. The time I spent at my field station was coupled with great enthusiasm to plant my own vegetable garden. Although this did not yield much success, Yadav Sonar's father and family always accounted for my failure and shared produce from their own garden. The bottle of fresh milk from their cows, left at my door, ensured that we'd have tea with milk, *kheer* and occasionally custard. I've huffed and puffed through the forest learning with Tangru Miji, but our friendship ensured that we always had the lung capacity to disagree about things. I've shared my love for the Diji anti-poaching camp with Moneswar Doimari and Niranjan Boro. I've learnt a lot from Pahi Tachang and other *gaon buddahs* (I've never forgotten a story he told that lasted 33 km as we drove down a winding road from Eaglenest to Pakke). Takum Nabam's energy and enthusiasm was an important part of keeping diversity alive and Pakke together. I've spent memorable times with power-couple Kime Rambia and Khoda Rakhi working together on various activities, yet finding time to chat over dinner about Lionel Messi and other tigers. I've also enjoyed the exhilaration of white-water rafting on the Kameng river and the silence of walking through the forest with his staff. It has been heartening to see the on-ground presence of officers like Rambia and the renewed energy of his staff. While I was writing up, I am thankful for his encouragement and his updates about Pakke. The carrot was to submit my Ph.D. and then we could do some treks within Pakke. In Pakke Kessang, I've spent many winter nights being cosy around the fire thanks to the endearing hospitality of Radhe Nabam and Nana Nabam's family; welcomed and housed by village chiefs (*gaon buddahs*); fed and mothered by the mother of all matriarchs who ironically hails from Lumta, a one-house village.

It is difficult to explain in words the actions of my other close friends in the field, while in Pakke. Kishore Dorje, Manjula Devi and family always had the capacity to carry a bit of sunshine at different times. At sun down, after a day's work we'd story and laugh. In the rain, we'd often make ourselves a cup of hot tea and Kishore would often direct the newest hip-hop songs my way. While keeping me occupied with his hectic songs, he thoughtfully observed what my field station

missed and his family often pitched in with goodies when we started our fieldwork at sunrise the next day. Ranjan Mallick remains one of the most trust-worthy and measured persons I know in life. He used words sparingly, but as neighbours, he and his family always opened their house and lives to me. Charan Basumatary, Chandan Ri and Neelam Dutta were the kind of friends who were always a phone call away when I missed the last bus or was stranded in the middle of nowhere. Calamity or not, a good time always followed.

I carried these stories to a wonderful set of people on a different continent in the tropical paradise of Cairns. I always wanted grad school to be a period where I could look back and have the best memories in life. I couldn't have been in a better place or have had a better set of friends. We explored every nook and corner with our roving eye for student discounts, two-for-one coffees and free concerts, counting the days until 'Friday beer o'clock' to plan for the weekend. What would follow on the weekends was: barbeques on the beach, house-parties, soaring spirits 'til the wee hours of the morning, Sunday breakfast to recover from the excesses of the previous day, cooling off in rainforest pools or just making joint shopping lists for the next week. The girls: Janet Gagul, Penny Hancock, Nalisa Neuendorf, Dagmar Meyer Steiger, Yoko Ishida, Ilisapeci Lyons, Valerie Guerin, Claudia Paz and the lone man: Grant Aiton, made all of the above happen and much more. Grant was not always alone when Julio Ugarte and Gabriel Porolak came along. Thanks also to Philo De Costa, Avril Underwood (and Ollie), Geoff Carr and Geoff Hyde for going out of their way to show me just how beautiful the other parts of Australia are.

I never wanted to leave because I was part of a lab that bustled with ideas, agreed and disagreed, but felt so warm and bonded. It was lovely to exchange Ph.D. stories with Eric Katovai; I will hopefully visit him in Papua New Guinea and the Solomon islands someday. Reuben Clements always had professional and personal wisdom that was well beyond his years (including his pearls about the ladder theory). Although our plans to sync our work-schedules never quite worked, Betsy Yaap and I were always natural allies who could talk about anything. Mason

Campbell was a Ph.D. buddy who made things not only less scary but also more funny. Oscar Venter, David Edwards, Ainhoa Magrach and Sean Sloan were post-docs that made a Ph.D. better: encouraging and supporting us while also spending spirit-filled times with us. My special thanks to Sean Sloan for his endurance to my annoyance and good humour!

As co-supervisors Susan Laurance and Jeff Sayer were both anchors and guided the wind in my sails. Susan Laurance set an example, by striking the perfect work-life balance and over the course of these years; I've learned a lot from her, both professionally and personally. I've also learned a lot from Jeff Sayer's expansive breadth of knowledge and his depth of experience, especially from across the international border of my field site. I also thank Marc Hockings and Matthew Linkie for their timely reviews.

There were several people who made the administration and the paper work of this Ph.D. easier: Debbie Berry, Chris Payne, Ryan Stevenson, Janet Catteral, my office mates Ana Palma and Hong Shen, and my colleague Lingfei Weng. Pamela Stelzer read and edited my drafts patiently. My heartfelt gratitude to Leanne Shillitoe can never be enough. It's not for any single act that I'd like to thank her, but she has made a habit of helping me and other graduate students immeasurably. Every time I returned from fieldwork, just knowing that she would be in building E1 was enough to reassure me that all would be well. She was able to work her administrative magic and was my most constant friend from start to finish.

It is also difficult to put in words how to thank Tana Tapi, Putal Sarmah, Janet Gagul, William Laurance, Umesh Srinivasan, and Luis Velho. In fact, just trying to outline how they've helped me has made me put off writing this section for a couple of weeks. This is my humble and rough-and-tumbled attempt.

Putul Sarmah has been an important life support to me. He was my field assistant who worked with me for the longest time. He had a way of making things special, notably a newly-painted, bright-blue field station as a New Year gift. He was my most trusted lieutenant: who walked through some treacherous terrain (a falling boulder nearly swept him away), kept fine company when spirits were failing, was comfortable in non-defined gender work roles, and was the engine of our mobile home. His wife pitched in to supplement our dietary needs or give us an earful if we became complacent. His brother, Koliya, spent many stints doing fieldwork with us making inspired food and was a valuable addition to the small army. The vagaries of age and Putul's yearning to try his hand at other things, means that he will always have my support in the path he chooses. He will undoubtedly be an asset as a full-time story-teller in the future.

Tana Tapi, the Field Director of Pakke Tiger Reserve, has made me learn and unlearn a lot in the pedagogy of wildlife management. Our partnership involved creating education centres and resource material, writing management plans, raising money for the basic needs of his front-line staff, training them, aiding in research that was relevant to the Forest Department, and just about anything that needed an extra pair of hands. In this way, he has made me walk-the-talk, helping to implement a few things that I believed were needed. More importantly, he helped me develop the sensitivity to understand the context, tough challenges and limitations within which the management of protected areas is done. Along with managing my Ph.D. research, I was often loaded with work that sometimes stretched me to my limits, but also pushed the boundaries of my capabilities and work possibilities.

In the field, he often made sure I settled in to newer field sites; his surprise visits to older field sites were often accompanied with fresh vegetables from his garden and other treats for us and his forest watchers. In addition, he always helped me plan the rations and materials that were required in remote areas. I had reliable assistants, porters and forest-watchers, and humour never went missing in any of these operations he organised. He'd often laugh with Putul and bond over hot-tea and *pakoras* about how stereotypical gender roles were reversed in our equation: while I went to the forest searching for animals Putul looked after the field station and cooked.

Off the field, whether I was gone for a few hours, days or weeks, it didn't matter. He would arrange for all of us (Chandan, Putul, Charan, Ranjan and Shivram) to have 'good food-and-discussion' sessions practically every day. Some of these remain my most memorable times not only in field. And every time I went back and forth from home, I left Arunachal with boxes of oranges, a machete (*dao*), smoked mithun meat; gifts were exchanged between Goa and Arunachal. My family has met all the people of Arunachal Pradesh who have been dear to me, but we eagerly count the days to when they visit us in our home, in Goa. Often while writing my Ph.D. (especially the times that I've been a bit tired of it), my mind would count the time till I would be reunited with these places and people again. In fact, with the same intention and feeling of calling my parents, I would often just pick up the phone and want to hear the voices of all these other people of my expanded family. Being mentored by a Field Director like him has not only meant memorable times in field, but in life as well.

My longing for a much-awaited sister was also realised during the course of this Ph.D., through my home-minister in Australia, Janet Gagul. Not only was there an instant connection, but her indomitable spirit is something that I loved and learnt a lot from. With her, I was never too tired to dance, never too sad to smile and never ran out of energy to move along with my Ph.D. Most importantly, she inspired me deeply with her every-day ways: by being the person she was, by telling me where she came from and by doing the different things she did.

In the larger scheme of things, it's difficult to thank Bill for being the kind of supervisor and person he is. I have transitioned from being his student to colleague without even thinking about it. He has the rare ability to nurture based on nature. Sometimes, all I wanted, as his student, was to have good argument or argue for argument's sake. At other times, I was a demanding friend who wanted to have dinner with him, as often as possible, to chat about life. Our time in Arunachal, where we talked about everything under the stars, had the substance and memories of what 'dear diary' entries are made of. Over the years together, I could not have asked for a better balance of his supervision and my independence; diversity and focus; free-will and deep-friendship.

Umesh Srinivasan is a field biologist, a medical doctor, but most of all, my best friend. He was an antidote to all my problems, and was the smiles in the sunshine and in the rain. More importantly, I wanted nothing less, yet I could not have asked for anything more.

As a child, my father walked with me hand-in-hand through the forests. As an adult, he didn't have my hand, but my back. Papa, thanks for that and so much more!

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I. **Figure 1.1**— Hunting has been recorded in 23 of the 28 Indian states and 7 territories, with the number of species reported to be hunted being positively correlated with the number of studies per state or territory ($r=0.82$, $P<0.0001$; Pearson correlation). Different colors indicate the number of species reported to be hunted in each state, whereas the inset numbers show the number of studies for Indian states and territories.

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III. **Figure 1.3** — For terrestrial vertebrates in India, most studies that mention hunting focus on the status of species or discuss hunting qualitatively. A smaller number of studies concern genetics, whereas relatively few focus specifically on the drivers or ecological impacts of hunting.

IV. **Figure 2.1** — The number of malaria cases reported over a four-year period (2006-2009) near Pakke Tiger Reserve in north-east India (data from the Seijosa Primary Health Centre). Separate lines are shown for infection by *Plasmodium vivax*, *P. falciparum*, and mixed infections, in which patients are simultaneously infected by both malaria species.

V. **Figure 3.1** – Map of the study area. The dark grey area is Eaglenest Wildlife Sanctuary (EWS). The light grey area represents a part of the larger community land area that we sampled. Our sampling backbone was along the Foothill-Chaku-Tenga road (black line). Points

represent camera trap locations, while the U-shapes represent transect segments for sign surveys.

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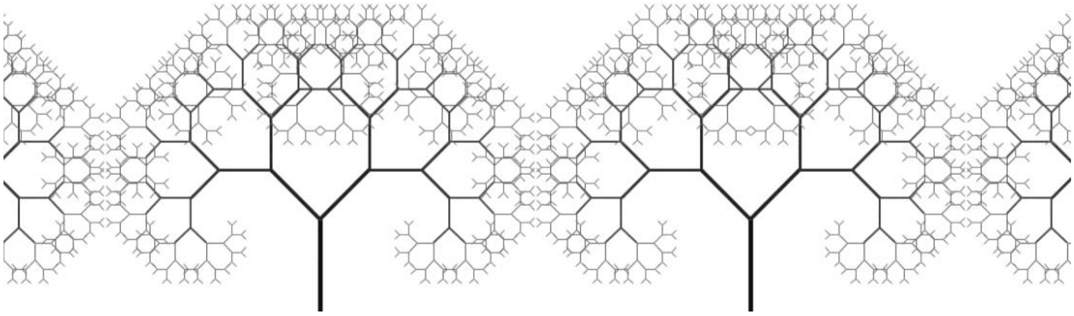
INTRODUCTION



Protected areas in the tropics account for a quarter of the world's nature reserves and collectively support over half of Earth's terrestrial biodiversity (Nelson and Chomitz, 2011). As such, they are enormously important for the future of native flora and fauna.

Despite the large extent of tropical protected areas, there is substantial overlap between human-use areas (for instance, for extractive and agricultural purposes) and landscapes vital to the conservation of globally significant biodiversity (Araujo and Rahbek, 2007). Human activities in such areas of overlap have more often than not resulted in deleterious impacts on populations of wild flora and fauna. Importantly, massive deforestation in and around the buffers of protected areas (DeFries et al., 2005), coupled with the overhunting of wildlife across the tropics, have been major causes for drastic population declines of numerous species. In some cases, over-hunting has even led to outright local extirpations (Milner-Gulland and Bennett, 2003; Bennett et al., 2006).

In such situations, protected areas are often considered the cornerstone of conservation strategies (Hockings, 2003) and the first line of defense to contain poaching and other forms of encroachment (Bruner et al., 2001; Nelson and Chomitz, 2011). Protected areas are also known to reduce deforestation rates in the surrounding and wider landscape (Gaveau et al., 2009), improve biodiversity conservation and community well-being (Levrington et al., 2010). However, one of the greatest challenges protected areas face, and one that undermines their potential for effective wildlife conservation, is continuing anthropogenic pressure arising from habitat loss, fragmentation (DeFries et al., 2005), and hunting (Wright, 2005; Laurance et al., 2012). Yet one of the broad themes when evaluating management effectiveness of protected areas is to understand whether the conservation values of protected areas are safeguarded (Hockings et al., 2006). But as protected areas continue to suffer degradation, and adjacent unprotected areas are converted to agriculture and other human uses (Kramer et al., 1997), a crucial knowledge gap is to understand how the existing habitats that remain within and outside of protected areas impact and sustain biodiversity.

FIGURE 1: A VIEW FROM THE COMMUNITY-MANAGED LAND AROUND EAGLENEST WILDLIFE SANCTUARY. PHOTO CREDIT: WILLIAM LAURANCE.

The decisions related to protected areas and their adjacent lands (which are often managed by resident communities) suffer from a lack of data-driven evidence. For instance, 60% of conservation-management decisions related to protected areas have had to rely on experience-based information given the absence of evidence

(Cook et al., 2010), but it is equally important to note that managers value empirical evidence as the most valuable source to implement management actions (Cook et al., 2012). Further, the paucity of data and rigorous studies (in terms of the biodiversity value) in community-managed land is a similar shortcoming (Bowler et al., 2011).

FIGURE 2: A VILLAGE NEXT TO SESSA ORCHID SANCTUARY. PHOTO CREDIT: WILLIAM LAURANCE.

An understanding of the relative merits of protected areas versus community-managed lands is especially important in the context of tropical developing countries that harbour many threatened wildlife species (Schipper et al., 2008) and experience socio-economic and cultural pressures that can imperil wildlife populations. More importantly, such research provides an opportunity to identify strategies that might allow facilitate human well-being while achieving big gains for wildlife conservation (DeFries et al., 2007).

In this context, deliberations about Indian nature conservation must be embedded in the existing biological and sociological contexts. It would almost be proverbial (and a subject of many essays, a few of which are included in the Appendices of this thesis) to say that conservation in India is complex. Most striking is the sheer size of India's population, which is set to overtake China as the world's most populous country by 2028, and is expected to continue growing at least until the 2060s (United Nations report, 2013). Meeting the needs of a growing economy and improving the standard of living for the estimated 363 million Indians currently living in poverty is an inescapable imperative (estimate of poverty derived in 2011-2012 by C. Rangarajan). At the same time, India is biodiversity rich — one whose environmental demise would be a global tragedy.

India harbours four global biodiversity hotspots, and its forests sustain half of the world's tigers, 60% of all Asian elephants, and 70% of all one-horned rhinoceros (Madhusudan, 2003; Amin et al., 2006). Approximately 270 million people use forest resources as primary and supplementary income sources (Fisher et al., 1997).

The tolerance for wildlife that many residents display is remarkable, to say the least. A study of three national parks in India indicates that 89% of the surveyed households reportedly received no compensation for crop-raiding and livestock predation. Such losses were non-trivial with modeled estimates of crop loss being as high as 82% and livestock losses up to 27% (Karanth et al., 2013). Despite this, substantial tolerance for wildlife-induced crop and livestock losses still prevails in many parts of India, although its degree varies by area and the species in question.

The sheer cultural diversity that exists by region within India indicates that there might be varying degrees of anthropogenic pressure, and thus differing outcomes for protected areas and their surrounding forests. Although the influences that jeopardise biodiversity within India vary widely by species and region, habitat loss and degradation and hunting are clearly the most predominant threats (Pandit et al., 2007; Datta et al., 2008; Karanth et al., 2010). This doctoral thesis is relatively eclectic and wide-ranging in nature. It is, however, unified by a clear focus on the relative fate of wildlife in protected and community-managed lands in the biologically rich lands of Arunachal Pradesh in north-east India, and on the factors that influence conservation outcomes in these contexts.

In Chapter 1, I review the literature examining hunting across India, seeking to highlight vital knowledge gaps, which can be the basis for future investigation. Specifically, I provide a synthesis of all hunting-related studies within India and examine the importance of various influences on hunting across multiple species and geographical locations.

FIGURE 3: A BLACK EAGLE FLYING OVER THE CANOPY IN EAGLENEST WILDLIFE SANCTUARY. PHOTO CREDIT: WILLIAM LAURANCE.

Arunachal Pradesh has suffered local extinctions of several important mammal and bird species from hunting and habitat loss (Datta et al., 2008; Karanth et al., 2010). The complex backdrop of socio-economic change and institutional inadequacies impinge on the effectiveness of habitat protection and wildlife conservation efforts there. In Chapter 2, I attempt to understand how disease in forest staff and residents living around a protected area can compromise wildlife conservation—a very real phenomenon that is typically overlooked by higher-level park managers and administrators. Specifically, I try to assess the burden of human malaria on front-line anti-poaching staff in the Pakke Tiger Reserve in Arunachal Pradesh, and how this could impact on wildlife management outcomes.

The north-east region of India has a socio-cultural landscape that is distinct from the rest of the country. Amongst the cultures of most tribal groups in Arunachal Pradesh, the hunting of wildlife has deep roots, and wild game is often preferred to domestic meat (Aiyadurai et al., 2010). Here, gun ownership is common and cultural norms and prevailing beliefs are strongly associated with the practice of hunting, even in Buddhist communities. In Chapter 3, I seek to obtain a refined understanding of how community-managed lands abutting Eaglenest Wildlife Sanctuary in Arunachal Pradesh compare with the sanctuary itself, in terms of the species richness and abundance of larger native mammals and of prevailing community practices and meat preferences. I also seek to understand the nature of hunting practices and taboos, and cultural and social forms of residential governance in the lands surrounding Eaglenest Wildlife Sanctuary.

In addition to studying a single reserve and its adjoining community-managed lands in detail, there are also important lessons to be learnt from examining multiple protected areas and their adjacent community-managed lands in this region. In Chapter 4, I discuss the results of lower-intensity but larger-scale transect-based surveys and comparisons between protected areas and community-managed lands across four sites in the Kameng Protected Area Complex in western Arunachal Pradesh. This landscape, of which Eaglenest is the centerpiece, is the largest contiguous forest tract in the Eastern Himalayan biodiversity hotspot, with an area of 3,500 km^2, and is a globally vital conservation region. This complex is especially important in Arunachal Pradesh, which accounts for two-thirds of all the remaining primary forest in India, with almost 62% of these forests under decentralised community management rather than state administration (Menon et al., 2001).

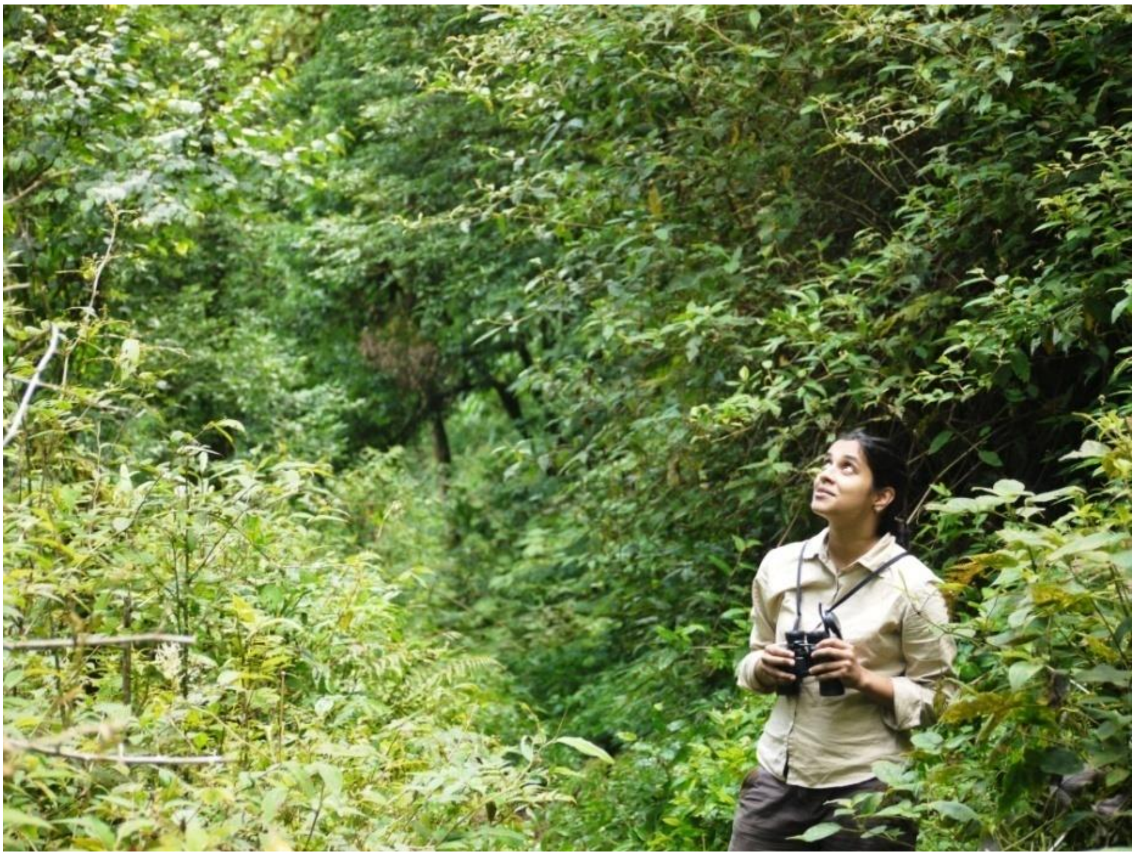


FIGURE 4: CONDUCTING FIELDWORK IN A COMMUNITY-MANAGED LAND. PHOTO CREDIT: WILLIAM LAURANCE.

Finally, in Chapter 5, I attempt to provide an integrated understanding of the social, cultural, economic and biological factors affecting hunting and the obstacles preventing the implementation of data-driven conservation on multiple levels, broadly including centralised forest management and community-based conservation initiatives.

CHAPTER PLAN FOR DISSERTATION:

CHAPTER 1: This chapter introduces the anthropogenic threats, such as hunting, to wet tropical forests in India. It is based on a review of literature on anthropogenic threats to Indian forests, with a special focus on the type of evaluation questions posed and the information generated from the hunting scene in India.

Based on:

Velho, N., Karanth, K. K. & Laurance, W.F. (2012). Hunting: A serious and understudied threat in India, a globally significant conservation region. *Biological Conservation* 148:210-215.

CHAPTER 2: In this chapter, I seek to understand the drivers of reduced patrolling effort in this region associated with disease risks to park staff. Patrolling efforts are compromised when challenges to human well-being are not considered by park management.

Based on:

Velho, N., Srinivasan, U., Prashanth, N.S. & Laurance, W.F. (2011). Human disease hinders anti-poaching efforts in Indian nature reserves. *Biological Conservation* 144:2382-2385.

CHAPTER 3: This chapter seeks to develop a working understanding of a single reserve and its adjoining lands from an in-depth, site-based analysis. In this chapter, I seek to obtain a detailed understanding of how community-managed lands abutting Eaglenest Wildlife Sanctuary compare in terms of the abundances of larger-bodied vertebrates. This analysis is based on transect data, camera trapping, and qualitative and quantitative socio-economic data.

Based on:

Velho, N. & Laurance, W.F. (2011). Hunting practices of an Indo-Tibetan Buddhist tribe in Arunachal Pradesh, north-east India. *Oryx* 47:389–392.

Velho, N., Srinivasan, U., Singh, P., & Laurance, W.F. (in press). Large mammal use of protected and community-managed lands in a biodiversity hotspot. *Animal Conservation* (in press).

CHAPTER 4: This chapter summarises a large-scale analysis contrasting protected areas and community-managed lands at four different locales. This analysis is based on a substantial overall sampling effort focusing on hunted fauna (sign-survey data collected from 98 transects, each 500 m in length, half of which were repeatedly sampled, along with 143 key-informant interviews). The results of this chapter will be submitted in the near future to *Conservation Biology* as:

Velho, N. & Laurance, W.F. (in prep). Protection from poaching: use of protected areas and community lands by mammals and other hunted species.

CHAPTER 5: In my final chapter, I present an inter-disciplinary perspective on hunting through my collected field data, and frame it in the context of conservation pressures and management strategies. I also discuss the potential for future studies to advance on-ground conservation of hunted species in this region. A synopsis of this chapter will be submitted as book chapter to *Orient Black Swan* (Aiyadurai A., & **Velho, N.,** The last hunters of Arunachal Pradesh: the past and present of wildlife hunting in north-east India).

SUPPLEMENTARY MATERIAL: This section highlights several important conservation issues that have come to the fore in recent years, and to which I have actively contributed. These articles are included as supplements because some were popular works (Appendices S9, S16 and S17) or non-refereed policy pieces (Appendix S1).

While the quandary of whether India should grow economically first and think of the environment later has been longstanding, the terms of this debate are being increasingly framed as a stark dichotomy (Appendix S1). The choices between economy and environment have been mostly based on air-pollution measures from western nations when they were industrialising in the past. Such models have not accounted for other cultural specifics, such as tolerance to wildlife and biodiversity in contexts such as India, where conservation is challenging yet hopeful.

The incongruence of time-scales--where human goals are short-term or inter-generational while the maintenance of ecosystem functioning usually requires longer timeframes--makes the planning of environmental protection challenging. The consequences of the often-prevailing 'growth at all costs' paradigm has been a weakening and constriction of several government and NGO bodies that formerly had a much more diverse set of voices in environmental governance and policy. For example, the Forest Advisory Committee and the National Board of Wildlife are supposed to evaluate whether development-project proponents adhere to legal provisions laid down to protected the environment. They are mandated to do site-specific inspections to understand biodiversity values or report legal violations. This in turn is supposed to aid the Environment and Forest Minister in deciding the merits and costs of allocating forest areas for development projects.

In recent years, the Forest Advisory Committee and National Board of Wildlife, which have had a significant representation of non-official members with wildlife expertise, have been sidelined politically (Appendix S2). The minutes of meetings were often not shared with non-official members from civil society and dissent has been quelled by a failure to renew the tenure of many members who voiced a difference of opinion on environmental matters (Appendix S4).

The flip-side is that scientists and civil society that are engaged in environmental governance are very fragmented. For instance, they may often define their views in terms of the 'empirical self' (a method that is objective and rigorous) and those of their colleagues as the 'contingent others' (a view that beliefs and actions flow from personal and social interests) (Appendix S3). This is especially challenging for conservation biologists, as scientists are expected to balance scientific data with the personal values they hold. While the challenges may differ from national to local levels, I strive in my writings to explore the relative merits of questions that are usually framed as a dichotomy—for instance, that of economic growth versus the environment, or protected areas versus community-managed lands.

SUMMARY OF CHAPTER 1

Hunting represents a major ongoing threat to biodiversity in the tropics, and in large parts of the tropics hunting is now one of the biggest threats to biodiversity (Harrison, 2011). There is more information about the economic and conservation contexts of hunting and the bushmeat crisis from the tropics of Africa and the Americas compared to Southeast Asia (Corlett, 2007).

However, the same type of information investigating factors that fuel hunting in India, which spans four global biodiversity hotspots, exists in small-pockets. This is despite the fact that some Indian regions have suffered severe population declines and local extinctions of hunted species, against a backdrop of range contractions for many species.

In this first chapter, I review the relevant hunting literature in India based on an online search of the refereed literature using six key words: hunting, poaching, bush meat, wild meat, wildlife trade and India. I worked with Krithi Karanth, a conservation biologist from India, and William Laurance, my Ph.D. supervisor (the published version of this chapter is attached as Appendix S5). Of 143 hunting studies, 127 reported threats to specific taxa and 16 reported hunting as a general threat to a landscape or region. In terms of identifying vulnerable species, we found substantial overlap between the Indian Wildlife Protection Act of 1972 (a national legal framework to protect such species) and the IUCN Red List criteria. However, we suggest that it is advisable to continuously update national policy in India with updated references of relevant research on hunted species.

We also found that hunting pressure varies geographically across the four recognized biodiversity hotspots in India. While the number of known hunted species is expected to rise as more studies are conducted, the available information thus far shows that north-east India, which harbours two global biodiversity hotspots, is particularly vulnerable to hunting. In Arunachal Pradesh in north-east India, there were many reports of hunted species and therefore it was very appropriate study site to focus my doctoral research fieldwork.

CHAPTER 1

HUNTING: A SERIOUS AND UNDERSTUDIED THREAT IN INDIA, A GLOBALLY SIGNIFICANT CONSERVATION REGION

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ABSTRACT

Tackling hunting is one of the greatest conservation challenges facing tropical wildlife. Wildlife in the tropical forests of India is vulnerable to hunting, although data on hunting impacts from the region are limited. We use a meta-analysis of hunting studies from India to identify the species and geographic regions most at risk, and to assess their legal protection. We found evidence of hunting in 114 mammal species, with larger-bodied mammals being particularly vulnerable. Although 75% of all studies focused on mammals, few actually quantified hunting impacts. Further, among studies of all taxa where hunting was mentioned, only 6% focused exclusively on hunting. With further research, we expect that the suite of species known to be exploited by hunters will increase. We conclude that the Eastern Himalaya and Indo-Myanmar biodiversity-hotspot complex is particularly vulnerable to hunting. Quantitative studies of hunting impacts are urgently needed across India, especially in this biodiversity-hotspot complex.

KEYWORDS: Arunachal Pradesh, bushmeat, hotspot, hunting, India, poaching, Western Ghats, wildlife.

1.1. INTRODUCTION

Many tropical regions suffer from chronic and intense hunting, which can have far-reaching impacts on wildlife and affect entire food webs and ecosystems (Wright et al., 2000; Milner-Gulland et al., 2003; Wright, 2005; Bennett et al., 2006). Reducing or mitigating the impacts of hunting on wildlife is often difficult to implement because it involves grappling with a range of socioeconomic, cultural, and biological challenges (Price and Gittleman, 2007).

The best-known studies that have shaped policy and perceptions on bushmeat and hunting come from Africa and South America (e.g. Peres, 2000; Fa et al., 2002; Walsh et al., 2003; Brashares et al., 2004). Although Asian wildlife are undergoing rapid range contractions and population extinctions, relatively few studies have documented the impacts of hunting on Asian biodiversity (e.g. O'Brien et al., 2003; Steinmetz et al., 2006; Corlett, 2007). India is a globally important biodiversity region that contains parts of four biodiversity hotspots, including the wet tropical forests of the Western Ghats, monsoonal forests in the Indo-Myanmar region, the montane forests of the Himalayas, and the Sundaland forests of the southern Nicobar Islands (Myers et al., 2000, Ceballos and Ehrlich, 2002). India also sustains nearly 1.2 billion people and is experiencing rapid economic development, creating many challenges for nature conservation.

The changing aspirations, lifestyles, social contexts, and land use in India have also altered the context for hunting. The first 90 years of colonial rule created a system of rewards and bounties and fervor for wildlife extermination. More than 80,000 tigers were killed from 1875 to 1925, averaging over four tigers (*Panthera tigris*) a day for 50 years (Rangarajan, 2001). Almost twice that number of leopards (*Panthera pardus*) and about 200,000 wolves (*Canis lupus*) were killed during the same period. Asiatic cheetahs (*Acinonyx jubatus*) were hunted to local extinction in India in the 1950s (Divyabhanusingh, 2000). As agriculture expanded in the country, many 'vermin' species such as hyena (*Hyaena hyaena*), dhole (*Cuon alpinus*), golden jackal (*Canis aureus*), tiger, and leopard were widely persecuted. Trophy hunting, which can depress the long-term reproductive success of target species (Coltman et al., 2003) has historically been another important threat to Indian wildlife.

Although technically prohibited in India since 1972 as a result of the Indian Wildlife (Protection) Act, hunting actually continues apace in many regions, as evidenced by further extinctions of local wildlife populations over the last decade (Datta et al., 2008; Gopal et al., 2010). Several additional Indian species still face a high risk of extinction; for instance, estimates of extinction probability are 96% for Asiatic lions (*Panthera leo persica*), 90% for swamp deer (*Cervus duvauceli*), and 81% for mouse deer (*Moschiola meminna*) (Karanth et al., 2010). Given the seriousness of hunting as a threat to Indian wildlife, we synthesized hunting studies published in India since passage of the 1972 Indian Wildlife (Protection) Act. By contrasting research on different taxa and key conservation regions, we attempt to discern the geographic impacts of hunting, identify the most vulnerable types of species, and highlight important gaps in current knowledge.

1.2. METHODS

We used the Web of Knowledge (http://pcs.isiknowledge.com, accessed from 1 to 24 June 2011) to search for relevant literature on hunting of Indian wildlife, with six keywords: hunting, poaching, bushmeat, wild meat, wildlife trade, India. We searched across all years and tabulated studies on all terrestrial vertebrate species across India. We listed the type of study, the number of species where hunting was reported as a threat, and the location of the study.

We classified each hunting study into one of four categories: (1) Those focused primarily on hunting, such as those identifying the socioeconomic or biological drivers of hunting or the effects of hunting on certain species; (2) Those aimed at assessing the distributions or abundance of species, where hunting was mentioned as a threat; (3) Those using genetic and molecular techniques to identify hunted species; and (4) Other studies, including commentaries, short notes, or qualitative discussions where hunting was mentioned. We also divided the studies taxonomically, into those focusing on mammals, birds, reptiles, or amphibians (two studies that assessed hunting on both birds and mammals were treated as separate data points for each taxon). Finally, for each taxon, we determined whether the study was conducted in any of the four Indian biodiversity hotspots.

For mammals, which were the focus of the bulk of studies we encountered, we collated data on body mass (Menon, 2003) to assess its effects on species vulnerability. Where body masses were reported as a range of values, we used the mid-point of the range for statistical analysis. We excluded the Malabar civet (*Viverra civettina*) from analysis as the validity of this species is uncertain. We compiled Red List data on the conservation status of mammals from the International Union for Conservation of Nature (IUCN) Red List (http://www.iucnredlist.org/apps/ redlist/search; accessed 25 June 2011). Data on the prohibition of hunting and five levels of legal protection of species were taken from the Wildlife Protection Act 1972 as amended in 2006 (www.moef.nic.in/legis/wildlife/wildlife2s1.pdf; accessed 27 June 2011).

1.2.1. STATISTICAL ANALYSIS

All analyses were carried out using the R statistical program (R Development Core Team, 2009). For mammals, we used a Generalized Linear Model (GLM) with Poisson errors and a log link to model the effect of body mass on the number of studies in which a species was identified as being vulnerable to hunting (which we use as a proxy for species vulnerability to hunting). Spearman rank correlations were used to assess relationships between the body mass of mammal species, their conservation status as indicated in the IUCN Red List data, and their degree of protection accorded by the Wildlife (Protection) Act. For these tests we excluded species that were listed as data deficient by the IUCN and/or not listed under the Wildlife Protection Act of India. These were the leaf deer (*Muntiacus putaoensis*), hairy-footed flying squirrel (*Belomys pearsoni*), orange-bellied squirrel (*Dremomys lokriah*), Chinese goral (*Naemorhaedus caudatus*), red goral (*N. baileyi*), Himalayan striped squirrel (*Tamiops maclellandi*), large-eared pika (*Ochotona macrotis*), and the Arunachal macaque (*Macaca munzala*).

1.3. RESULTS

Our search of relevant publications yielded 143 hunting studies, of which 127 reported threats to specific taxa and 16 reported hunting as a general threat in landscapes or regions. Hunting was reported in 23 of the 28 states and 7 union territories of India. The number of species in each state reported to be threatened by hunting was positively correlated with the number of published studies per state (Fig. 1.1). From 1972-2011, the number of studies that reported hunted as a threat to wildlife rose steadily with each passing decade (Fig. 1.2).

Among the 143 studies we encountered, only 5.6% actually quantified the effects of hunting. Nearly half (44.1%) were qualitative discussions of hunting as a threat to certain species, and many others (40.9%) focused on the status of species. The remainder (9.4%) were genetic and molecular studies. Although mostly appearing in just the last decade, genetic and molecular studies have now been conducted on a range of hunted species such as the Indian one-horned rhinoceros (*Rhinoceros unicornis*) (Kapur et al., 2003), Asian elephant (*Elephas maximus*) (Vidya et al., 2005; Gupta et al., 2006; Singh et al., 2006; Thitaram et al., 2008), large felids (Singh et al., 2004), four mongoose species (*Herpestes* spp.) (Sahajpal et al., 2008), peacock (*Pavo cristatus*) (Saini et al., 2007), snakes (Dubey et al., 2011), and three crocodile species (Meganathan et al., 2010).

Among terrestrial vertebrates, most (75.6%) hunting studies focused on mammals, with a smaller number focusing on birds (19.7%). Few studies were conducted on reptiles (3.9%) and amphibians (0.8%).

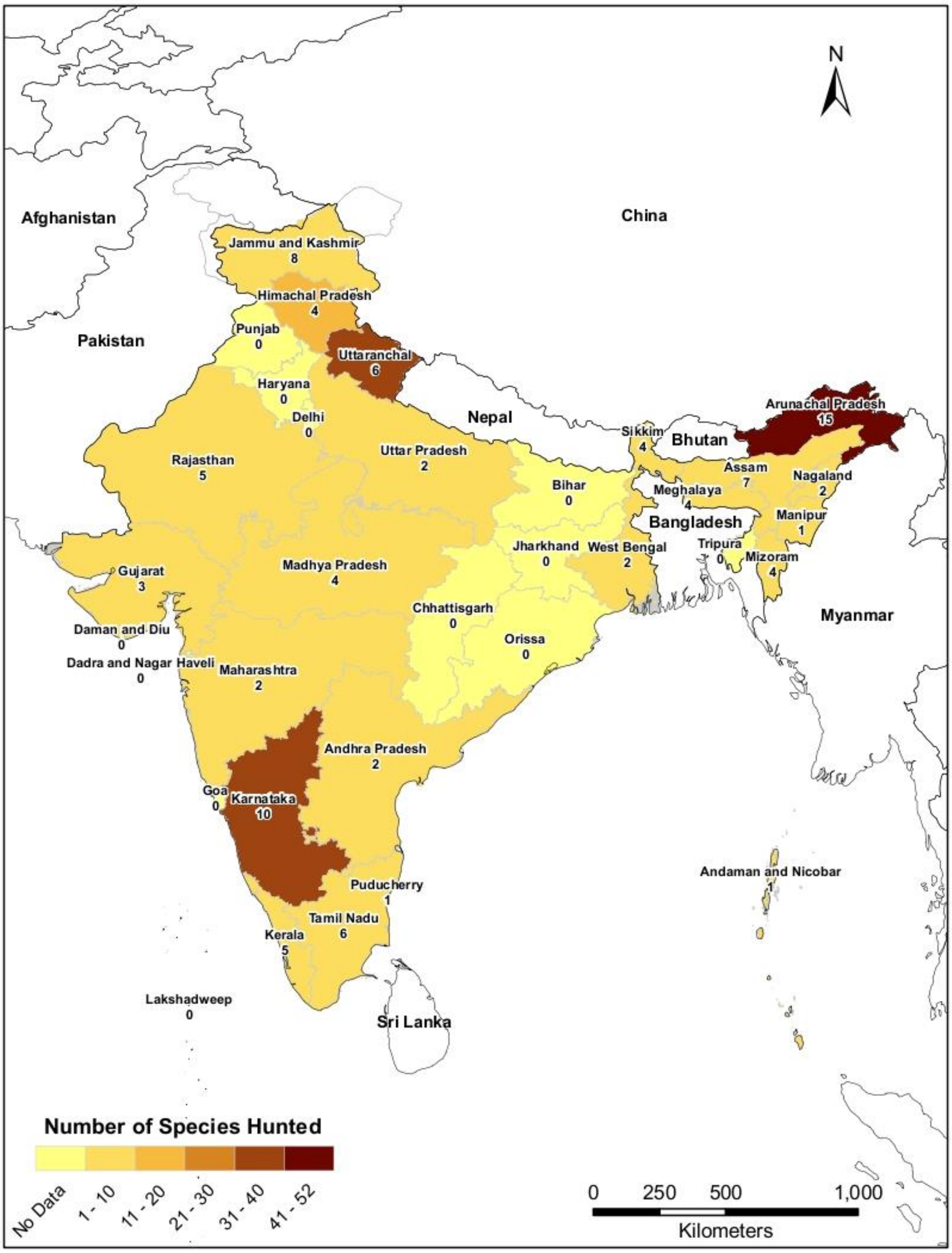

Figure 1.1 — Hunting has been recorded in 23 of the 28 Indian states and 7 territories, with the number of species reported to be hunted being positively correlated with the number of studies per state or territory (r=0.82, P<0.0001; Pearson correlation). Different colours indicate the number of species reported to be hunted in each state, whereas the inset numbers show the number of studies for Indian states and territories.

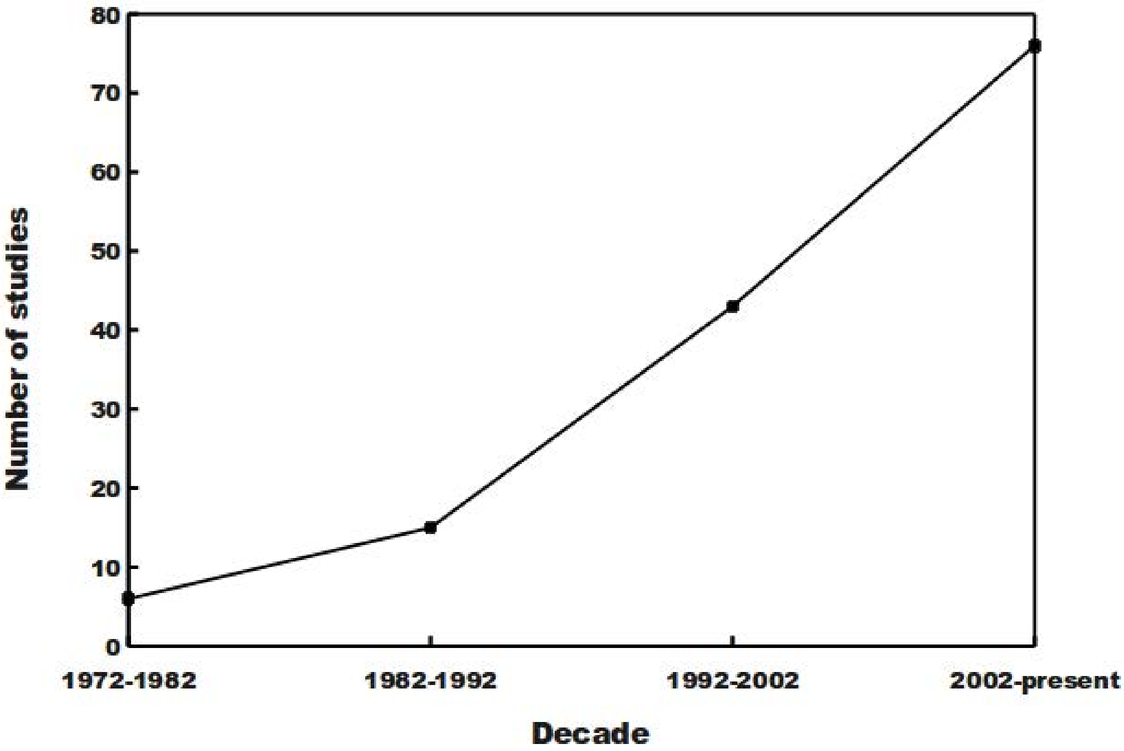

Figure 1.2 — From 1972 to 2011, the number of studies reporting hunting as a threat to Indian wildlife has risen steadily each decade.

1.3.1. MAMMALS

Overall, 114 species of mammals are reported to be hunted in India. Most studies have been qualitative rather than quantitative (Fig. 1.3), but some geographic differences in hunting methods have been reported. According to Kaul et al., (2004), hunters in Uttaranchal state used guns (42%) and snares (48%) in roughly equal frequency, whereas in Himachal Pradesh state hunters used exclusively guns. In Karnataka state, most (94%) hunters mostly used home-made muzzle-loading guns (Madhusudan and Karanth, 2002), although use of snares was also reported (Kumara and Singh, 2004). The reasons cited for hunting varied, ranging from 'cultural reasons' (Aiyadurai et al., 2010), to 'non-essential' hunting for food (Madhusudan and Karanth, 2002), to illegal commercial hunting for export (Heinen and Blair, 1993).

Hunting can affect the behavior and abundance of exploited species. For example, encounter rates of diurnal mammals declined in locales where guns were used in the daytime, whereas encounter rates of nocturnal mammals declined where night-time snares were used (Kumara and Singh, 2004). Six of nine large mammal species declined in abundance at a heavily hunted site relative to a site with less hunting (Madhusudan and Karanth, 2002). Hunting can also alter the population structure of some species. For example, adult male elephants were decimated by poaching for tusks over a 20-year period in Periyar Tiger Reserve in southern India, leading to a dramatically skewed adult sex ratio (1 male: 101 females) (Sukumar et al., 1998).

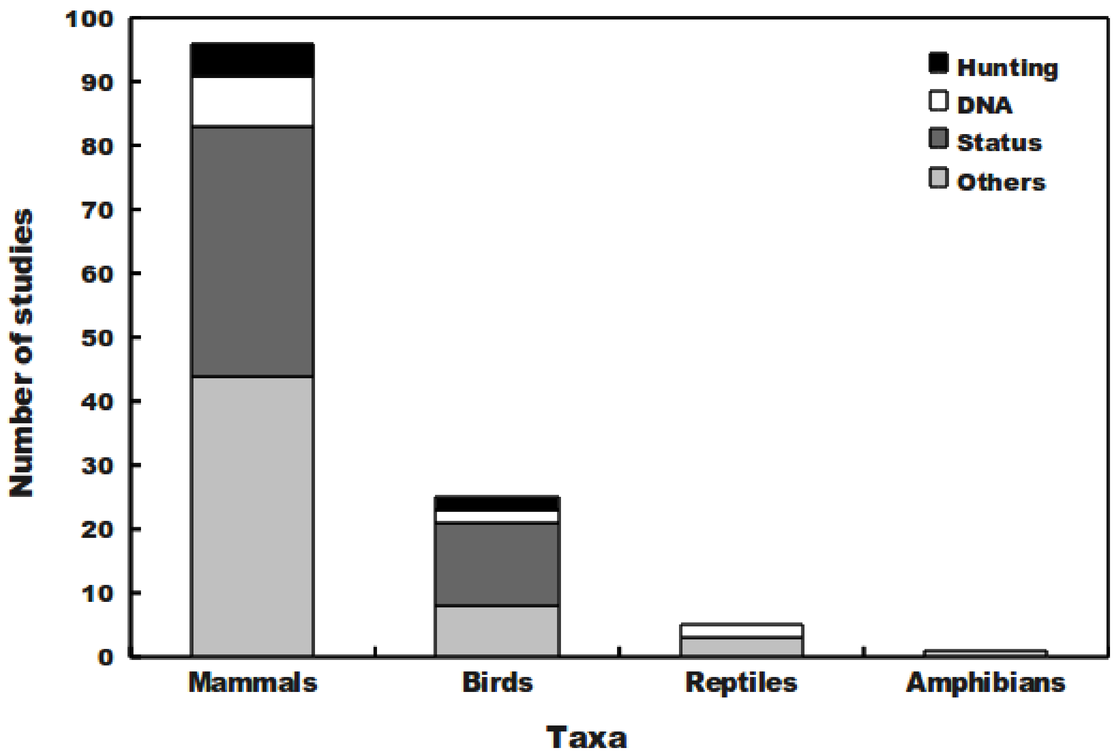

Figure 1.3—For terrestrial vertebrates in India, most studies that mention hunting focus on the status of species or discuss hunting qualitatively. A smaller number of studies concern genetics, whereas relatively few focus specifically on the drivers or ecological impacts of hunting.

1.3.2. MAMMALS AND BODY MASS

Assuming that the frequency with which a species is reported to be hunted approximately reflects the intensity of hunting pressure it experiences, our findings suggest that larger-bodied mammal species are hunted more intensively than are smaller-bodied species ($z_{1,108}$=7.68, P<0.001; GLM with Poisson errors and log link). Furthermore, larger-bodied mammals in India are more seriously threatened with extinction based on the IUCN Red List (r_s=0.435, P<0.0001), and are afforded higher levels of protection under the Indian Wildlife (Protection) Act (r_s=0.325, P=0.0007). The protection of Indian species under the Indian Wildlife (Protection) Act and their vulnerability under the IUCN Red List are also strongly correlated (r_s=0.456, P<0.0001), indicating that Indian and international assessments of species risk are largely concordant (all Spearman rank correlations).

1.3.3. BIRDS

Many bird species are hunted in India. Hunting has been reported as a threat to game birds (Galliformes) (Gaston et al., 1983; Datta, 2000; Kaul et al., 2004; Bisht et al., 2007), water birds (Pandit, 1988; Singh, 1998; Gupta, 2004; Bhattacharyya and Kapil, 2010), and larger-bodied species such as hornbills (Datta, 1998, Sethi and Howe, 2009) and great Indian bustard (*Ardeotis nigriceps*) (Ishtiaq et al., 2011). Hunting is reported as a threat to a number of endangered species, including the western tragopan (*Tragopan melanocephalus*), Nicobar megapode (*Megapodius nicobariensis*) (Sankaran, 1995), great Indian bustard (Rahmani, 1996; Ishtiaq et al., 2011) and white-winged wood duck (*Cairina scutulata*) (Green, 1993).

1.3.4. OTHER TAXA

There are few hunting reports for Indian reptiles and amphibians (Fig. 3). Hunting for consumption and wildlife trade is reported as a threat to the salt water crocodile (*Crocodylus porosus*) (Whitaker and Whitaker, 1978) and at least nine turtle species (Bhupathy et al., 2000; Choudhury, 2001). Hunting of specimens for biological dissection was reported as a threat to Indian amphibians (Daniels, 1991).

1.3.5. HUNTING IN BIODIVERSITY HOTSPOTS

Across the Indo-Myanmar and Eastern Himalaya biodiversity-hotspot complex, a total of 94 mammal species are reported to be hunted. This figure is considerably higher than the 33 species reported to be hunted across the Western Ghats, the 22 hunted species recorded in the Western Himalayas, and the zero hunted species reported from the Nicobar Islands. Hunting was found to be particularly widespread in Arunachal Pradesh state in far north-east India (Chetry et al., 2003; Arunachalam et al., 2004), which lies within the Indo-Myanmar and Eastern Himalaya hotspot. In this state, 33 mammal species are reported to be hunted, with 57% of these being endangered, threatened, or vulnerable (Aiyadurai et al., 2010). Local extinctions of tiger populations have also been recorded at several sites within Arunachal Pradesh state (Mishra et al., 2006; Datta et al., 2008).

1.3.5.1. HUNTING IN NORTH-EAST INDIA

Hunting and bush-meat consumption is prevalent across north-east India. Approximately 1 in every 40 people from a single tribe hunted near a tiger reserve (Datta et al., 2008). Wild-meat contributed up to 25% of the income in certain tribes and wild-meat consumption did not necessarily decrease with an increase in income (Hilaludin and Ghose, 2005). While India has a relatively strong legal framework (Dalvi et al., 2013), the lack of awareness of relevant laws (only 35% of 154 interviewees in Arunachal Pradesh were aware of the Wildlife Protection Act which prohibits hunting) and inflexible restrictions fail to incorporate local governance structures, rendering them ineffective in certain contexts (Dollo et al., 2010; Datta-Roy, 2011).

The commercialisation of wild-meat in nearby markets in towns and cities in north-east India is another source of concern (Datta-Roy, 2011). Over 15 days, 53 species of birds and mammals (a total of 773 dead) were recorded in the markets of the capital city of Nagaland (Hilaludin and Ghose, 2005). Furthermore, across the sampled markets in two states, all animals were thought to have come from the adjoining rural areas (Hilaludin and Ghose, 2005). In another market in

Tuensang, Nagaland with a district population of just 29,772 people, an estimated 13,067 birds and 3,567 mammals were sold annually and these animals were sourced from a radius of 50 km (Bhupathy et al., 2013). The estimated annual value of wild-meat sold at this domestic market is 18, 50,000 INR per year ($ 35,399-41,793 USD).

Residents' hunting had substantially diminished the population density of several species. Carnivore and prey species in Namdapha Tiger Reserve, Arunachal Pradesh state, have suffered hunting mediated declines in populations and the near extirpation of tigers from this site (Datta et al., 2008). The threat of hunting remains species specific in Namdapha Tiger Reserve; in the reserve, hunting was posited to be a significant threat to primates (Chetry et al., 2003) but much less of a threat to the globally threatened Rufous-necked hornbill (Naniwadekar et al., 2014). The impact of hunting remains variable (across five sampled sites) with Great hornbill extirpations recorded from many sites within two protected areas (Naniwadekar et al., 2014). The downstream impact of hunting decreased hornbill abundances, reduced seed rain and altered recruitment of hornbill-dispersed tree species (Naniwadekar et al., 2015). Other signs of hunting-mediated decline were further away from villages (Aiyadurai et al., 2010): a decline in the number of species sold in markets (Bhupathy et al., 2013); a perceived sharp decline of larger-bodied species (Chapter 3) and declines reported even for smaller species such as squirrels (Dollo et al., 2010).

However, a much wider range of species were targeted by hunters across north-east India (Hilaludin and Ghose, 2005; Bhupathy et al., 2013). Thirty three mammals were targeted across four sites in Arunachal Pradesh state (20 were IUCN threatened species) with the recorded number of hunted mammals, birds and reptiles increasing to 134 species across three north-east Indian states (Hilaludin and Ghose, 2005). Most studies have focused geographically on only two of the seven north-east Indian states, Arunachal Pradesh and Nagaland (exceptions are Hilaludin and Ghose 2005 including Mizoram, and Das et al., 2003 including threatened Hoolock gibbons in Assam). For example, a survey across six districts in Meghalaya found that slow loris (*Nycticebus bengalensis*) are hunted opportunistically for food and kept as pets locally (Radhakrishna et al., 2010). There was preliminary evidence of unsustainable hunting levels from around Mizoram state where common birds were not seen around villages and hunting was thought to be an immediate threat to wildlife (Mishra et al., 1998). Mass killing of Amur falcons (*Falco amurensis*) have been reported in some parts of Assam and Manipur states (Shashank Dalvi, pers. comm.).

The reasons to hunt vary widely within and across sites. For example, in Ziro Valley in Arunachal Pradesh, 54% of 85 households surveyed reported hunting for subsistence, 25% for bush meat sale, 10% for medicinal purposes and 5% for pleasure (Selvan et al., 2013). However, the motivation behind subsistence hunting remains contested by others (Sethi, 2013). In this general area, there was a 40-fold increase (from 1986 to 2008) in the monetary value of the orange-bellied Himalayan squirrel (*Dremomys lokriah*), used mainly for medicinal purpose (Dollo et al., 2010). Yet another study, across four tribes in Arunachal Pradesh, shows that the primary reasons for hunting are for domestic use of meat and medicinal purposes (Datta-Roy, 2011). A prevailing motivation for hunting is unlikely to emerge, although the domestic use of wild animals remained significant.

Overall, monitoring species' declines in north-east India is important given that a wide collection of people and market surveys indicated hunting-mediated declines. The larger picture that emerges is that hunting has strong cultural underpinnings and the commercialisation of wild meat to local markets is a source of concern (Datta-Roy, 2011).

1.4. DISCUSSION

A key conclusion from our analysis is the larger-bodied mammal species appear to be more intensively hunted, and more vulnerable to global endangerment, than are smaller-bodied mammals. We acknowledge an inherent taxonomic bias in reporting, as large-bodied mammals are likely to be more intensively studied that smaller species. This result accords with other studies (Short and Smith, 1994; Peres; 2000; Wright, 2005) and may reflect both lower reproductive rates in larger species, which increases their vulnerability to chronic mortality, as well as increased hunting pressure on larger species (Robinson and Bennett, 2000).

In general, there is good concordance between the Indian Wildlife (Protection) Act and the IUCN Red List in terms of identifying the most threatened species, although continued efforts are needed for science to inform Indian government policy. For instance, several mammal species, such as the red goral, Chinese goral, Arunachal macaque, and leaf deer, have been recently described in India and are currently not accorded any degree of protection under the Indian Wildlife (Protection) Act. Further, the Indian Wildlife (Protection) Act does not list a large number of hunted but lesser known taxa such as birds, amphibians and reptiles.

A second important conclusion is that hunting pressure varies geographically among India's four biodiversity hotspots, appearing to be particularly intense in the Indo-Myanmar and Eastern Himalaya hotspot complex compared with the Western Ghats, Western Himalayas, and Nicobar Islands. This pattern could be influenced to some degree by the greater number of hunting-related studies in the Indo-Myanmar/Eastern Himalayan region (Fig. 1.1), but it is so pronounced that this is unlikely to be the sole explanation. There are known to be strong geographic and cultural differences among regions in India, ranging from strong traditional practices of wildlife preservation to tradition-driven hunting for meat (Madhusudan and Karanth, 2002). In this remote region of north-east India, gun ownership is common and hunting is deeply embedded culturally, with wild meat often being preferred over domestic (Aiyadurai et al., 2010). In regions such as this, strategies for promoting community-based conservation and engaging village councils are likely to be more effective than top-down government control in reducing hunting impacts in priority areas (Mishra et al., 2006; Dollo et al., 2010). However, in other regions in India, strengthening of protected areas has not only been recommended to decrease the threats of hunting (Madhusudan and Karanth, 2000, 2002), but protected areas have been positively associated with lower extinction of 18 mammalian species (Karanth et al., 2010). Army forces posted on India's northern borders are also reported to engage actively in hunting (Fox et al., 1991; Mallon, 1991; Mishra et al., 2004; Bhatnagar et al., 2006, 2009; Namgail et al., 2009), and army personnel need to sensitized to avoid hunting of sensitive species and areas.

Finally, our review highlights a number of important deficits in current knowledge of hunting impacts in India. In India, as elsewhere in the tropics, data on hunting are usually collected over short periods, under changing local contexts, and in the background of rapid economic development (Robinson and Bennett, 2000; Sodhi et al., 2004). There is a need for more strong quantitative information on hunting from all across Asia, where there have been few quantitative studies of hunting and proxies for hunting (Clayton et al., 1997; O'Brien et al., 2003). More information is needed on sustainable harvests of different species (Shine et al., 1999), and the potentially important impacts of hunting on plant-animal interactions (Corlett, 1998). Hunting is widespread in India but research on hunting is highly variable among different Indian states and territories (Fig. 1.1), and among different vertebrate taxa (Fig. 1.3). Research on hunting has been steadily increasing in India over time (Fig. 1.2) and, as more data become available, it is virtually certain that the number of species known to be exploited by hunters will increase. With India's already dense human population expected to cross 1.3 billion by the latter half of this century (Gupta, 2002), human pressures on wildlife will increase even further.

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SUMMARY OF CHAPTER 2

Research on hunting spans a wide range of themes and approaches, from protecting individual species to addressing social, economic and health-related challenges. For instance, anti-poaching in protected areas maybe an effective tool to protect hunted species, whereas better logistical support, including servicing and provisioning of park staff, is required to improve the outcomes of patrolling. In this chapter, I and my coauthors attempt to explain the downstream effects of malaria on park management, which may in turn affect efforts to control poaching.

Most remote and inaccessible areas, especially in north-east India, continue to remain highly endemic for malaria. A number of internationally important tiger reserves in India are located in areas where there is a high incidence of sickness and death related to malaria, which often remains unquantified. I chose Pakke Tiger Reserve in Arunachal Pradesh as a study site to understand the impact of malaria on people living in this remote region and the downstream effects it has on wildlife protection. I worked with a multi-disciplinary team – Prashanth NS, a public-health doctor; Umesh Srinivasan, a medical doctor and wildlife biologist; and William Laurance, my doctoral supervisor (the published version of this chapter is attached as Appendix S6).

Malaria adversely affected not only the residents but also the front-line public-service staff working in remote areas. At a government-run primary health centre near Pakke Tiger Reserve, there were a total of 2,353 malaria cases reported over a four-year period. Over the same period, 70% of all Forest Department staff suffered from malaria. Park management officials spent almost 3% of their total budget treating malaria and lost 44,160 human hours of effort over four years. The lack of quality care for malaria at the government-run primary health centre led to increased dependence on expensive care at private clinics, which in turn increased the individual and institutional burden on both forest watchers and the Forest Department, respectively.

CHAPTER 2

HUMAN DISEASE HINDERS ANTI-POACHING EFFORTS IN INDIAN NATURE RESERVES

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ABSTRACT

Where hunting pressure is high, anti-poaching efforts are often crucial for protecting native wildlife populations in nature reserves. However, many reserves suffer from inadequate support and provisioning of staff, especially in developing nations. In Pakke Tiger Reserve in north-east India, we found that malarial infection is a serious hindrance for front-line patrolling staff that seriously limits the time they can spend in the field. We assessed the consequences of malaria both for local people and park staff in the general region and its indirect effects on wildlife protection. To accomplish this we compiled data from annual epidemiological records of malaria, the number of malaria cases and associated mortality, financial costs, and loss of time spent patrolling. Over a four-year period (2006-2009), the majority (71%) of Forest Department staff in Pakke Tiger Reserve suffered from malaria. Malaria treatment cost park managers nearly 3% of their total budget and caused a net loss of 44,160 man hours of anti-poaching effort. The government forest and health departments involved in the employment and health of park staff have separate missions and responsibilities, yet our findings show that a multi-disciplinary approach to conservation is essential to avoid overall systemic failure.

KEYWORDS: India; malaria; Pakke Tiger Reserve; park management; poaching; protected areas

2.1. INTRODUCTION

Nature reserves in developing nations often suffer from chronic poaching, which can have a serious impact on native wildlife populations (Terborgh et al., 2002; Laurance et al., 2006; Corlett, 2007). Anti-poaching patrols can be vital for reducing hunting pressure. To ensure effective park protection, a general rule of thumb is to aim for an anti-poaching staff density of 1 person per 20 km^2 (Bell & Clarke, 1986) or 0.07 patrolling staff per km^2 (Thai Department of National Parks, 2012). However, the efficiency of patrolling staff also strongly depends on the logistical support, servicing, and provisioning they receive (Leader-Williams et al., 1990).

Pakke Wildlife Sanctuary and Tiger Reserve is a protected area within the Eastern Himalaya global biodiversity hotspot (Myers et al., 2000) of north-east India. Within the reserve, the density of anti-poaching staff is well within suggested guidelines (1 person per 8.56 km^2, Leader-Williams et al., 1990). However, anti-poaching patrols are nonetheless challenging for park staff, given that the reserve has undulating terrain, spans an inter-state boundary, and has a long history of sanctioned hunting (until as late as 2000). Equally significant is that malaria seriously diminishes anti-poaching activities in the reserve.

Malaria is one of the most serious human maladies in the tropics and subtropics, with around 225 million cases occurring worldwide each year (WHO, 2010). The disease is caused by protozoan blood parasites (*Plasmodium* spp.) which are largely vectored by female *Anopheles* mosquitoes. India accounts for 76% of the 2.5 million malaria cases reported annually in South-east Asia (Kumar et al., 2007). A recent retrospective study from over 6000 areas in India estimated that 205,000 people below the age of 70 die from malaria every year, nearly half of which are adults (over 15 years old; Dhingra et al., 2010). North-east India, which is rich in forests and wildlife, has an especially high malarial incidence, with over 5 reported malaria cases per thousand people. Most other areas of India have <2 cases per thousand people (Kumar et al., 2007).

In addition to killing many people, malaria is a debilitating disease that creates a massive socio-economic burden, especially for the poor and in areas with limited access to health care (Sachs and Malaney, 2002). Malaria reduces human productivity in various ways, including efforts to promote wildlife conservation. Over a four-year period, we assessed the impacts of malaria on anti-poaching efforts in Pakke Tiger Reserve, both by estimating its direct impact on forest patrollers and its potential downstream consequences for park protection. We used data on malaria incidence, augmented with extensive interview data, to understand how malaria hampers on-the-ground protection efforts in this internationally important wildlife reserve.

2.2. METHODS

2.2.1. STUDY SITE

Pakke Wildlife Sanctuary and Tiger Reserve (92o 36' E, 26o 54' N) spans an area of 862 km2 in western Arunachal Pradesh, on the inter-state border of Assam and Arunachal in north-east India (Velho et al., 2009). In total, 144 Forest Department staff are employed in the reserve (101 are casual workers who are paid daily wages, and the rest are permanent staff recruited by the State government). Casual workers are not entitled to paid or unpaid leave, though sometimes concessions are granted by employers. Permanent staff are entitled to 15 days casual leave, up to 40 days of sick leave and those who have worked for about 240 days yearly, are entitled to earned leave. Most are from the *Nyishi* community and reside around the periphery of the park. Staff are supposed to safeguard anti-poaching camps for 24 hours a day, go out daily on patrolling routes and act on information about where abouts of poachers. At present, 24 anti-poaching camps operate within the reserve, with each camp manned by 3-4 guards who collectively patrol an area of ~20 km^2. These camps are equipped with wireless networks, and free medical treatment is nominally available for staff posted in camps, although many incur personal costs for treatment (see below).

During the dry season, vehicles are immediately sent for forest watchers suffering from malaria. Two major malaria-causing protozoan species, *Plasmodium vivax* and *P. falciparum* are present in north-east India, and some individuals suffer simultaneous infections from both species (*P. falciparum*, which is responsible for most malaria deaths, appears to be increasing in India; Dash et al., 2008). Infected individuals are treated at one of four government-run primary health centers (headquartered at Seijosa, with satellite centers at Niti Darlong, Nomarah, and Dipik) or a private clinic in the vicinity of the park. During the monsoonal season, road communication is disrupted by heavy rains and flooding, and elephants are used to access the park.

2.2.2. DATA COLLECTION

We assessed the impact of malaria on anti-poaching activities over a four-year period (2006-2009) by using a combination of annual epidemiological reports from the main primary health center at Seijosa (which is located near the Pakke Tiger Reserve headquarters), from registers of the Forest Department, and from records of medical expenses incurred by park staff to treat malaria. We also interviewed 20 park staff to characterize their personal medical expenses and the extent to which patrolling was affected. We used a combination of semi-structured interviews and open-ended questions. The semi-structured interviews were to find out about the duration of leave of absence, time of year, treatment type (private, public or a combination of both) and how much the out of pocket expenses related to malaria treatment costs were. Our open-ended questions were mainly to get insights about any additional insights related to malaria on the family of anti-poaching staff, poaching threats and other information interviewees wanted to share with us. Further, we visited local medical facilities near the park and interviewed doctors and other practitioners to assess their malaria treatment courses, the expenses these incurred for patients, and the limitations they faced. Mean monthly rainfall data for 2006-2009 were extracted from precipitation datasets generated by MODIS (Moderate Resolution Imaging Spectroradiometer) satellite coverage for the geographic coordinates of Pakke Tiger Reserve.

2.3. RESULTS

2.3.1. MALARIA IMPACTS ON LOCAL RESIDENTS

At the principal health clinic at Seijosa, a total of 2,353 malaria cases were reported during our four-year study. Malaria incidence peaks in the warmer months, from May through August (Fig. 2.1). Using data from the Seijosa clinic, we found a strong positive relationship between the mean monthly numbers of reported malaria cases and malaria-related deaths ($F_{1,10}$ = 54.5, R^2 = 84.5%, P<0.0001; linear regression). The mortality rate of patients diagnosed with malaria was 12.9%. When available, chloroquinine and primaquinine phosphate tablets used for malaria treatment are provided free of cost at the Seijosa clinic, but other drugs and diagnostic test kits usually had to be purchased from a nearby pharmacy at the patient's expense.

2.3.2. MALARIA IMPACTS ON RESERVE STAFF

Among the 144 Forest Department staff, most (70.8%) suffered from malaria during our four-year study. In total, 15 deaths were recorded among the staff or their immediate family members. Of the 20 staff we interviewed, 90% had previously visited a private health clinic because needed medicines were not available at the nearby government-run health center. At the private facilities, the cost per patient of the prescribed line of treatment, often involving in-patient care and supportive treatment with intravenous fluids ranged from \$ 50-155 (2,250-7,000 rupees), a cost that should be reimbursed by the Forest Department but was often delayed or unpaid because of insufficient department funds. In addition, severely ill staff were referred to larger hospitals, where each incurred costs ranging from \$ 33-133 (1,500-6,000 rupees). Hence, when a forest guard contracts malaria, they must typically contribute the equivalent of 1.5 times their monthly salary towards treatment.

From 2006-2009, park authorities spent 2.8% of their total annual budget of ~\$ 197,200 (~8,875,000 rupees) for treatment of staff suffering from malaria. In addition, the department faced unpaid bills of \$ 4,400 (200,000 rupees) that were owed to employees for overdue reimbursements. Thus, malaria represents a serious cost for the Forest Department; both via the loss of funds earmarked for park protection as well its impacts on anti-poaching efforts.

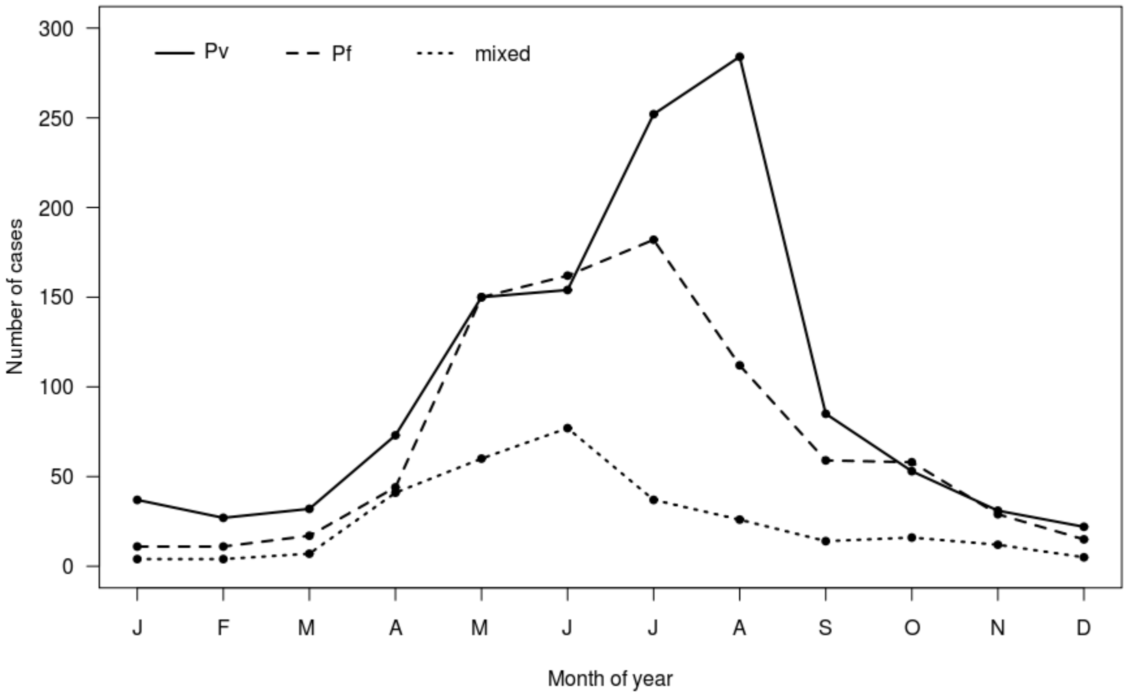

Figure 2.1 — The number of malaria cases reported over a four-year period (2006-2009) near Pakke Tiger Reserve in north-east India (data from the Seijosa Primary Health Centre). Separate lines are shown for infection by *Plasmodium vivax*, *P. falciparum*, and mixed infections, in which patients are simultaneously infected by both malaria species.

2.3.2.1. MALARIA IMPACTS ON ANTI-POACHING ACTIVITIES

The monthly incidence of malaria cases ($F_{1,10}$ = 121.3, R^2 = 92.4%) and deaths ($F_{1,10}$ = 94.6, R^2 = 90.4%) is strongly and positively related to average monthly rainfall. Malaria incidence peaks in the monsoonal months of May and August (Fig. 2.1), which is also when park authorities face an annual financial crunch (Tana Tapi, pers. comm.). The 24 anti-poaching camps in Pakke Tiger Reserve are operated 24 hours a day in all seasons. Assuming an average of 3.5 guards per camp, a total of 735,840 man-hours is required each year to maintain anti-poaching activities. Among 101 staff directly involved in anti-poaching work, 92 cases of malaria were reported during our study. The duration of absence from work due to malaria, its treatment, recovery and convalescence usually takes 20 days. This amounts to a loss of at least 44,160 human-hours of effort over four years, which is equivalent to having one anti-poaching camp running at half-strength for the entire four-year period.

2.4. DISCUSSION

In Pakke Tiger Reserve in north-east India, efforts to limit wildlife poaching are hindered by a high incidence of malaria among park staff. In this context, malaria has very real impacts on park enforcement efforts and cost, and also takes a serious toll on the health, personal finances, and even survival of park guards.

Our study focused on a single nature reserve, but there is no question that other reserves in India face comparable challenges from malaria. For instance, 93% of the land area of Mizoram state in north-east India is predicted to have areas favorable for malaria (Srivastava et al., 2001). Many reserves in north-east India occur in high-malaria zones, including Dampa Wildlife Sanctuary in Mizoram state, Kaziranga National Park in Assam state (Prakash et al., 1997), and Namdapha Wildlife Sanctuary and Tiger Reserve in Arunachal Pradesh state (Prashanth N.S., 2010). Malaria is also an acute problem in the Simplipal Biosphere Reserve in central-eastern India (Rout and Thatoi, 2009; Aditya Panda, pers. comm.) and in the Terai Arc along the India-Nepal border, which contains 12 nature reserves (Seidensticker et al., 2010). Staffs in these and many other nature reserves are likely to suffer chronic challenges from malaria, but the magnitude of this impact remains unquantified.

Our findings highlight a need for incorporating multi-dimensional approaches such as conservation medicine into mainstream protected-area management (Koch, 2005). Tropical diseases are known to deter human and cattle intrusion into wildlife habitats (Cleaveland et al., 2003). Beyond this, however, we believe the impact of human diseases on the viability of nature-conservation areas has received surprisingly little attention. At Pakke Tiger Reserve, poachers might conceivably be deterred by malaria during the monsoons, but anecdotal evidence from interviews with local residents suggests that poaching actually increases during this period. In rainy conditions, poachers can more easily avoid detection as they make very little noise at while hiking on wet leaf litter (Tangru Miji, pers. comm.). At other times of the year, dry leaf litter makes it difficult to move quietly, potentially alerting both the target species of hunters and patrolling park guards. During this wet period, road communication is disrupted from heavy downpours and elephants are the only means to transport staff suffering any illness. Further studies (using data from interviews, direct reports with the Forest Department and mortality observations in the field) should address whether poaching is in fact facilitated by the high prevalence of malaria among anti-poaching staff during monsoons and whether the effort required in arresting poachers changes with season.

The dilemma facing the managers of Pakke Tiger Reserve results from an inter-play of factors such as the institutional failure of the public health sector, the physical remoteness of the reserve, and the high prevalence of malaria in this region. Although the responsibilities of the forest and health departments are clearly differentiated in India, we believe that effective action from both are needed to ensure a successful conservation outcome. In the near term, donations by private individuals or corporations could help to alleviate the financial burden of disease being borne by the Forest Department (ad-hoc payment of staff medical bills, although an ultimate solution will require improved health services in the region.

In an effort to reduce malaria incidence at Pakke Tiger Reserve, in March 2010 we distributed 120 permethrin-treated Olyset mosquito nets ($ 23USD per net) to staff stationed at anti-poaching camps. Only three cases of malaria were reported as of December 2010, which is well after the expected peak in malaria cases during the monsoon season. This rate of infection is perhaps 8-10 times lower than would otherwise be expected. Although distribution of insecticide-treated nets is a part of a nationwide National Vector-bourne Disease Control Program, we did not see its use among park staff or in the village. This suggests that some relatively simple counter-measures such as insecticide-treated nets could significantly improve the welfare and effectiveness of park guards in regions where malaria and other mosquito-vectored diseases are prevalent.

ACKNOWLEDGEMENTS

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SUMMARY OF CHAPTER 3

Protected areas (including areas that are nominally fully protected and those managed for multiple uses) encompass about a quarter of the total tropical forest estate. However there is a substantial overlap between settled areas that humans find favourable and areas needed to support native biodiversity. We know that massive deforestation and over-hunting of wildlife across the tropics are major causes of declines in populations and local extinctions of numerous species. Yet, mitigation of these problems requires an understanding of the unique circumstances in any particular locale, which includes the relevant socio-economic, cultural and biological factors.

Despite growing interest in the relative value of community-managed lands and protected areas, knowledge about the biodiversity value that each sustains remains scarce in the biodiversity-rich tropics. In this chapter, I and my colleagues investigate the relative abundance of a suite of hunted mammal species that are nominally protected in and around Eaglenest Wildlife Sanctuary. This general area is one of the most biodiverse regions in the world, considered second only to the northern Andes in terms of its high richness and local endemism of species.

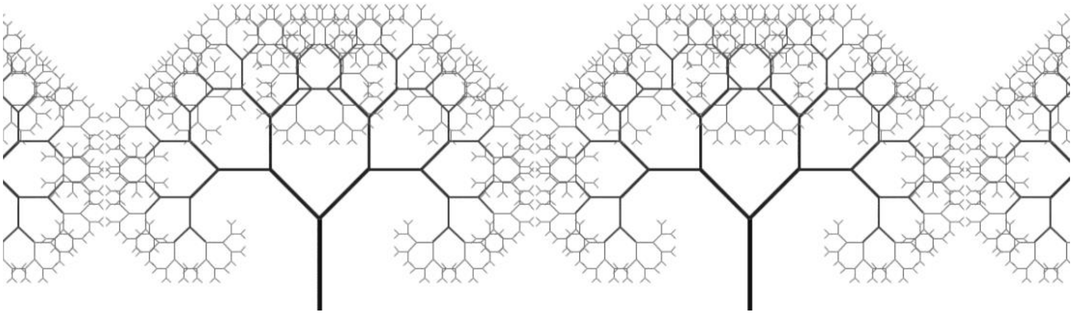
Apart from these exceptional biological values, Eaglenest Wildlife Sanctuary and its surrounding community forests have intriguing cultural setting. In 1959, the Dalai Lama made an epic 15-day journey, fleeing the Tibetan capital, over the Himalayan mountains and into India. While in India, he walked through Eaglenest Wildlife Sanctuary and down to plains of Assam state. He was granted political asylum by the Indian Government. This and subsequent visits by the Dalai Lama to areas around Eaglenest Wildlife Sanctuary have influenced animistic tribes to follow a sect of Tibetan Buddhism.

I followed the Dalai Lama's path to speak with local residents about their views on wildlife and the land they share with a diversity of wildlife species. I supplemented these analyses with a questionnaire-based survey to explore connections between the patterns of animal distribution and the changing distributions and abundances of those species. To collect field data, I used camera traps and hiked a large number of standardised transects, to understand the efficacy of Eaglenest Wildlife Sanctuary and its adjacent community-managed lands forth conservation of larger mammals (>0.5 kg). For this chapter (the published version of which is attached as Appendix S7), I worked with Priya Singh, a wildlife biologist who helped with camera trapping and data entry; and Umesh Srinivasan and William Laurance, with whom I collaborated on other chapters as well.

Our findings showed that community-managed lands can have surprising, and largely previously unrecognized, potential for conserving smaller-bodied wildlife species of conservation concern. However, taboos that protect species may be eroding in real time. While killing elephants was still clearly taboo and the relative abundances of Asian elephants across the Sanctuary and community-managed lands were still substantial, the gaur, a bovid species, was faring poorly in community-managed lands. In such situations, we conclude that protected areas such as Eaglenest are essential for such large and heavily hunted species.

CHAPTER 3

LARGE MAMMAL USE OF PROTECTED AND COMMUNITY-MANAGED LAND IN AN INDIAN BIODIVERSITY HOTSPOT



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ABSTRACT

In large parts of the biodiversity-rich tropics, various forest governance regimes often coexist, ranging from governmental administration to highly decentralised community management. Two common forms of such governance are protected areas, and community lands open to limited resource extraction. We studied wildlife occurrences in the north-east Indian state of Arunachal Pradesh, where the Eaglenest Wildlife Sanctuary (EWS) is situated adjacent to community lands governed by the Bugun and Shertkupen tribes. We conducted transect-based mammal-sign surveys and camera trapping for mammals (>0.5 kg), and interviewed members of the resident tribes to understand their hunting practices and causes of wildlife declines. Interviews indicated perceived hunting-induced declines in the abundances of mammals such as the tiger *Panthera tigris*, gaur *Bos gaurus*, and river otters *Lutrogale* and *Aonyx* species. Larger species such as *B. gaurus* were much more abundant within EWS than outside of it. Community-managed lands harboured smaller-bodied species, including some of conservation importance such as the red panda *Ailurus fulgens*, clouded leopard *Neofelis nebulosa* and golden cat *Pardofelis temminckii*. Our findings show that protected areas may have important non-substitutive values but adjoining community-managed lands may also have important conservation values for a different set of species.

KEYWORDS: Arunachal Pradesh; community lands; cultural taboos; hunting; Shertukpens; protected area.

3.1. INTRODUCTION

Protected areas are often effective reservoirs of biodiversity (Watson et al., 2014), decreasing species extinction risks (Karanth et al., 2010), preventing damage to ecological communities (Laurance et al., 2012), and maintaining essential ecosystem processes and services (Watson et al., 2014). Despite this, only 15.4% of the global terrestrial and inland area is protected, of which only half of the catergorised protected areas can be considered as strict nature reserves (IUCN I-IV) (Juffe-Bignoli et al., 2014). Although there have been some local successes (including extent and biodiversity coverage of protected areas), the rate of biodiversity loss does not appear to be decreasing (Butchart et al., 2010). Large areas of natural habitat thus remain outside of formal governmental administration, and under alternative management regimes that may vary in their efficacy for biodiversity protection.

It is important to understand the role of various management regimes in conserving biodiversity, especially in the developing and tropical world, where most global biodiversity is concentrated (Schipper et al., 2008) and species declines are occurring most rapidly (Dirzo et al., 2014). One such approach is that of community-based forest management by resident groups or institutions, with varying degrees of governance and involvement (Bowler et al., 2011). These are often typified by a local-scale participatory administration that incorporates the rights of resident communities to extract natural resources (with a view towards poverty alleviation with greater participation of poor and marginalized communities; Agrawal and Gupta, 2005).

Despite the emerging importance of decentralisation as a forest management approach in the developing world (Agrawal and Gupta, 2005), relatively little is known about the biodiversity value of such lands, especially in relation to (and in concert with) nearby protected areas. Assessments of the conservation efficacy of community-managed lands have yielded equivocal insights. For instance, community-managed forests and indigenous lands can reduce deforestation (Bray et al., 2003; Nepstad et al., 2006; Ellis and Porter-Bolland, 2008), increase forest biodiversity (Persha et al., 2011) and may promote forest protection at large spatial scales (Mathur and Sinha, 2008). However, protected areas are generally more effective in stopping land clearing, but may fail to suppress more localised threats such as logging, hunting, fire and grazing (Bruner et al., 2001).

A shortcoming of past evaluations of community-managed lands versus protected areas has been that comparisons are often geographically unmatched (but see Nelson and Chomitz, 2011 for fire frequencies, and Goswami et al., 2014 for an analysis of elephants), making inferences about conservation efficacy complicated and difficult to interpret. Further, a traditional focus on differences in forest-cover change or other anthropogenic disturbances between community lands and protected areas provides no direct information on the value of these management regimes for biodiversity conservation.

In this study, we assess the presence of mammal species in community-managed lands and an adjoining protected area within the same biophysical landscape in north-east India. We used transect-based animal-sign surveys and camera trapping in conjunction with interviews to assess the persistence of a range of mammal species in both management regimes. We assessed patterns of bushmeat hunting in an Indo-Tibetan tribe that has cultural and Buddhist religious practices to document the changing threats to wildlife around Eaglenest Wildlife Sanctuary. We evaluated how cultural practices or the shared values, beliefs and social interactions of an Indo-Tibetan tribe mediate hunting impacts, and how traditional laws (which are implemented by a legally empowered village council) and taboos affect hunting. We predicted that (a) because of human disturbances such as hunting, larger, potentially targeted species should respond more positively to protection than do smaller species, (b) for all species, abundance (a proxy that is reflected by the occurrence of animal signs) should increase with distance from roads, and (c) the perceptions of key informants should accurately reflect observed patterns of species occurrence across the two management regimes.

3.2. METHODS

3.2.1. STUDY AREA

The study was conducted in Eaglenest Wildlife Sanctuary (EWS) and adjacent community-managed lands in the Indian state of Arunachal Pradesh (Fig. 3.1). Arunachal Pradesh state borders Tibet to the north, Myanmar to the east, and Bhutan to the west. EWS and its adjacent forests are part of the Eastern Himalaya Global Biodiversity Hotspot (Mittermeier et al., 2004), and are the centerpiece of the 3500 km^2 Kameng Protected Area Complex, the largest patch of contiguous forest in Arunachal Pradesh (Athreya, 2006). EWS has an altitudinal range of 100-3300 m and an average annual rainfall of 1500-3000 mm (Choudhury, 2003). Our study area varies in elevation from 1800 to 2800 m, with montane wet-temperate broadleaf forest (Champion and Seth, 1968) as the dominant habitat.

Since 1989, EWS has been managed as a protected area by the Arunachal Pradesh Forest Department. Although under government administration, the Shertukpen tribal community considers EWS to be part of their traditional community lands. In the past, the Shertukpen migrated annually through parts of EWS to barter essential commodities with other communities residing to the south in the plains of Assam (Fig. 3.1). With increased road connectivity and access to Shertukpen villages and towns in the hills of Arunachal Pradesh, annual migrations to the plains are no longer essential for economic purposes, and have almost entirely ceased. In the past the Shertukpens were shifting cultivators and hunters with substantial trade links with people from the adjoining Assam plains, with whom they exchange key commodities. EWS is now a protected area but is considered by the Shertukpen tribe to represent part of their community land, through which they formerly transited yearly to the Assam plains as part of their barter economy. They have now shifted to growing cash crops such as tomatoes and, with increased road connectivity, their annual migrations to the plains are no longer essential for economic purposes. The Buguns are a much smaller tribe now compared with their numbers before. This, they attribute to a disease (most likely to be small pox and cholera) that spread in their villages of Chindit and Dikhiyang before the

1950s. The population census in 2002, counted their number to be 1384.

EWS has had a history of anthropogenic use. Selective logging and road maintenance were carried out by the General Reserve Engineering Force (GREF) (Srinivasan, 2013), a road-building branch of the Indian Army. GREF staff and labour lived in camps and maintained the Foothill-Chaku-Tenga road, which was built in the 1950s (Fig. 3.1). This road connected the higher altitudes and border areas of Arunachal Pradesh with the plains of Assam state. In 1996, the Supreme Court of India passed an order that banned logging. This resulted in areas of regenerating selectively logged forest embedded within the primary forests of EWS.

Community-managed lands or unclassified state forests are recorded as forests by the Arunachal Pradesh Forest Department, but they are under the de facto control of resident tribal communities (Naniwadekar et al., 2014). The community-managed lands adjacent to EWS are owned and managed by the Bugun and Shertukpen tribes. Within their respective community lands, village councils manage forest areas demarcated by traditional boundaries. We sampled community lands under the jurisdiction of the Singchung Village Council (Bugun tribe) and the Tukpen Village Council (Shertukpen tribe).

Land management practices within these community lands are variable. The Shertukpen tribe has a larger populace with prominent clan-based ownership. Land administered by the Bugun tribe is typically owned by individual tribe members, and often leased to second- or third-generation Nepali immigrant families, who cultivate tomato, cabbage, potato, and kiwi in return for part of the produce or an annual tax. Prior to the 1996 Supreme Court order banning logging, many Bugun and Shertukpen people depended on timber harvests as an important source of income, resulting in areas of selectively logged forest. This heterogeneity in past and current land-use has resulted in a mosaic of land-uses in community lands, ranging from active cultivation, new and old fallows, older secondary or logged forest, and primary forest (Athreya, 2006).

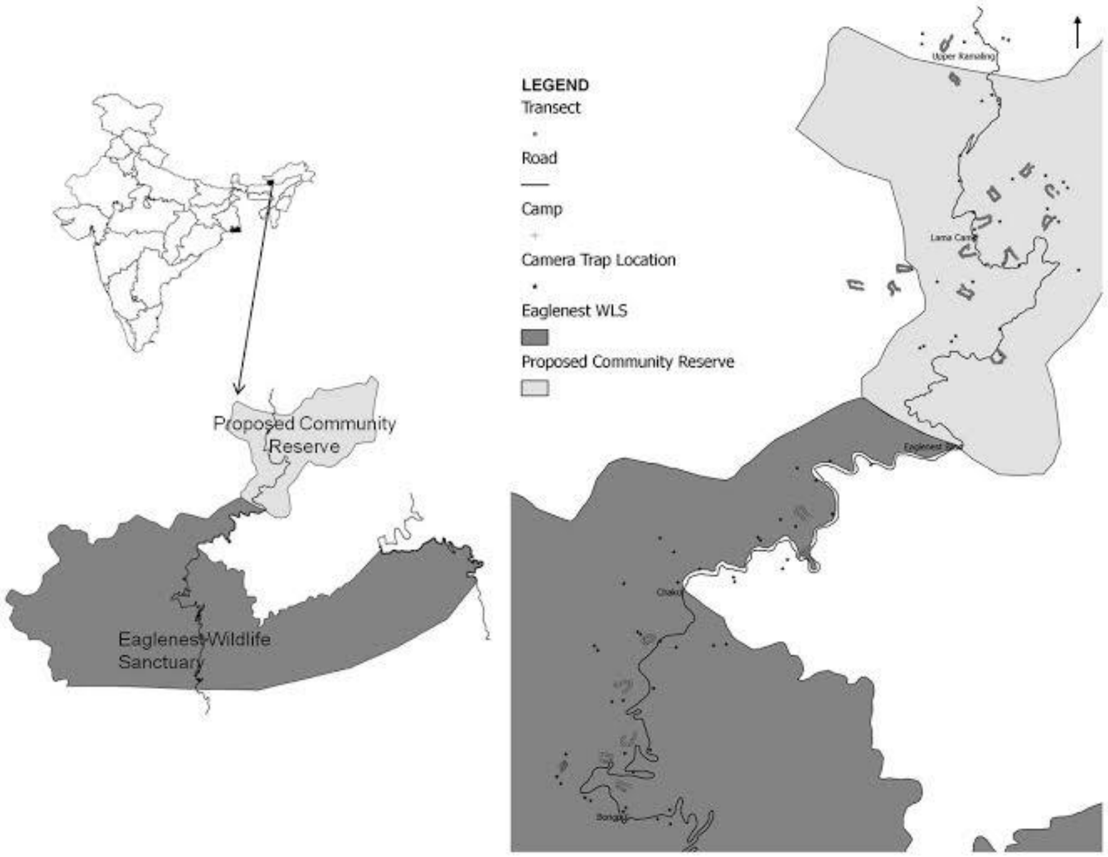


Figure 3.1 - Map of the study area. The dark grey area is Eaglenest Wildlife Sanctuary (EWS). The light grey area represents a part of the larger community land area that we sampled. Our sampling backbone was along the Foothill-Chaku-Tenga road (black line). Points represent camera trap locations, while the U-shapes represent transect segments for sign surveys.

3.2.1.2. CULTURE AND RELIGION

Cultural and religious practices in the study area also vary, and might impact hunting practices and the forest management practices in the area. The Shertukpen and Bugun practise Buddhism, with the Bugun practise of Buddhism influenced by the visit of 14th Dalai Lama to these areas. Despite identifying themselves as Buddhist, certain animistic beliefs and practices co-exist and are embedded within Buddhist practices. While most Nepalis followed Hinduism (and a minority Buddhism) in the past, most have converted to Christianity over the last generation.

3.2.2. DATA COLLECTION

3.2.2.1. SIGN SURVEYS

To ensure that sampling of community lands captured the spectrum of dominant land-uses, we stratified our sampling at 14 sites across the three prevalent habitat types: agriculture and fallow, secondary forests, and primary forests. In EWS, which had only primary and secondary forest, we sampled 11 sites. Because our study area is extremely steep, with dissected terrain that limits physical accessibility, we used a segment of the Foothill-Chaku-Tenga road (Fig. 3.1) as the backbone of our sampling effort. Within EWS and the adjacent community lands, a representative section of road (averaging 10-12 km in length) was selected (Fig. 3.1). Each of these roads was then subdivided into one kilometre long segments. In general, for community lands we had to sample distances further away from the road to find primary and secondary forests compared to EWS, although there was no significant difference (overlapping confidence intervals) between these two regimes, in terms of average distance of transects from road.

At each one kilometer segment, we established a 500 m-long U-shaped transect with two 200 m-long parallel sections joined by a 100 m-long section. In some cases, we had to deviate around impassable topography, but not beyond a 20^{o} angle from the transect bearing (unless confronted with dangerous topography or extremely steep slopes). Each transect was divided into 20 m segments. In each segment, we recorded the presence of all interpretable mammal signs (such as paw prints, hoofmarks, feces, and scrapes). Two observers walked along each segment a few meters apart, and recorded mammal signs independently. Information collected by both observers was used to estimate the number of transect segments occupied by each species by taking into account detection probability using the Lincoln-Peterson estimator (Seber, 1982). We also recorded any mammals that were identified visually or acoustically along each segment. Because we could not identify small carnivore signs to the species level, we treated small carnivores as a single guild. We also collected data on topography (slope), and habitat characteristics within 5 x 5 m plots positioned at 20 m intervals along in the transect (using ordinal variables to estimate relative canopy cover [1-4] and understory cover [1-4], the number of trees >20 cm diameter-at-breast-height (DBH), DBH of the largest tree, the number of fallen logs, the presence of invasive plant species, and any signs of human disturbance, such as cut stumps or vehicle tracks). We conducted transect-based sign surveys in October-November 2011 and repeated them in August-September 2012. Due to a major landslide, we could not resample one transect in the community-managed land.

3.2.2.2. CAMERA TRAPPING

Using the road as a sampling backbone, we conducted camera trapping in two adjacent blocks representing EWS and the community lands between April and June 2013. Each block was overlaid with a grid of 1 x 1 km cells. Within each cell, we deployed a Cuddeback Attack (Model 1149; Non Typical Inc., Green Bay, Wisconsin, USA; www.cuddeback.com) passive infra-red camera trap in each of the 40 grids (22 in EWS and 18 in the community land). We chose trap locations based on presence of tracks, trails, and animal signs within each grid. We baited camera trap locations with a combination of rotting banana and smoked dried fish to maximise capture probabilities. Traps were attached to trees about 25 cm above ground to ensure that small animals were not missed. We moved each trap after 20 days to a new location within the same grid (therefore sampling two locations within each grid), and checked the traps every five days to ensure they were working properly. Our sampling effort was 856 trap-nights in EWS and 677 trap-nights in the community lands. Camera losses from theft, elephant damage, and camera malfunctions did not allow us to precisely equalize sampling effort in the two management regimes.

3.2.2.3. INTERVIEWS

We conducted key-informant interviews between July 2012 and August 2013. While choosing key informants, we used three basic criteria – their role in the community, their knowledge about wildlife, and their willingness to speak to us. Village chiefs, youth leaders, teachers, local council members, and administrative officers were considered as those having an important role in the community. Our approach was to first meet the village head, and then other members who played an important role in the community. Once interviews commenced, we asked interviewees to refer us to other potentially key informants such as hunters, former loggers, and those involved in nature-based tourism.

PHOTOGRAPH 5: VILLAGE CHIEF AND ONE OF OUR INTERVIEWEES AROUND EAGLENEST WILDLIFE SANCTUARY. PHOTO CREDIT: ELIZABETH SOUMYA.

Interviewees belonged to the Shertukpen (also called Sherdukpen) and Bugun tribes as well as second- or third-generations settlers from Nepal (now Indian citizens). We conducted interviews in Hindi, the most widely spoken language in the state. We were careful to ensure that no Forest Department personnel were involved while conducting interviews. Most people were willing to be interviewed (only five residents refused). In this way, we interviewed 99 residents from six large settlements near the periphery of EWS. Our questionnaires were semi-structured, with open-ended questions to investigate hunting and wildlife taboos and restrictions. In addition, using photographs depicting the species occurring in EWS and the surrounding forest, we asked interviewees to assess population trends separately for each species over the last three decades. Responses were classified on a scale from minus two (for extirpations) to plus two (for large increases); a score of zero indicated no change. We also collected information on species status, threat perceptions, taboos, penalties and regulations related to hunting, illegal fishing, and logging. Given that previous studies have shown that hunting plays an important role in daily activities of these people (Aiyadurai et al., 2010), we also collected data on hunting motivations, patterns, and methods, as well as preferred species. We also asked our informants if they believed that there was a higher abundance of animals in their community-managed lands or within EWS. Each interview lasted about 90 minutes. Apart of these 99 interviews, we also took down detailed qualitative notes with 50 residents of the Shertukpen community from three large settlements (Rupa, Thungre and Shergaon). Our approach suffers from potential pitfalls, such as non-truthful disclosures, errors with recall data and limited replication that are comparable to other studies (Rao et al., 2010). Notably, our study portrays the perceptions of hunters and people who have direct interface with forests but not the rest of the population. In our study area only men hunt, and therefore one male hunter per household was interviewed. We collected information on patterns, methods, preferred game species for consumption, motivation, taboos, penalties and regulations related to hunting.

PHOTOGRAPH 6: BUGUN FAMILY AROUND THE COMMUNITY-MANAGED LAND IN EAGLENEST WILDLIFE SANCTUARY. PHOTO CREDIT: ELIZABETH SOUMYA.

3.2.3. STATISTICAL ANALYSIS

We used Program R (R Development Core Team 2014) for all analyses. We used logistic Generalised Linear Mixed Models (GLMMs) to investigate, for each species, the relationship between the detection-corrected proportion of transect segments with signs (henceforth, referred to as abundance) and our predictor variables. Across data from all transects and repeated sampling, we excluded five detections from the analyses – one each of Himalayan serow *Capricornis thar*, Himalayan black bear *Ursus thibetanus*, and Asian elephant *Elephas maximus*, and two detections of Indian wild dog *Cuon alpinus*. Each of these were single records on a particular transect, that were detected by only one of the two observers. We were therefore unable to calculate detection probability. Because repeated measures on the same sign survey were not independent of each other, we included transect identity as a random effect in all models. Prior to creating a global model and candidate model set, we checked for associations among our predictor variables by calculating correlation coefficients for every pair of the predictor variables and by examining variance inflation factors in the package *usdm* (Naimi, 2013) in Program R.

We selected *a priori* a global model in which abundance was a function of protection regime, sampling season, habitat disturbance, distance to road, and species identity. Because we expected species-specific responses to differ, we also included interactions of species identity with protection regime, habitat disturbance, and distance to road. We then created a candidate model set with all possible simpler subsets of the global model using the *dredge* function in the R package *MuMIn* (Barton, 2013). We selected models for inference based on Akaike's Information Criterion (AICc), corrected for sample size, which trades off model fit and model complexity (Burnham and Anderson, 2002). To explore the relative contribution of the fixed and random effects to the overall variance explained by the selected model, we used the *r.squared GLMM* function in the R package *MuMIn*, which calculates both a marginal R^2 (variance explained by fixed effects alone) and a conditional R^2 (variance explained by fixed and random effects combined; Nakagawa and Shielzeth, 2013). Finally, we used the *predictSE* function in the R package *MuMin* to generate predicted values from the selected model.

From our camera-trapping data, repeated captures of the same species at the same camera within a one-hour period were collapsed into a single record. These data were used to estimate species richness using the Jackknife 1 species-richness estimator, and community similarity using the Sorensen's, Morisita-Horn, and Bray-Curtis dissimilarity indices. Sorenson's index calculates community dissimilarity based on species occurrence alone, whereas the Morisita-Horn and Bray-Curtis indices take into account the relative abundances of species as well. The effort-standardized number of independent captures of each species was computed and plotted as a function of body size.

From our interview data, most interviewees were unable to distinguish similar-looking species such as two macaques *Macaca* spp., smaller tree squirrels *Callosciurus* spp. and *Dremomys lokhriah*, and two species of river otters *Lutrogale* and *Aonyx* spp. The species within each of these groups were therefore pooled and the average body mass for each group was used. We only included species for which were there were more than 50 responses (excluding interviewees who did not know about these species or felt they did not occur in the forests they were familiar with). This approach yielded enough information to infer population trends over a three-decade period for 20 species. We then modeled the average scores in species increase, decline or no-change (across all interviewees) as a function of species body mass.

3.3. RESULTS

3.3.1. SIGN SURVEYS

Topographically, the protected area and community-managed land were similar. The median elevation in EWS (protected area) was 2149 m (95% CI: 1931 – 2574 m), and 2377 m (2115 – 2798 m) in the community land. Median slope was 22.8° (19.9-27.9°) in EWS and 24.4° (18.2-29.2°) in the community land. Median aspect in EWS was 215° (138–276°) and 226° (147-289°) in the community land. Transect-segment occupancy across all species was not spatially auto-correlated (Moran's I observed = 0.27).

Our predictor variables were not collinear (variance inflation factor < 1.30, with correlations ranging from -0.12 to 0.17). Distance to the nearest village and protection regime (protected area and community land) were correlated because EWS has no settlements, but the community land does. Of these two variables, we retained protection regime as a predictor, but note that distance to village might also have a bearing on species occurrences and distributions. Our global model fit the data well (Pearson's R between observed and model-fitted values = 0.73). Of the 70 models in our candidate model set, the global model performed best (ΔAICc values for all models was greater than 7; Appendix S8). The proportion of variance explained by our fixed effects (marginal R^2) was 0.43, and the cumulative variance explained (conditional R^2) along with the random effect (transect identity) was 0.46. From the second sampling of each transect, the response of each species was qualitatively very similar to that of the first season (Fig. 3.2 and 3.3).

Contrary to our expectations, most species did not show appreciable differences in abundance either with protection regime or habitat disturbance (Fig. 3.2 and 3.4). These include, barking deer *Muntiacus muntjak*, Himalayan black bear and small carnivores which include yellow-throated marten *Martes flavigula*, golden cat *Pardofelis temminckii,* marbled cat *Pardofelis marmorata,* leopard cat *Prionailurus bengalensis* and Himalayan crestless porcupine *Hystrix brachyura*. However, as expected, larger-bodied species such as the Asian elephant and Himalayan serow were more abundant in EWS than in the community-managed land, and also appeared to prefer more degraded habitats ($\beta \pm$ SE; protection regime: Asian elephant= -1.25 ± 0.32; Himalayan serow = -1.80 ± 0.64; disturbance: Asian elephant= 2.27 ± 0.36; Himalayan serow = 0.98 ± 0.52; Fig. 3.2). Gaur *Bos gaurus* was most strongly influenced by protection, and was much more abundant within EWS than in the community-managed land (protection regime: -4.39 ± 0.70; disturbance: 0.75 ± 0.36; Fig. 3.2 and 3.4). In contrast, wild pig *Sus scrofa* appeared to prefer more-intact forests in community lands (protection regime: 1.75 ± 0.71; disturbance: -1.08 ± 0.90; Fig. 3.2 and 3.4).

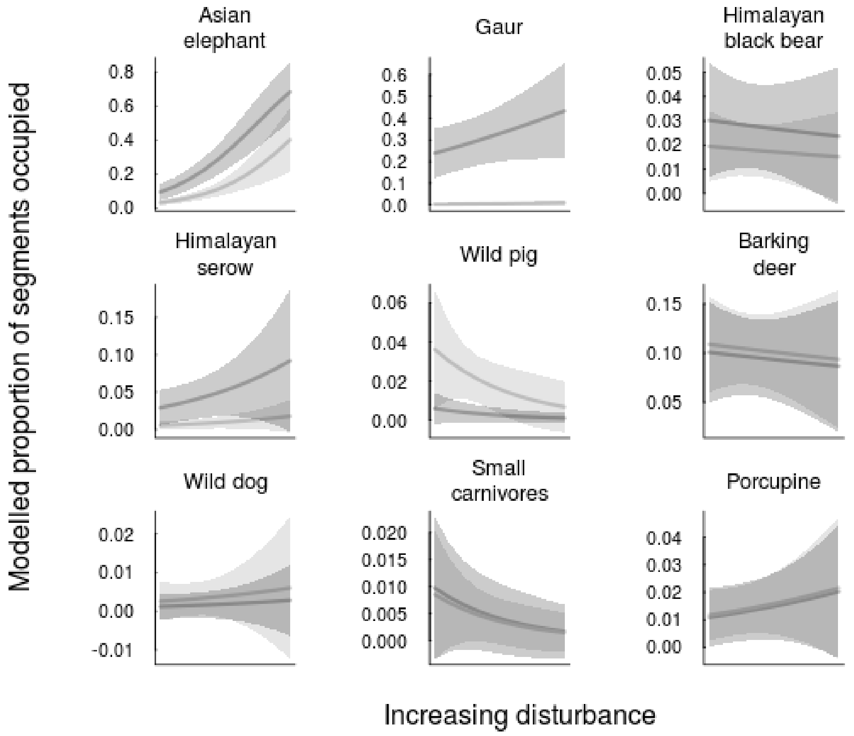
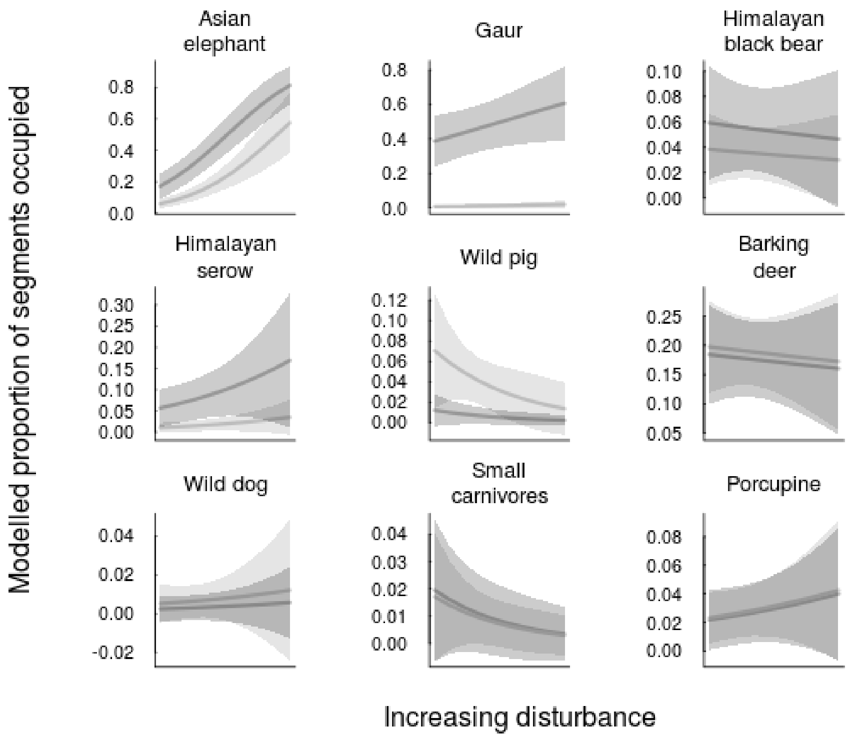


Figure 3.2 – The relationship between proportion of segments occupied and habitat degradation in the protected area (dark grey) and community land (light grey). Solid lines represent fitted (predicted) values from the GLMM, and the lighter polygons, the 95% confidence interval associated with the modeled predictions. Elephant, gaur and serow appeared to prefer more degraded habitats in the protected area, whereas wild pig occurred in more intact forest in community land. The other species showed no clear patterns with either protection regime or habitat degradation. From left to right and top to bottom, species are arranged in order of decreasing body mass. Transects that were walked on the first sampling occasion are represented above.



Figures 3.3 – Details are the same as figure 3.2 but transects that were walked on the second sampling occasion are represented above.

Most species did not show appreciable differences in abundance with increasing distance from the road (for Asian elephant, Himalayan black bear, Indian wild dog, wild pig and barking deer, the range of β ± SE was -0.10 to 0.70 0.70 ± 0.21 to 1.29; Fig. 3.4 and 3.5). However, gaur (1.73 ± 0.32), Himalayan serow (2.18 ± 0.66) and small carnivores (2.07 ± 0.76) showed an increase in abundance with increasing distance from the road. Himalayan crestless porcupine was the only species that showed a higher occurrence closer to roads (2.32 ± 1.063).

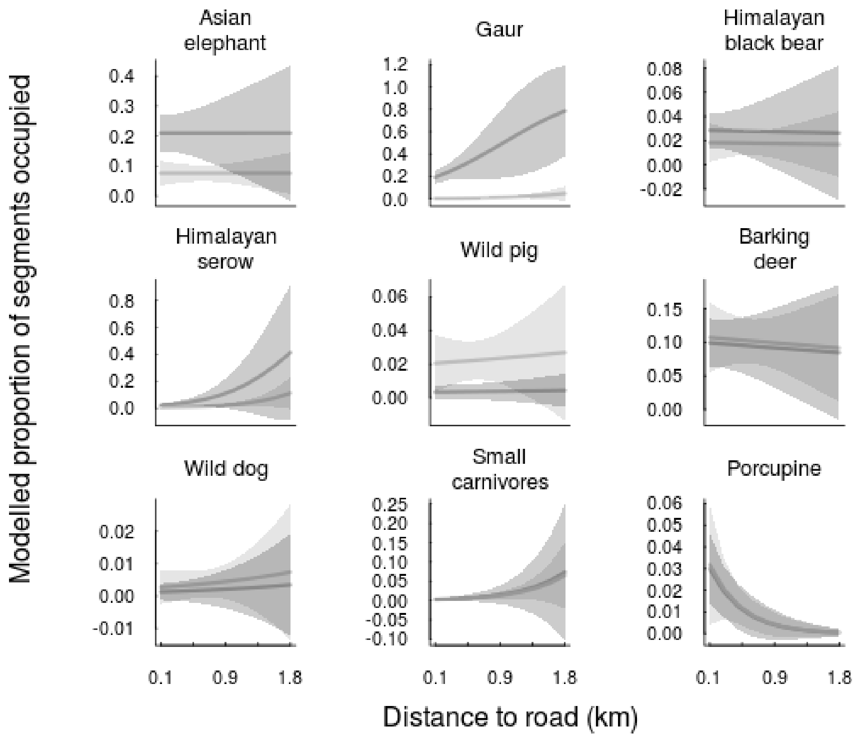
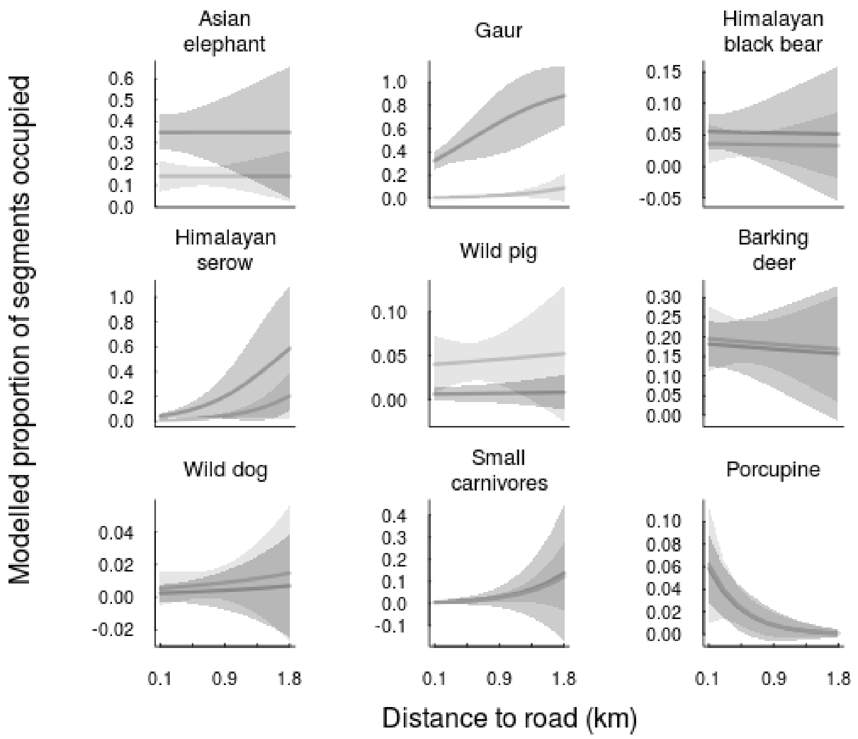


Figure 3.4 - The relationship between proportion of segments occupied and increasing distance from road in the protected area (dark grey) and community land (light grey). Solid lines represent fitted (predicted) values from the GLMM, and the lighter polygons, the 95% confidence interval associated with the modeled predictions. Gaur, serow and small carnivores appeared to prefer areas away from roads, whereas there were more porcupine signs closer to the road. The other species showed no clear patterns with increasing distance from the road. From left to right and top to bottom, species are arranged in order of decreasing body mass. Transects that were walked on the first sampling occasion are represented above.



Figures 3.5 – Details are the same as figure 3.4 but transects that were walked on the second sampling occasion are represented above.

3.3.2. CAMERA TRAPPING

Larger-bodied species had more detections inside EWS compared with community land. For smaller-bodied species the reverse was found (Fig. 3.6; a few camera trap photographs are shown in Appendix S9). Species richness was comparable between EWS and the community lands (Jackknife 1 estimator: PA = 16.77 ± 2.54 SE, community land = 15.77 ± 1.88). However, these regimes did differ slightly in species identity (Sorenson's index = 0.25; with 0 = completely similar and 1 = completely dissimilar). Mammal communities across the two regimes were more dissimilar in terms of the relative abundances of different mammal species (Morista-Horn index = 0.43 and Bray Curtis index = 0.60), indicating that while the same species may occur in both regimes, they had different relative abundances.

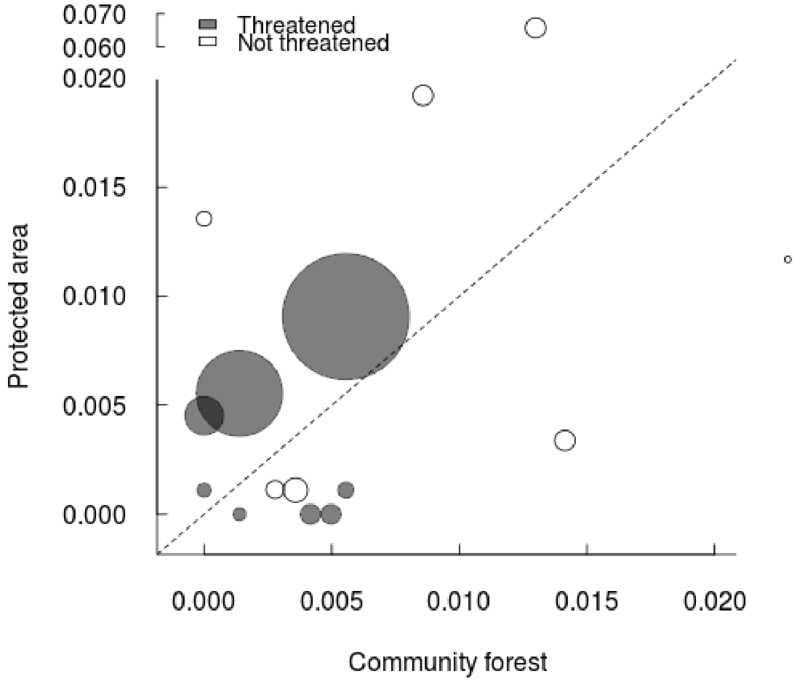


Figure 3.6 - Relative abundance (effort-standardised number of photographic captures) of various species in community land versus protected area. The size of the bubble is proportionate to species body mass. The dotted line represents equal capture rates in community land and protected area. The bubbles above the line represents a greater number of photographic captures of large bodied species in EWS, and those below the line represent greater number of photographic captures of smaller bodied species in the community land.

PLATE 6: CAMERA TRAP IMAGES FROM THIS STUDY. (FROM LEFT TO RIGHT AND TOP TO BOTTOM: ASIAN ELEPHANT, GOLDEN CAT, HIMALAYAN BLACK BEAR, BARKING DEER, WILD DOG, RED PANDA).

3.3.3. INTERVIEWS

3.3.3.1 OVERVIEW OF THREATS ACROSS ALL KEY-INFORMANTS

A majority of respondents (91.9%) thought that more wildlife occurred within EWS than in community lands (5.1% were unaware of any differences, and 3.0% felt that there was no difference). A majority (86.9%) also opined that wildlife was in a general state of decline (10.1% did not know, and 3.0% thought there was no decline). Hunting was suggested to be the main reason for species declines (71.1%), followed by logging (38.4%), human population increase (29.3%), and militancy (14.1%). Hunting was predominantly carried out using guns (85.9%) while a few hunters used both guns and dogs (5.1%). Snares were still reported to be used (18.2%), despite formal restrictions against their use by some village councils.

Taboos and hunting restrictions were diverse across the three communities that live around EWS. While species such as gaur are reported as a taboo, there was high variability across resident communities. These ranged from an absence of restrictions related to wildlife hunting, to some taboos being relatively better known and followed (such as the restrictions on hunting tiger and Asian elephant; Fig. 3.7).

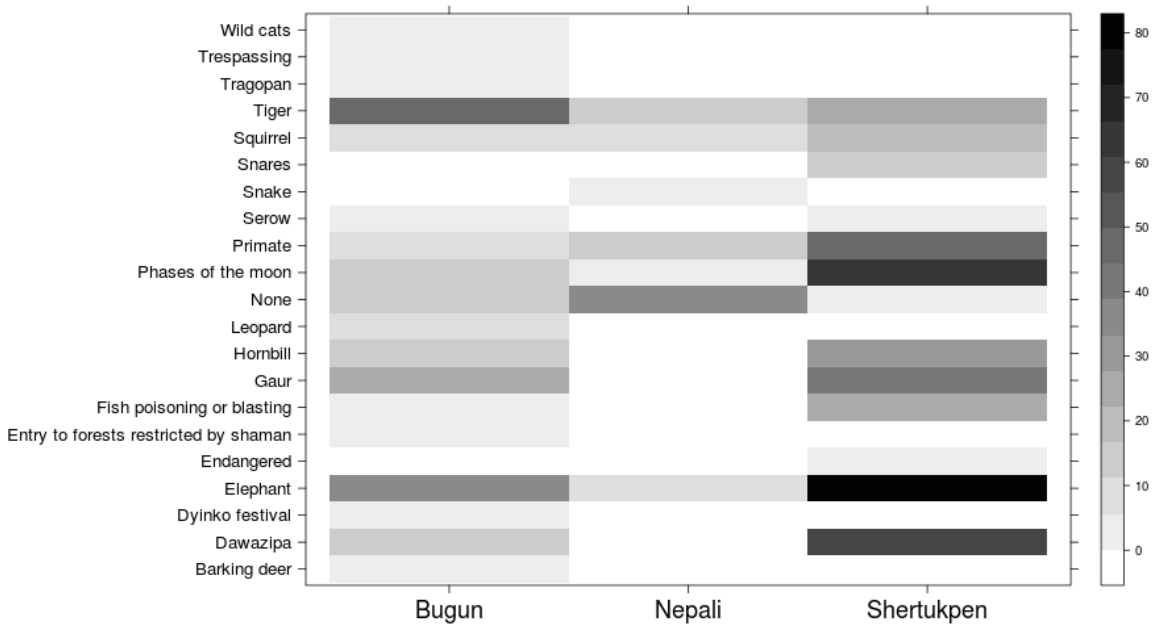


Figure 3.7 - Percentage of respondents in three communities (Buguns, Shertukpens and Nepalis) that reported a hunting restriction or a taboo. Taboos vary widely across communities, although there are some commonalities (for instance, tiger, elephant).

Interestingly, interviewees did report drastic declines of tiger, which are a taboo species, as well as otters and leopard *Panthera pardus*, which were not reported as taboos. Asian elephant and *Macaca* spp. were perceived to have increased in abundance over time (Fig. 3.8). In general interviewees reported greater declines in species abundances with increasing body size (except for Asian elephant; which are a taboo species; Figs. 3.7, 3.8).

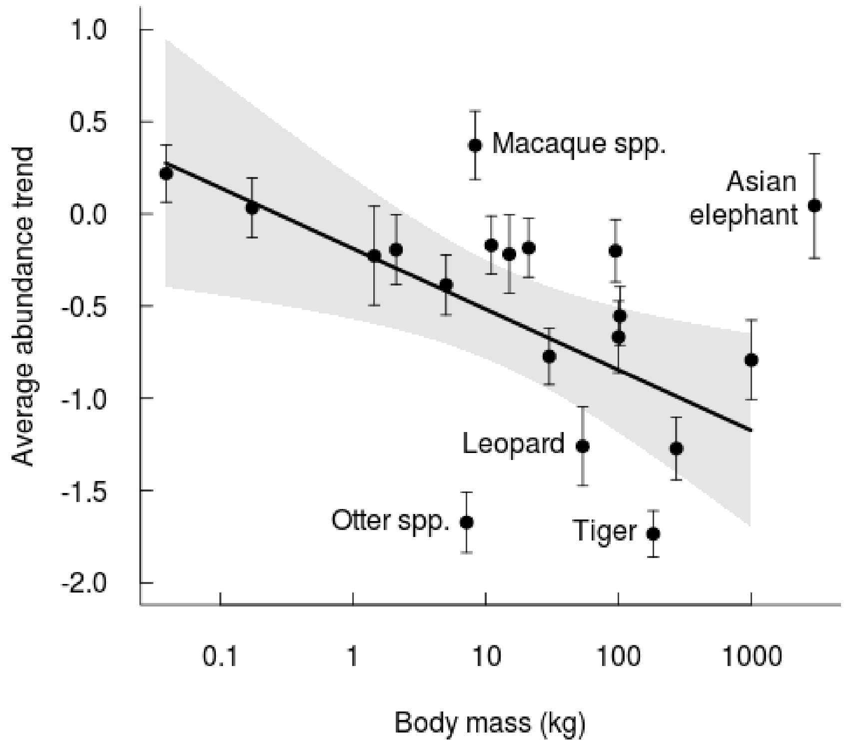


Figure 3.8 – Perceived average species decline scores from key informant interviews. Tigers, otters and leopard populations were reported to have declined the most, whereas elephants, a taboo species, and macaques were reported to have increased. The solid line shows the fitted ordinary least squared prediction for species declines with increasing body mass, and the grey polygon the 95% confidence interval of the prediction. Note that elephant is not part of the regression.

3.3.3.2 A PROFILE OF HUNTING OF THE SHERTUKPEN COMMUNITY

Twenty species (18 mammal and 2 bird species) were reportedly hunted. Although interviewees stated that they do not hunt small birds and only a few pheasant species, the number of bird species hunted is likely to be an underestimate given that birds are usually not recalled during important hunting events (Aiyadurai et al., 2010). All hunters used guns to shoot wildlife; a small number (6%) also used dogs trained to track and flush animals.

The most common reasons given for hunting were recreation, provision of meat and commercial purposes (Table 3.1). Species considered taboo to hunters (see below), except the cattle-like gaur are not hunted for recreation. Species hunted for recreation are also valued for their meat (Table 3.1). Among available wildlife and domestic species, respondents listed 12 species preferred for consumption. Overall, bushmeat was ranked more highly than domestic meat (Table 3.2); 96% of all respondents preferred wild over domestic meat, mostly for taste and perceived meat purity.

Our Shertukpen interviewees indicated that, until two generations ago, tribe members did not eat domesticated-animal meat (except sheep and yak), as domestic animals were considered impure. Poultry, eggs, onions and garlic were also not formerly part of their diet. The breeding of domestic pigs is not allowed in the village, and beef is also not consumed.

Species such as tiger, clawless otter and Himalayan musk deer *Moschus chrysogaster* have been exploited for commercial markets. Hunters, mainly from outside Assam and Rajasthan state, reportedly came to hunt otters and tigers. Himalayan black bear is heavily hunted for its gall bladder, which is traded to people from Bhutan and Assam state, and can fetch INR 10,000–25,000 ($ 180–450 USD) each.

Table 3.1 - Reasons for hunting given by 50 male interviewees from the Shertukpen tribe around Eaglenest Wildlife Sanctuary, the percentage of those interviewed who hunt for each purpose, and the species hunted.

Reasons for hunting	%	Species
Recreation	72	Any species that is not culturally taboo (except for gaur)
Meat	54	Barking deer *Muntiacus muntjac*, Himalayan serow *Capricornis thar*, wild pig *Sus scrofa*, Himalayan goral *Naemorhedus goral*, sambar *Rusa unicolor*, gaur *Bos gaurus*
Commercial	16	Himalayan black bear *Ursus thibetanus*, Himalayan musk deer *Moschus chrysogaster*, otter, tiger
Tradition/ culture	12	Himalayan serow, Himalayan black bear, Malayan porcupine *Hystrix brachyura*
Festivals	10	Barking deer, Himalayan serow, wild pig, Himalayan goral, sambar
Products	6	Barking deer skin, Himalayan serow horn, bear skin
Retaliation	4	Primates (3 spp.), squirrels (4 spp.), wild dog *Cuon alpinus*, marbled cat *Pardofelis marmorata*, leopard cat *Prionailurus bengalensis*, Malayan porcupine

Some species are used in traditional medicine and for their cultural importance. The meat of the Himalayan black bear and the intestines of the Malayan porcupine *Hystrix brachyura* are believed to cure malaria and dysentery. The horn of the Himalayan serow *Capricornis thar* is used in festivals and for treating abscesses. The wattle of the tragopan is used as ornamentation in a religious ceremony. Animal parts are rarely used to make utilitarian products (although bear skins are sometimes used to make winter mattresses), but rather are sold to other tribes (such as the Akas and Nyishis for ornamental use in their headgear, bags and machete sheaths).

Hunting taboos (cultural prohibitions sometimes drawn from religious tenets) within the community are well known; 94% of respondents knew of their existence. Killing of the revered Asian elephant is the most widespread (76%) cultural taboo. Respondents stated that primates (40%), gaur (30%), hornbills (28%), squirrels (22%) and tigers (18%) were also considered taboo species. In addition, four respondents (8%) listed the Himalayan serow and small passerine birds as taboo species.

However, three respondents (6%) stated that it was not forbidden to kill taboo species such as primates and squirrels when they raid crops; it was only taboo to eat their meat. Hunting of the Himalayan serow was considered taboo until a few generations ago, as it was considered to be a 'mount of the gods'. They are now widely hunted, and were ranked as the fourth most-preferred bushmeat species (Table 3.2). Taboos are also changing for gaur and tiger. Respondents stated that when a gaur is killed its tail is cut off and depredation is attributed to a wild predator, such as the dhole or tiger. The meat is not sold but distributed in the village to share the burden of sin. Blame for killing the once-revered tiger is diverted to a lower-status member of another Shertukpen clan. In 1990 these clan members were brought into the Shertukpen fold, and there is no longer any segregation.

The village council has a decentralized, three-tier system, with village chiefs as heads, administrative members, and nine members from each clan that provide information to the other tiers. The council has prohibited (1) the use of dynamite or bleaching for fishing, (2) tree felling within a 3-km radius of the council headquarters and at certain sacred sites, (3) the ignition of forest fires, (4) trapping and snaring of wild animals, and (5) hunting on holy days (the 8th, 15th and 30th day of each month).

Fines for hunting infractions range from INR 10,000 ($ 180 USD) for dynamiting rivers to INR 1,200 ($ 22 USD) for hunting. The fees are reviewed every 3 years, and are subject to change. Five to six years ago the council adopted a month-long hunting ban during the holy month (termed Phogde or Dawazipa). The ban was reduced 2–3 years ago to a 16-day period, following strident lobbying by hunters.

Table 3.2 - Wildlife species preferred for consumption as indicated in interviews with 50 men from the Shertukpen tribe around Eaglenest Wildlife Sanctuary.

Preferred species for consumption	Percent of responses
Barking deer	96
Wild pig	68
Himalayan black bear	44
Himalayan serow	18
Himalayan goral	16
Sambar	8
Malayan porcupine	4
Khaleej pheasant *Lophura leucomelanos*	2
Chicken	2
Fish	2
Mutton	2
Pork	2

3.4. DISCUSSION

In our north-east Indian landscape, mammal species varied in their responses to forest management (protected area versus community-managed lands), distance to road, and habitat disturbances (Figs. 3.2-3.5). Although species richness did not differ significantly between EWS and the community lands, these regimes were dissimilar when a proxy for relative abundance (independent photographic captures) was taken into consideration. Body size appeared to be an important predictor of species responses, with larger-bodied species found more frequently within EWS whereas smaller-bodied species were more abundant in community lands (Fig. 3.6).

Based on our interviews of key community members, the overall reported trend of greater declines with increased body mass underscores the widely reported vulnerability of larger-bodied species (Fig. 3.8). The accelerated declines of large-bodied species may be mediated by their intrinsic biological traits (low fecundity, long gestation period) in synergy with human impacts such as targeted hunting (Cardillo et al., 2005). The case of gaur is especially noteworthy. Gaur is a large-bodied species (~ 1000 kg) that is nearly absent in community lands, and taboos against its hunting are rapidly eroding (Velho and Laurance, 2013); this highlights the importance of taking into account both species-specific traits and cultural contexts in conservation planning.

Declines in abundances of several species are likely to be related to hunting pressure, which residents perceive to be a major threat to wildlife in the area, as well as in other parts of Arunachal Pradesh state (Aiyadurai et al., 2010; Velho et al., 2012). Hunting practices in north-east India have closer cultural affinities with those in South-east Asia than with peninsular India. Like nearby Myanmar, wild pig and deer are the most preferred species for hunters (Rao et al., 2005). Our interviewees expressed an overwhelming preference for bushmeat over domestic meat, with their views mirroring those of villagers in Laos that wild game 'tasted better, was healthier for you and fun to pursue' (Hansel, 2004).

Interviewees reported dramatic declines of tiger, leopard, and otters over the last three decades (Fig. 3.8). While the killing of tigers remains a well-established local taboo compared with killing of leopards, this traditional restriction appears not to be effective enough to halt drastic declines of these species, which are targeted for illegal cross-border wildlife trade. Less obvious, but of equal concern, were the reported drastic declines of otter species, which have high illegal-trade value.

While our data help identify a few species that are most vulnerable to illegal trade, more site-specific data are needed to support national and international wildlife-trade databases (Toledo et al., 2012).

Elephant and *Macaca* spp. were notable exceptions to the overall picture of declining wildlife populations. Restriction on elephant hunting is a strictly codified taboo, in both community lands as well as EWS. While our data on elephant occurrences do not show dramatic differences between EWS and the community lands, we do not have occurrence data on *Macaca* spp. to compare with the reported trends. However, interviewees reported crop raiding and agricultural losses to both elephants and *Macaca* spp. Whether these species benefit from human 'care-takers' (through cultural mores) despite their perceived impact on crops needs further investigation (Lee and Priston, 2005). Further, it would be beneficial to understand the spatial context of crop-raiding, seasonality and the effectiveness of the existing guarding strategies against agricultural loses (Linkie et al., 2007).

One of the important findings we document here is the rich complexity of human interactions with wildlife, and how these interactions vary with ethnicity, space, and time. For instance, in the last few decades, Nepalis have settled in community lands managed by the Bugun tribe, and practise intensive agriculture, changing the environments around EWS. This relatively recent immigration has also brought in much greater diversity in wildlife-related cultural practices in and around EWS (Fig. 3.7). Studies from other parts of the Himalayas indicate that Tibetan Buddhism, followed by the Bugun and Shertukpen tribes, may play an important role in species conservation (Li et al., 2014). In our landscape hunting is embedded in animistic beliefs before the advent of Buddhism, with bushmeat still sought for festival celebrations. Buddhist monks have played a key role in lobbying for the hunting ban during the breeding season, and hunting may have declined in the general area in 2003 following the visit of Dalai Lama (Mishra et al., 2006). However, the cultural heterogeneity across the various ethnic groups that reside around protected areas and how this varies with time needs to be considered when tailoring outreach programs that seek to reduce poaching pressures (Steinmetz et al., 2014).

Our findings also reveal a major gulf between local taboos and practices and national wildlife legislation (which has not factored these different cultural contexts into government policies) in India. On the one hand, the Wildlife (Protection) Act, which is national legislation that prohibits hunting of any protected species, is often not enforced. On the other hand, Shertukpen village councils have instituted hunting bans during the peak wildlife-breeding season (May–June) and have banned traps and snares (but not guns) for hunting. The future will bring important challenges for the sustainability of bushmeat hunting as taboos weaken, commercial markets expand and human populations continue to grow. Wildlife species exploited for legal or illegal trade can face particularly acute pressures (Laurance et al., 2006). In west and central Africa, stakeholders have attempted to reach a consensus to balance bushmeat harvests and conservation (Bennett et al., 2006). Apart from strengthening governance and institutions, they call for engagement across the public health, development and other sectors. Similar partnerships are needed in India to balance wildlife conservation with hunting, given the tension between hunters and formalized rules (either traditional or national), which often play out in the context of rapid social and environmental changes. This gamut of partnerships, especially at the national level, should include religious and cultural leaders as their teachings might influence attitudes and rules governing hunting at local levels.

The biodiversity value of EWS and its surrounding areas cannot be overstated. This region may contain the second-highest level of biodiversity in the world, after the northern Andes (Price, 2012). From our study, we argue that it is moot to debate whether EWS or its surrounding community lands have greater values for wildlife conservation. EWS harbours vulnerable large-bodied species and may provide an important refugium for hunted species. However, the community lands are important reservoirs for small bodied-species such as the vulnerable red panda *Ailurus fulgens* and the critically endangered Bugun Liocichla *Liocichla bugunorum*, a recently discovered bird species known only from 150 ha of community land (Athreya, 2006). In this context, the Bugun tribe is beginning to initiate a ~9,000-ha community conservation area adjacent to EWS (Fig. 3.1). This would maximise the conservation values of the larger landscape, ensuring that

EWS will not be isolated.

An important perspective that arises from our study is that protected areas and community-managed lands can be complementary, protecting different species in different ways. In Arunachal Pradesh state, 62% of the forests are community-managed and with growing populations and resource use, it is estimated that 50% of the state's forests will be lost by 2021 (Menon et al., 2001). Similar trends are occurring elsewhere; for instance, human populations are growing rapidly in many of the world's 35 biodiversity hotspots (Bradshaw and Brook, 2014). In such contexts, protected areas are vital but community-managed lands could also play an important and possibly complementary role in promoting nature conservation.

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SUMMARY OF CHAPTER 4

Although protected areas are considered the first line of defense for wildlife protection, many species in protected areas have continued to decline in abundance. In the tropics, a substantial number of protected areas have suffered severe population declines and local extirpations of hunted species, species range contractions, and native forest loss (Laurance et al., 2012). Furthermore, of all threatened terrestrial birds, mammals and amphibians, as many as 17% are not found in a single protected area (Venter et al., 2014). These problems are pronounced in many areas, due in part to the *ad hoc* selection of areas for protection (Joppa and Pfaff, 2009).

Additionally, cultural norms and institutional failure contribute to reduced conservation efficacy. In the remote region of north-east India, gun ownership is common and hunting is deeply embedded culturally, with wild meat often preferred over domestic meat. This provides a useful setting to understand the relative importance of protected areas as compared to adjacent lands, which are often managed by resident communities. Considering prevailing markets, cultural views and failing governmental institutions, a key unstudied element is comparing the mammalian diversity harboured in formally protected areas versus those in the adjacent community-managed lands.

In Chapter 3, I addressed this question at one particular site. Here, I address the same question across four different sites in the largest continuous tract of forest in the Eastern Himalaya biodiversity hotspot. While many people assisted me in the field beyond any tangible measure, for this chapter I collaborated formally with my supervisor William Laurance. Over a 2.5-year period, I hiked 98 transects (half of which were resampled on a second occasion) across four independent paired sites, each constituted by a protected area and its adjoining community-managed lands. In addition, I interviewed 143 resident tribal members to understand their traditional hunting practices and to make inferences about the causes of wildlife declines.

We found that protected areas had higher overall species richness and were important for apparently declining species. On a site-specific basis, some community-managed lands had mammal species richness and abundances comparable to those of a protected area, and in one case their relative abundances of mammals were higher. Interviewees indicated that hunting had induced declines in the abundances of larger-bodied mammals in community-managed lands, but their overall observations of species declines did not correlate strongly with the field data I collected. However, their observations did correlate with my transect field surveys for certain key species, such as gaur and sambar, which are suffering drastic population declines. These large-bodied species were much more abundant within protected areas than outside of them and also tended to occur further away from roads in both the protected area and community-managed lands. Hence, the degree to which protected areas and community-managed lands protect wildlife species depends upon the species in question, with larger-bodied species usually faring better within protected areas.

CHAPTER 4

PROTECTION FROM POACHING: USE OF PROTECTED AREAS AND COMMUNITY LANDS BY MAMMALS AND OTHER HUNTED SPECIES

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ABSTRACT

In large parts of the biodiversity-rich tropics, various forest governance regimes often coexist, ranging from governmental administration to highly decentralised community management. Two common forms of such governance are protected areas, and community-managed lands subject to limited resource extraction. We studied wildlife occurrences in the northeast Indian biodiversity hotspot, where three protected areas are situated adjacent to community-managed lands. We conducted transect-based sign surveys and interviewed members of resident tribes to understand their traditional hunting practices and the causes of wildlife declines. Interviewees perceived hunting-induced declines in the abundances of large-bodied mammals such as tiger *Panthera tigris*, sambar *Rusa unicolor*, gaur *Bos gaurus* and large-bodied birds such as hornbills. They also perceive hunting as a significant threat to the biodiversity of this landscape. Our findings from one protected area (Eaglenest Wildlife Sanctuary) show that larger species, such as the gaur, are much more abundant within the protected area than outside of it. Sambar (a large-bodied herbivore), were invariably more abundant within protected areas than nearby community lands and also were less abundant near roads. Contrary to our expectations, most smaller-bodied species were not negatively affected by the presence of mostly-unpaved roads. Our findings show that protected areas have higher species richness than nearby community-managed lands and are important for large-bodied species, especially in the lower altitudes where patrolling might have significant benefits. However, some community lands harboured high biodiversity, and so could be complementary to the existing protected area network.

KEYWORDS: Arunachal Pradesh; community lands; hunting; Kameng Protected Area Complex, Pakke Tiger Reserve; protected area

4.1. INTRODUCTION

Terrestrial protected areas cover 15.4% of the world's land area (Juffe-Bignoli et al., 2014). Within the tropics about a quarter of all forested lands are afforded some degree of protection (Nelson and Chomitz, 2011), but the type and extent of protection varies geographically. While land afforded at least some level of protection is much higher in South and Central America (25 - 28% of the land is listed in IUCN Categories I-VI, which includes all types of formal protected areas), the figure is much lower in Asia (12.4%) (Juffe-Bignoli et al., 2014). Notably, the area of lands that are intended to receive strict protection in the tropics is uniformly low in both the Neotropics and Indo-Malayan region (Jenkins and Joppa, 2009).

The diversity of land protection regimes in the tropics provides a setting in which to understand the relative importance of protected areas compared to adjacent forests that are often managed by resident communities. Furthermore, the relatively small fraction of strictly protected areas can often make their ecological representation, species populations and biodiversity patterns inadequate within the entire protected area network (Rodrigues et al., 2004; Venter et al., 2014). However, protected areas are important reservoirs for maintaining biodiversity (Karanth et al., 2010) and reducing deforestation (Nolte et al., 2013). They are often considered the first line of defense for wildlife protection (Bruner et al., 2001) and have important values for biodiversity and community well-being (Leverington et al., 2010).

Continuing anthropogenic pressures arising from habitat loss, fragmentation, and hunting are serious challenges in protected areas (DeFries et al., 2005; Laurance et al., 2012). As protected areas continue to be degraded and adjacent community-managed forests are converted for agriculture and other human uses, obtaining on-ground information about the relative biodiversity values of protected areas and community-managed lands remains a crucial challenge. Past evaluations have largely focused on forest cover (Ellis and Porter-Bolland, 2008; Nolte et al., 2013) and abiotic pressures such as fire frequency (Nelson and Chomitz, 2011) as proxies for reserve 'health', but often these comparisons are geographically unmatched—

limiting one's confidence in their conclusions (but see Nelson and Chomitz, 2011, but see Goswami et al., 2014 for a matched comparison on elephants). It is also acknowledged that the evidence supporting the efficacy of community-forest management remains weak due to a paucity of rigorously designed studies (Bowler et al., 2011).

An understanding of protected areas versus community-managed lands is especially important in a highly populous, megadiverse developing country such as India. This nation sustains half of the world's tigers, 60 percent of all Asiatic elephants, and 70 percent of all one-horned rhinoceros (Madhusudan, 2003; Amin et al., 2006). Although the threats to biodiversity vary widely by species and region, habitat loss and degradation and hunting remain the predominant stresses to Indian biodiversity (Datta et al., 2008; Karanth et al., 2010; Velho et al., 2012).

Arunachal Pradesh, in north-east India, harbours two global biodiversity hotspots, and has the second-highest level of biodiversity globally, after the northern Andes (Price, 2012). Extirpation of important mammal species such as tigers has occurred in the state (Datta et al., 2008), impacted by socio-economic changes and institutional inadequacies (Datta et al., 2008; Aiyadurai et al., 2010). However, the effectiveness of existing protected areas and adjacent community-managed lands in preserving wildlife remains a key unstudied element. Our study seeks to addresses how much biodiversity (defined as a range of detectable mammals and larger birds such as hornbills and pheasants) is harboured in formally protected areas versus adjacent community-managed lands.

Specifically, we used transect-based animal-sign surveys in conjunction with interviews of local residents to assess the persistence of a range of mammal species in each management regime across four independent sites, using a paired study design. We predicted that (a) human disturbances will affect large-bodied species more negatively than smaller-bodied species, (b) animal abundance (as reflected in the occurrence of animal signs) should increase with distance from roads (c) key informant observations will relatively accurately reflect species occurrences in each of these two management regimes.

4.2. METHODS

4.2.1. STUDY SITE

Our study area spanned four independent, paired sites (8 sites in total) in the Kameng Protected Area Complex, which, at 3,500 km^2, is the largest contiguous forest tract in the Eastern Himalaya Global Biodiversity hotspot. Historically there has been no formal land-tenure system in the state, apart from the established hierarchy of ownership rights among tribes: individual, family, clan, village and tribe. Different tribes and clans have clearly demarcated land management and inter-community land boundaries that operate as areas of management. The relatively recent Arunachal Pradesh (Land Settlement and Records) Act – 2000 tries to formalise land-tenure, but customary rights are still exercised by different tribes. Although forest lands officially belong to the government (Chapter 4, Section 33 of the Assam Forest Regulation Act, 1891), there is great resistance to the government exerting control over these forests. In this region, protected areas are owned and managed by the state government, whereas in community forests (or unclassified state forests) tribal people exercise their customary rights, including shifting cultivation, hunting and collecting fuelwood and non-timber forest products.

We sampled community-managed lands belonging to four tribes: Nyishi, Aka, Bugun and Shertukpen. Our study spans three protected areas and the adjacent community-managed lands of these four tribes. Thus, we have four independent comparisons of respective community-managed lands at the lower (median: 667 m asl) and higher (median: 1346 m asl) reaches of Pakke Tiger Reserve, at Sessa Orchid Sanctuary, and at Eaglenest Wildlife Sanctuary (Fig. 4.1).

Topographically, the paired sites are similar. The aspect (median 210.4, 95% CI: 24.6–351), elevation (1155, 95% CI: 142-2785.4) and slope (19.7, 95% CI: 1.6-36) in community-managed lands is similar to that in the protected areas (aspect: 186.8, 95% CI: 18-335.2, elevation: 1417.5 95% CI: 141 -2481.6 and slope: 23.2 95% CI: 0.7–44.7).

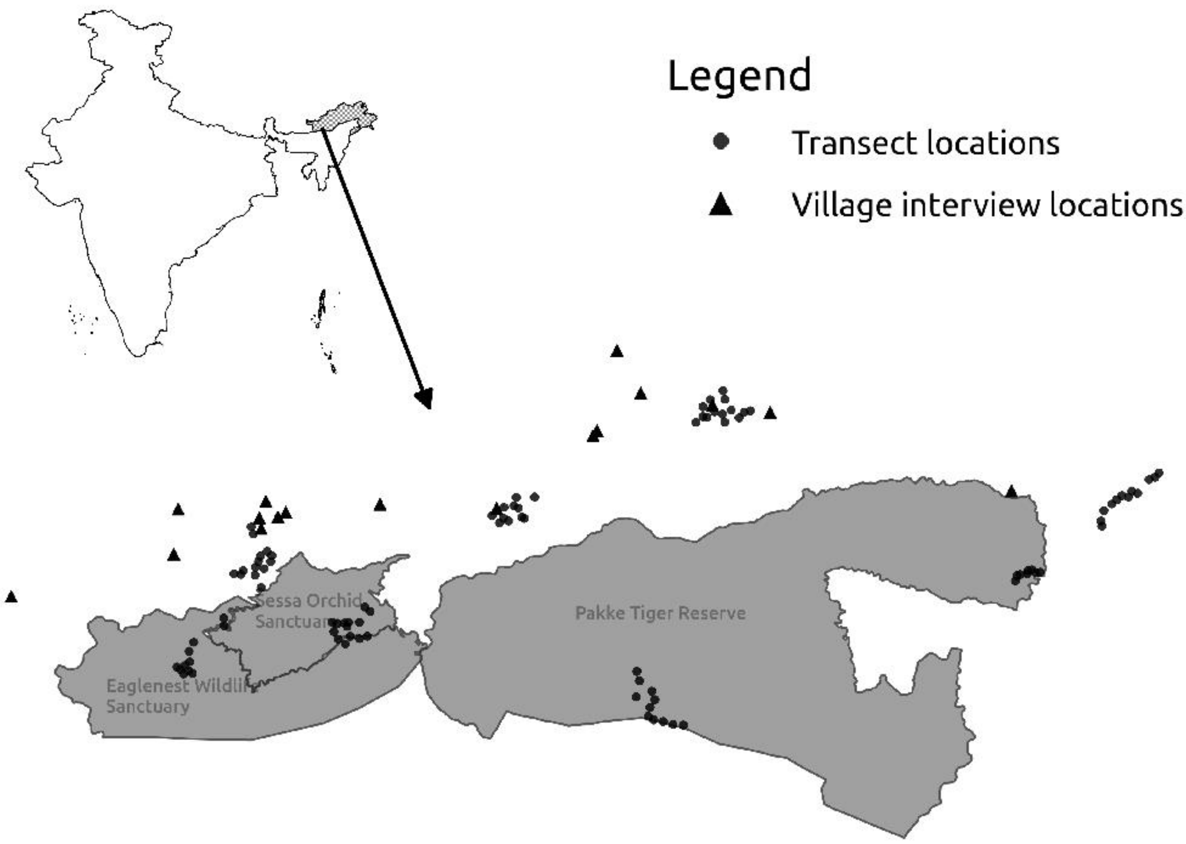

Figure 4.1 — Map of the study area where the dark grey are the protected areas and the sampled locations have been marked in the map.

4.2.2. DATA COLLECTION

4.2.2.1. SIGN SURVEYS

Each of these four sites has a road or a path that we used as a sampling backbone. Within each site, we used several 1 km-long segments of the path or road as independent units to sample different habitat types: agriculture and fallow; secondary and logged forests; and primary forests (which we define as relatively undisturbed forests with no ongoing anthropogenic modification). For each 1 km segment of road, we walked 500m-long U-shaped transects within the habitat of interest (Fig. 4.1). At each transect, we recorded direct and indirect signs of detectable mammals and larger birds, such pheasants and hornbills, every 20 m. Two observers walked along each segment a few metres apart, recording these signs independently. In total, we had 44 transects in protected areas and 54 transects in community-managed lands; the sample size for the latter was slightly larger given that they had more varied land-use types than did the protected areas. From October 2011 to March 2013, we walked a total of 98 transects, of which we re-sampled roughly half of these transects (48) at two sites (Eaglenest Wildlife Sanctuary and the lower reaches of Pakke Tiger Reserve). At every 20 m interval, we also established 5 m x 5 m vegetation plots (see Methods of Chapter 3 for details).

PLATE 7: ELEPHANT DUNG (LEFT, PHOTO CREDIT: WILLIAM LAURANCE) AND ELEPHANT AT EAGLENEST WILDLIFE SANCTUARY (PHOTO CREDIT: ROHAN PANDIT).

4.2.2.2. INTERVIEWS

We conducted 143 key-informant interviews, but excluded another 46 key informants from within Pakke Tiger Reserve, to help us understand the general trends in animal populations across both regimes in this general landscape. We excluded the 46 informants at Pakke because it was the only protected area we could get information from, and so was unreplicated in our study. The 143 key-informants we used were residents of local communities who were village council members, past and present loggers, hunters, ex-hunters, people who worked in nature-based tourism and others who had a direct connection to the community-managed land and knew about different species in the general landscape. We asked them about wildlife trends over the last 30 years. If they felt populations of any known species had declined, we asked for explanations and qualitative information to understand why and how these declines had occurred. Given that we were interested in understanding local views towards species abundance trends, we asked respondents to classify species on a scale from -2 (for extirpations) to +2 (for large increases), with a score of zero indicating no change in abundance.

We were also interested in comparing the perceptions of abundance trends over time in a community-managed land and protected area. While we were able to obtain general information on overall wildlife abundance across both regimes across the general landscape, collecting information on individual species trends was only logistically possible at one site. For this comparison, the key-informant profiles in the community-managed lands were the same as those mentioned above and mainly belonged to the Aka tribe, with a lesser number from the Nyishi tribe. The lower reaches of Pakke Tiger Reserve are uninhabited and so we chose to interview long-term research assistants, people involved in nature-based tourism, forest watchers and guards. As such, their profiles differ from the typical interviewees at other sites. We acknowledge that population declines might be underestimated within Pakke (because many of the interviewees worked for the Forest Department and might not be comfortable reporting declines), but we hope to have minimised this bias as NV has worked with and is well-known to the key-informants at Pakke for the past 8 years. In this way, we conducted a total of 84 key-informant interviews (46 within the protected area and 38 from the community-managed lands) from our paired site in and around Pakke Tiger Reserve.

4.2.2.4. STATISTICAL ANALYSIS

We used Program R (R Development Core Team 2015) for all analyses. As a first step, we quantified the variability of vegetation characteristics across our transects using Non-metric Multidimensional Scaling (NMDS). Our data were transformed using the Wisconsin double standardisation function. Because multivariate analysis cannot manage missing data, we excluded one transect from community-managed land that had a tree-density value of zero, and therefore was missing values for related variables such as canopy cover and tree girth. However, we retained this transect for our assessment of animal signs. We used the *metaMDS* function in the R package *vegan* for our ordination analysis. This *metaMDS* function uses the Bray-Curtis index to quantify dissimilarity in vegetation characteristics across our transects (Oksanen et al., 2013). To interpret how our variables were associated with the NMDS axis values, we used Pearson's correlations between each axis and the original vegetation variables.

To assess animal 'abundance' (defined below), information collected by both observers was used to estimate the number of transect segments occupied by each species by taking into account detection probability using the Lincoln-Peterson estimator (Seber, 1982). We could not calculate detection probabilities for wild pig, serow and elephant, in only one transect each; nor for small carnivores and squirrels, in two transects; and nor for Himalayan black bears, detected in four transects. The calculation was not possible because, in each of these transects, only one observer detected a single sign, which was not detected by the second observer.

In all areas except within the Eaglenest Wildlife Sanctuary (where domestic hunting dogs and the semi-domesticated cow-like mithun *Bos frontalis* were not present), we excluded a certain animals from the species-level analysis because it is difficult to distinguish their signs. Specifically, signs of domestic dogs and wild dogs are very similar, as are the signs of the mithun and its wild counterpart, the gaur (*Bos gaurus*). Therefore, these species were excluded from the analyses.

We used a logistic Generalised Linear Mixed Models (GLMMs) to investigate the relationship between the detection-corrected proportion of transect segments occupied by signs of each species (hereafter referred to as its 'abundance') and our predictor variables. We used two separate analyses, for guilds (carnivores, herbivores, canopy and ground-dwelling taxa) and for relatively abundant species or closely related species groups (14 in total, including hornbills and small carnivores, each of which was considered a single taxon). We modeled the response of guilds to predictors such as forest-management regime, sampling season, linear distance to the nearest road and an index of disturbance (from our NMDS analysis) and their statistical interactions (guild:regime, guild:distance to road and guild:disturbance). We conducted a separate analysis to understand the response of species to the same set of predictors and their interactions (species:regime, species:distance to road and species:disturbance). The details of model building are outlined below. Because we had repeated measures within each site that were not independent, we used site as a random effect in our mixed models. We checked for collinearity between all our predictor variables by calculating correlation coefficients and variance inflation factors in the package *usdm* (Naimi, 2013).

We created *a priori,* a global model in which animal abundance is a function of protection regime, sampling season, habitat disturbance, distance to road and species (or guild) identity. Also included were the interactions of species (or guild) identity with protection regime, habitat disturbance and distance to road. We created candidate model sets and simpler subsets of the global model using the *dredge* function in the *MuMIn* package (Barton, 2013). Models were selected based on Akaike's Information Criterion (see the 'Data analysis' section of Chapter 3). We re-ran the analysis with only new animal signs ($\leq$ 10 days old, age of signs was estimated by visiting the same place after an animal was sighted during a pilot study). We found that our best model results for species and guilds did not change. Consequently, we decided to use all animal signs for the analysis to increase the amount of data included in the model.

To identify predictors of species richness for selected mammals and birds, we use the average number of signs per transect (averaged across two repeats, where applicable) in a transect-by-species matrix. We used the package *vegan* to calculate species richness and perform site-wise comparisons. We report bootstrapped values of species richness and standard errors to make site-wise comparisons among the four sites. The estimated species richness was similar whether we used only fresh signs or all signs, and hence we used latter for our analysis. Additionally, we plotted rank abundance curves (for community-managed lands and protected areas) for each of the four sites using the package *BiodiversityR* (Kindt and Coe, 2005).

Our interview analysis only included species for which there were at least 10 responses by key-informants. If our interviewee was unsure about species identity (or thought it was not found in the area), the species was excluded as a data point from that interview. Using this approach, we had enough information to model population trends of 23 species from within Pakke Tiger Reserve and 29 species from within the adjacent community-managed lands. Then we plotted the average species scores as a function of body mass. We used an average body size for similar-looking squirrel species, for similar-looking otter species, and for two macaque species.

4.3. RESULTS

4.3.1. VEGETATION RESULTS

We examined the first two dimensions generated by our NMDS analysis in relation to vegetation covariates (stress = 0.13). On axis 1, undisturbed habitats tended to have high canopy height (Pearson's r = -0.72), high tree density (-0.54), larger-girthed trees (-0.36) and the lowest tree branches tended to be higher (-0.36). Also, undisturbed forests had higher liana abundance (-0.32) likely because the sampled areas under active agriculture lack substrate for lianas to climb upon. In degraded or disturbed areas there were more human signs (0.74), invasive plant species (0.72), cut stumps (0.45) and under-storey cover (0.22) (Fig. 4.2). On axis 2, disturbed habitats did not show an increase in human signs (-0.16) and invasive species (–0.29) while undisturbed habitats showed a weaker relationship with tree density (-0.28) and tree girth (-0.01) (Fig. 4.3). Thus, it was more biologically meaningful to interpret NMDS axis 1 as the principal disturbance axis for further analyses, and not NMDS axis 2. When over-laying transects over a disturbance space represented by NMDS axes 1 and 2, we found that transects we had classified *a priori* as secondary forest clustered between primary forests and agricultural/fallow land (Fig. 4.4). This enhanced the confidence of our *a priori* classification of forests into primary and secondary forests and agricultural/fallows.

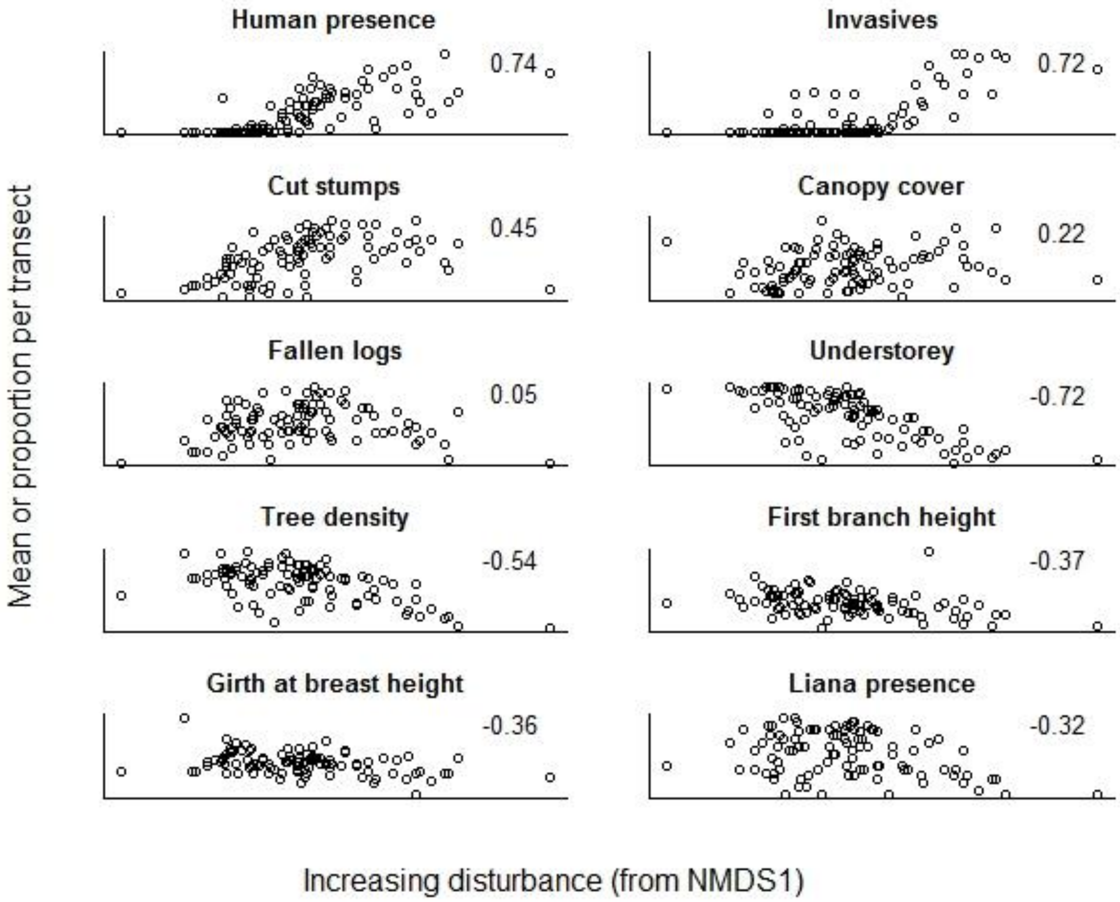

Figure 4.2 — Correlations of our original habitat variables with NMDS Axis 1. The variables are arranged in descending order of the strength of their Pearson's correlation coefficients.

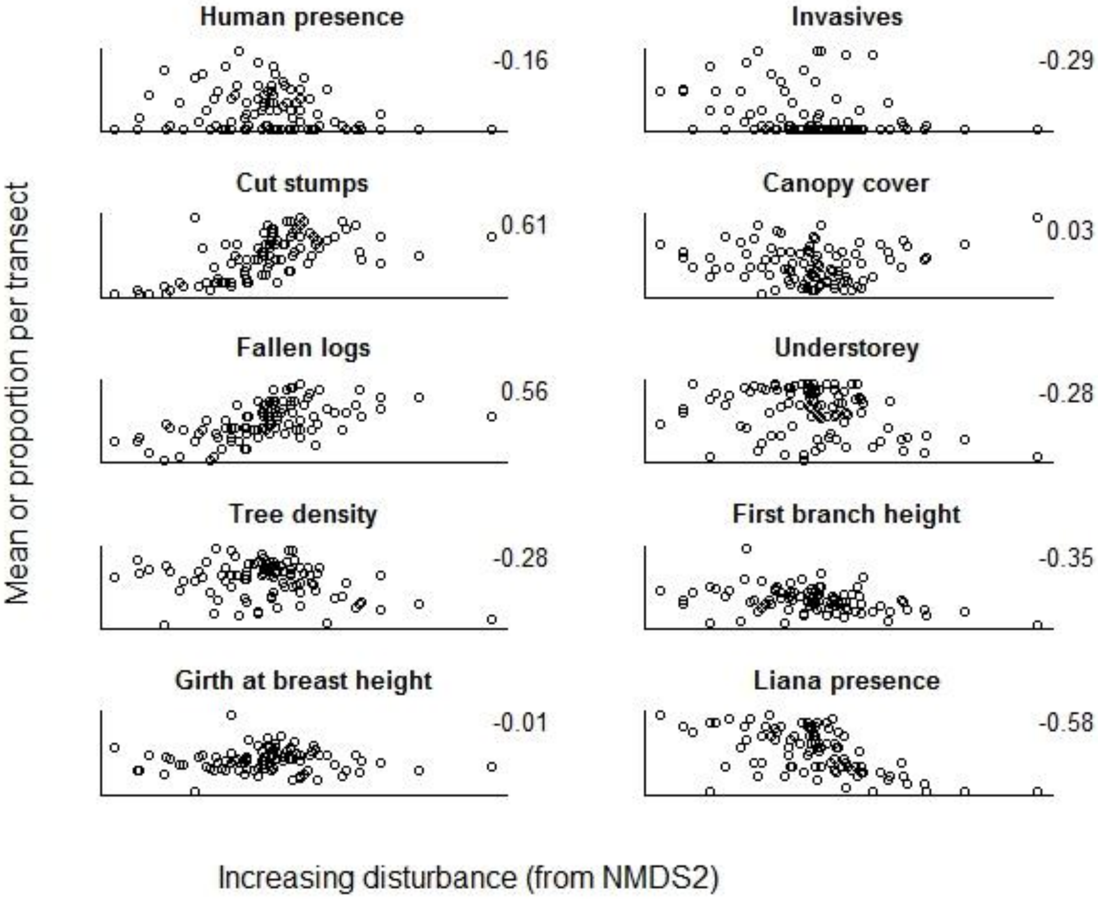

Figure 4.3 — Correlations of our original habitat variables with NMDS Axis 1. The variables are arranged in the same order as in the previous figure. NMDS axis 2 does not represent a very good disturbance axis compared to NMDS axis 1.

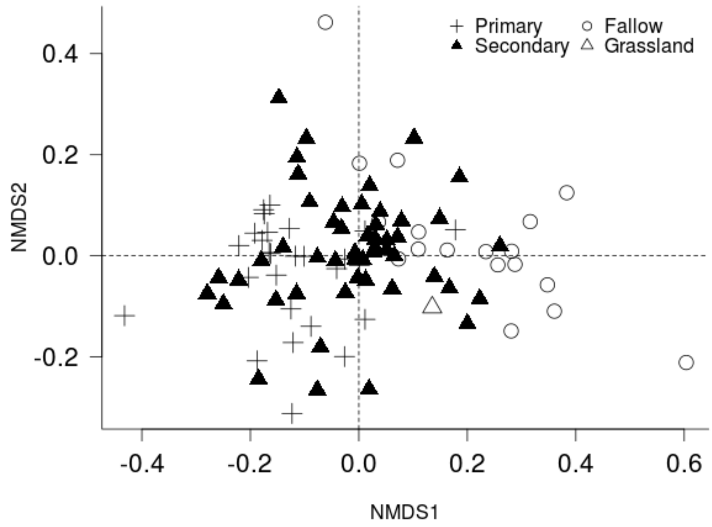

Figure 4.4 — Transects across different habitat types in ordination space. The dotted lines at zero divide the graph visually.

4.3.2. GUILD AND SPECIES-WISE ANALYSES

Our predictor variables were not collinear (variance inflation factor < 1.34; correlation coefficients ranging between 0.12 and 0.44). Distance to the nearest village and protection regime (protected area versus community land) was correlated because our protected areas have no settlements, whereas the community lands do. We retained protection regime as a predictor but note that distance to village might have a bearing on our results. The proportion of transect segments occupied (by all species) was not spatially autocorrelated (Moran's I observed = 0.47).

Our global model of abundance was a function of protection regime, sampling season, habitat disturbance, distance to road, and species identity. The interactions of guild or species identity with protection regime, habitat disturbance, and distance to road were also part of this model. However, our global guild model did not fit the data as well (Pearson's R between observed and model-fitted values = 0.48) as our global species model (0.63).

Of the 70 models in our candidate model set, the global model performed best (ΔAICc values for all models was greater than 7) for both guild (Appendix S10) and the species-level analyses (Appendix S13).

Table 4.1 – The estimates from the best model from our guild level analysis across four paired sites. The intercept values are provided for protection regime, while the slope values are presented for disturbance and distance to road.

Guild	Protection regime ($\beta \pm$ SE)	Disturbance	Road
Canopy	-2.89 ± 0.66	-0.046 ± 0.21	0.15 ± 0.08
Ground	2.25 ± 0.68	-0.15 ± 0.23	-0.36 ± 0.1
Herbivore	1.96 ± 0.66	-0.40± 0.21	-0.20 ± 0.07
Carnivore	2.84 ± 0.72	-0.80 ± 0.28	-0.96 ± 0.24

The four main guilds (canopy, ground, herbivore and carnivore taxa), in which we categorized our 27 species, responded to our covariates in different ways. The responses of all four guilds did not change across years (Appendix S11 and S12). However, each guild responded differently to protection regime, habitat disturbance and distance to road. As expected, the canopy guild was more abundant in protected areas than in community-managed lands. It showed a very weak negative relationship with disturbance, although this guild appeared to favour areas further from roads (Table 4.1, Fig. 4.5). The ground-dwelling guild showed a weak negative relationship with disturbance but was more negatively influenced by distance to road (Table 4.1). The herbivore guild appeared to favour undisturbed areas and showed a negative relationship with distance to road (Table 4.1, Fig.4. 6). The carnivore guild appears to prefer undisturbed forests and strongly prefer roads (Table 4.1, Fig. 4.6).

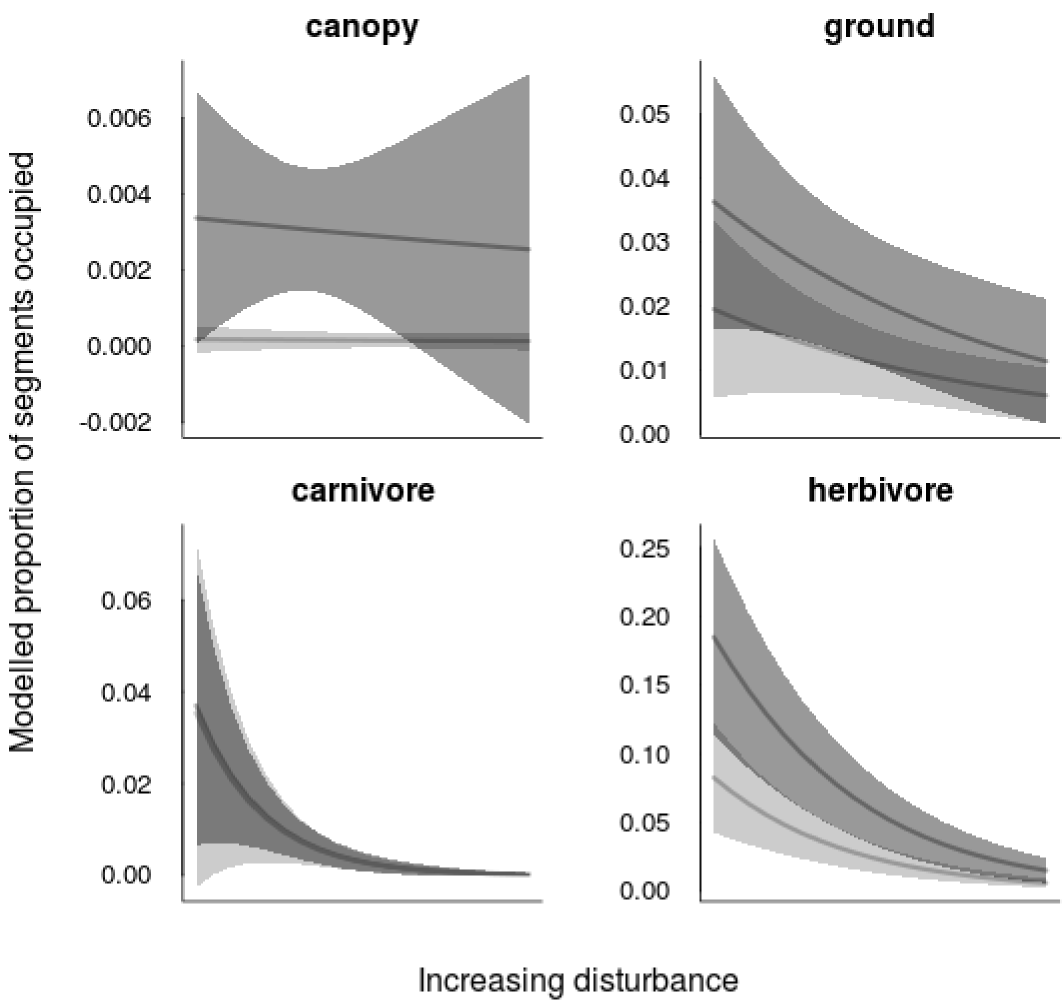

Figure 4.5 — Relationship between the abundance of four mammal guilds (as estimated by the detectability-corrected proportion of transect segments occupied) and increasing disturbance of protected areas (dark grey) and community lands (light grey), across four paired sites. Solid lines represent fitted (predicted) values from the GLMM, and the lighter polygons show the 95% confidence interval associated with the modeled predictions. Except for the canopy guild, which did not show a strong relationship, the other guilds favoured undisturbed areas. These transects were walked during the first sampling occasion.

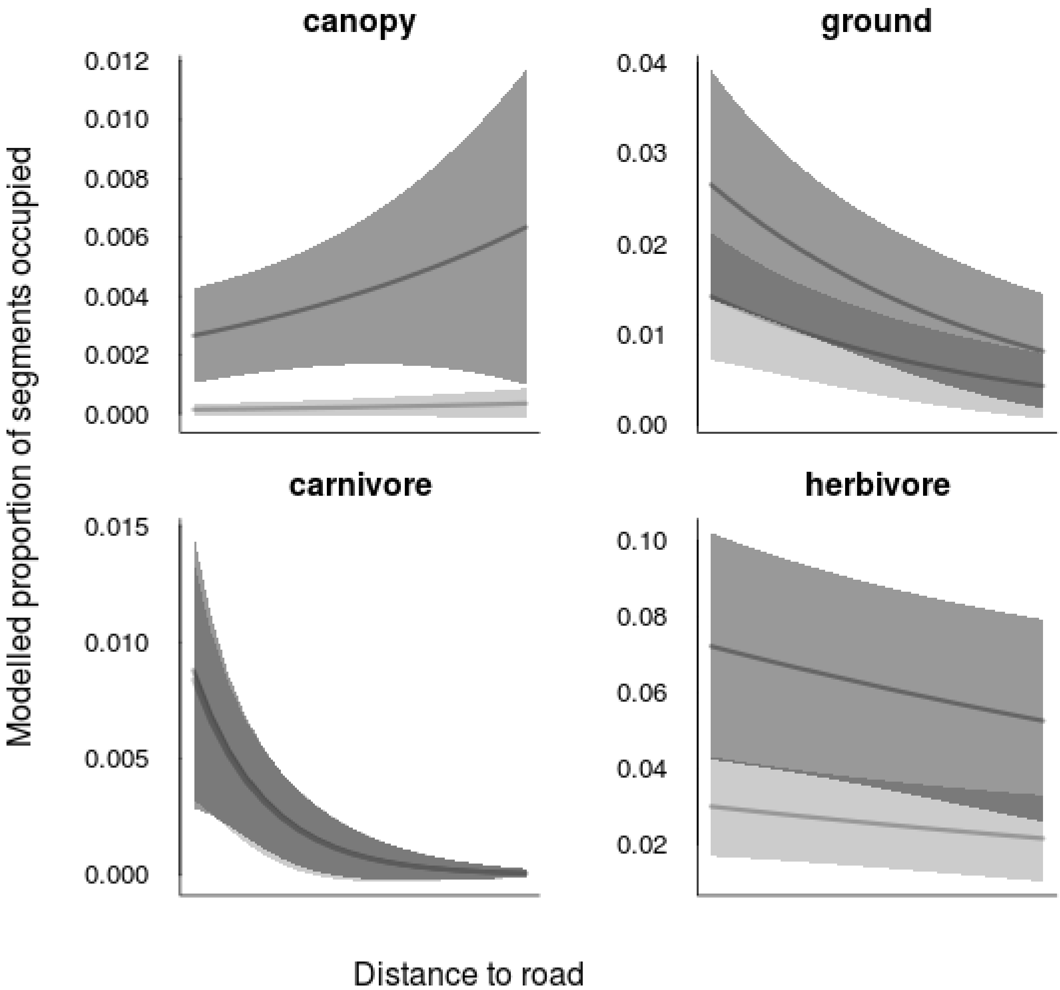

Figure 4.6 — Relationship between the abundance estimates of four mammal guilds and increasing distance from road in protected areas (dark grey) and community-managed lands (light grey), across four paired sites. Solid lines represent fitted (predicted) values from the GLMM, and the lighter polygons are the 95% confidence interval associated with the modeled predictions. The canopy guild appeared to prefer areas away from roads, whereas other guilds appeared more abundant closer to roads. These transects were walked during the first sampling occasion.

We analysed a subset of 14 species (for which had adequate data) and found that their responses varied with protection regime, distance to road, habitat disturbance and sampling session and the interactions with these factors. For different species in sampling season 1 and 2 the responses were qualitatively similar (Appendix 14 and 15). In general, except for barking deer and wild dogs, all species were found more frequently within the protected area. As expected, the magnitude of difference was much greater for larger-bodied species such as the Asian elephant, sambar and gaur. Sambar and gaur appeared to prefer more degraded habitats within the protected area (Table 4.2, Fig.4. 7).

Table 4.2 – The estimates are from the best model from our species level analysis across four paired sites. The intercept values are provided for protection regime, while the slope values are presented for disturbance and distance to road.

Species	Protection regime	Disturbance	Distance to road
Asian elephant	- 1.35 ± 0.21	0.32 ± 0.11	-0.33 ± 0.09
Gaur	-4.39 ± 0.70	0.75 ± 0.36	1.73 ± 0.32
Sambar	-3.39 ± 0.36	0.91 ± 0.14	0.44 ± 0.07
Himalayan black bear	-0.23 ± 0.34	0.27 ± 0.23	0.59 ± 0.25
Himalayan serow	-0.36 ± 0.31	0.11 ± 0.18	-0.04 ± 0.12
Wild pig	-0.84 ± 0.28	0.33 ± 0.14	0.22 ± 0.08
Barking deer	0.20 ± 0.14	-0.78 ± 0.08	-0.16 ± 0.06
Wild dog	0.67 ± 1.35	0.72 ± 1.51	0.69 ± 1.29
Small carnivores	-0.64 ± 0.42	0.84 ± 0.21	-0.37 ± 0.21
Porcupines	-0.34 ± 0.29	0.37 ± 0.16	-0.23 ± 0.14
Pheasants	-1.25 ± 0.32	0.54 ± 0.16	-0.003 ± 0.10
Orange-bellied squirrel	-2.11 ± 1.13	0.11 ± 0.44	0.32 ± 0.15
Hoary-bellied squirrel	-2.90 ± 1.17	0.72 ± 0.41	0.06 ± 0.21

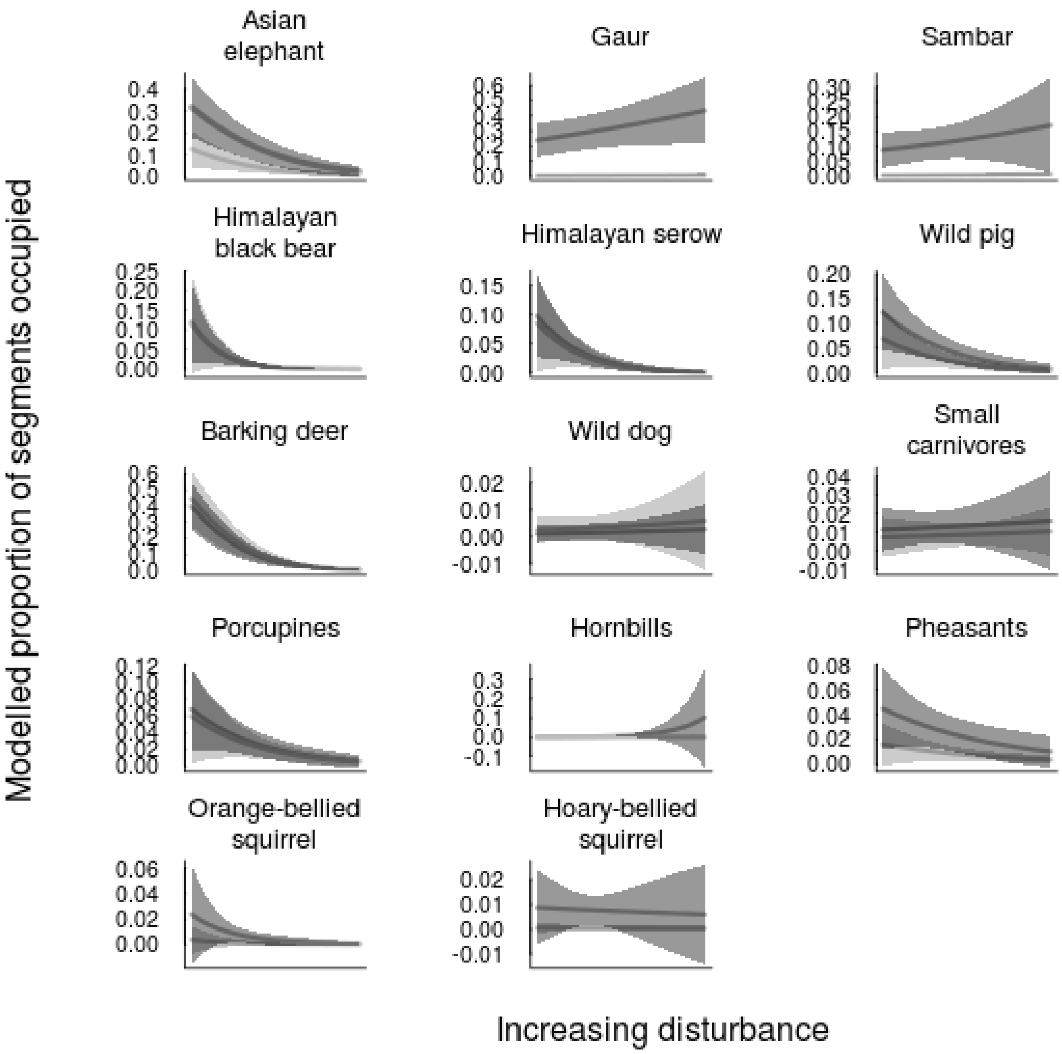

Figure 4.7 - Relationship between species abundance estimates and disturbance in protected areas (dark grey) and community-managed lands (light grey), across four paired sites. Solid lines represent fitted (predicted) values from the GLMM, and the lighter polygons are the 95% confidence interval associated with the modeled predictions. Gaur and sambar appeared to prefer disturbed areas in the protected areas, whereas all other species appeared to prefer undisturbed areas. From left to right and top to bottom, species are arranged in order of decreasing body mass. These transects were walked during the first sampling occasion.

Most species did not show appreciable differences of abundance with increasing distance from the road (for elephant, bear, serow, barking deer, small carnivores, porcupines, pheasants, hoary-bellied squirrels). However gaur, sambar and hornbills appeared to prefer to be a distance away from roads (Table 4.2, Fig. 4.8).

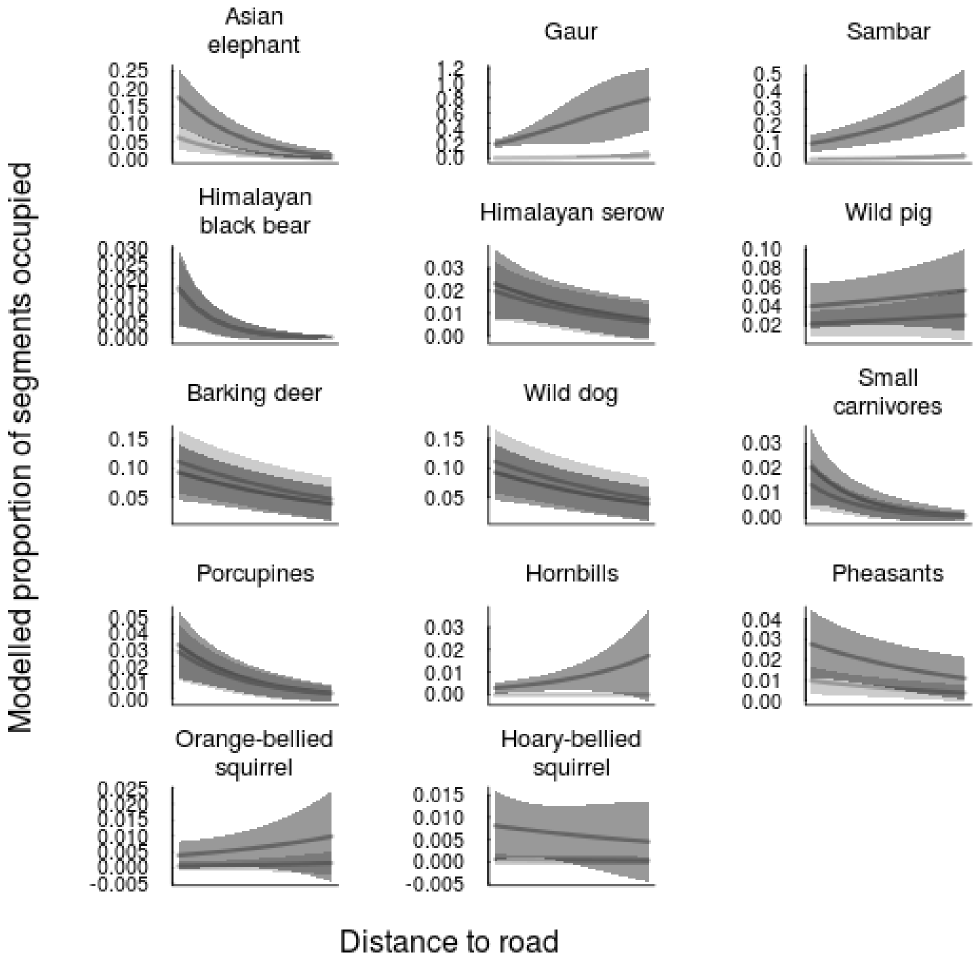

Figure 4.8 — Relationship between species abundance estimates and distance to roads in protected areas (dark grey) and community-managed lands (light grey), across four paired sites. Solid lines represent fitted (predicted) values from the GLMM, and the lighter polygons, the 95% confidence interval associated with the modeled predictions. Gaur, sambar and hornbills appeared to prefer areas away from roads. From left to right and top to bottom, species are arranged in order of decreasing body mass. These transects were walked during the first sampling occasion.

4.3.3. SPECIES RICHNESS

We recorded a total of 27 species (including small carnivores and pheasants). In general, protected areas tended to have higher species richness (estimated species richness bootstrap: 16.35 to 25 ± SE 0 to 0.44), although community-managed lands still had many species (10.16 to 16.35 ± 0.48 to 0.40) (Fig. 4.9). Although the species richness was variable, protected areas seemed to have higher eveness, except for Sessa Orchid Sanctuary (Fig. 4.10).

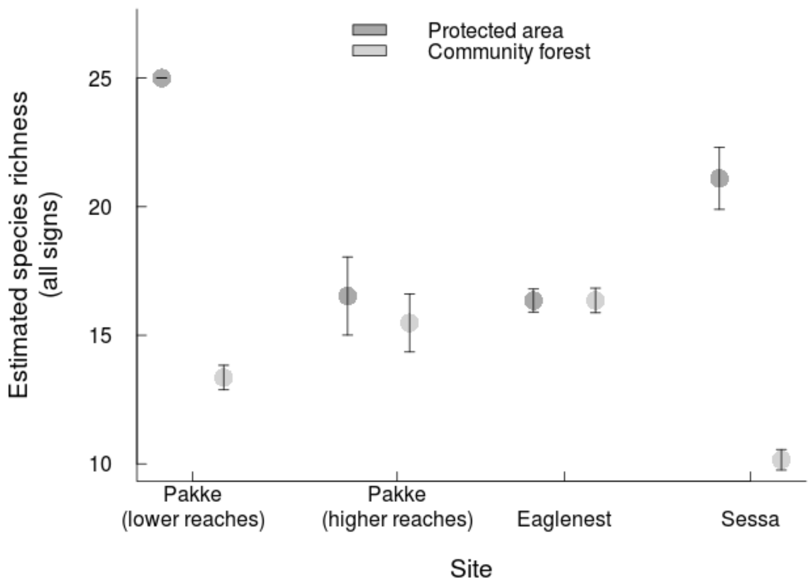

Figure 4.9 — Bootstrapped species richness estimates with standard errors across four independent site comparisons. Pakke Tiger Reserve (lower reaches) had the highest species richness, while the community-managed land adjacent to Sessa had the lowest.

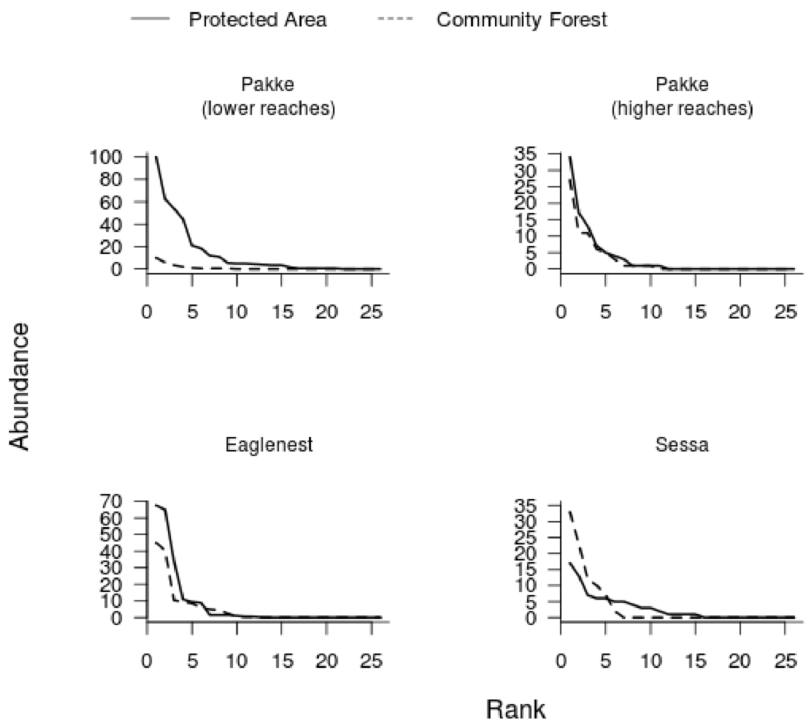

Figure 4.10 — Except for the community-managed land around Sessa Orchid Sanctuary, protected areas appeared to have higher species abundance and evenness of communities (a combination of a higher abundance value with flatter species-abundance relationship).

4.3.3. INTERVIEWS

Interviewees overwhelmingly felt that wildlife was in a general state of decline (89.5%), with less than 3% stating that wildlife has not declined. Most felt that protected areas harbour more wildlife (82.5%) when compared with community-managed lands (1.40%); only a few felt it was equal (4.89%) and a small percentage said they did not know (9.08%). The major declines were thought to be caused by hunting (69.93%), growing human populations (35.66%), logging (30.76%), urbanisation (13.28%) and militancy (9.79%). Interviewees said that hunting was predominantly for meat, followed by for sport (Table 4.3). However, there were multiple reasons stated to hunt the same species (Table 4.3). They stated an overwhelming preference for wild meat (79.02%) over domestic meat

(18.17%). Most people used guns to hunt (86.7%), and many used snares and steel traps (39.16%). Only a small percentage used dogs (9.79%) and traditional weapons such bows and arrows (9.09%). When the mean scores of species (i.e. the perceived abundance over the last 30 years) were plotted against body size, interviewees reported a decline of large-bodied species in community-managed lands (Fig. 4.11). When we compared our interview data with our transects, we did not find a significant correlation between species status (as reported by our interviewees) and our transect estimates (intercept values from our GLMMs) (Pearson's R = 0.38, 95% CI: -0.22-0.77).

Table 4.3 – Motivations for hunting and the species that are hunted, based on 143 key-informant interviews in Arunachal Pradesh state in north-east India.

Reasons for hunting	Percent	Species
Meat	61.5	All species except taboo species (in some tribes: elephants, cats and hornbills)
Recreation	42.6	All species except taboo species (in some tribes: elephants, cats and hornbills)
Retaliation/crop raiding	24.4	Primates, wild pig, porcupines, wild dogs
Commercial (to outside markets)	17.4	Himalayan black bear, Himalayan musk deer, otter, tiger, pangolins
Tradition/culture	10.4	Himalayan serow, Himalayan black bear, Malayan porcupine, hornbills
Festivals	9.7	Barking deer, Himalayan serow, wild pig, Himalayan goral, sambar
Other animal products	2.0	Barking deer skin, Himalayan serow horn, bear skin, hornbill casques

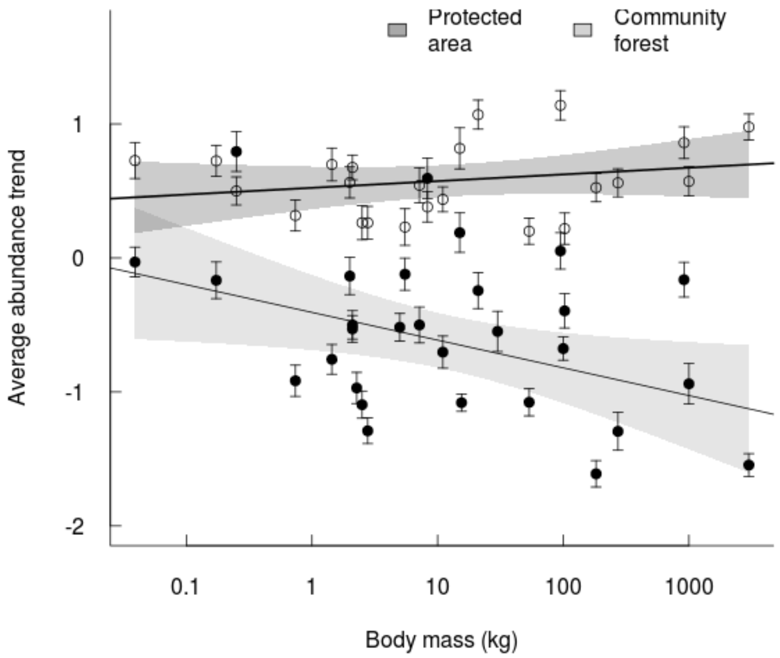

Figure 4.11 — Average scores for trends in species abundances over time based on key informant interviews. The open dots are means and standard errors for each species in Pakke Tiger Reserve, whereas the black dots are means and standard errors for each species in the adjacent community-managed land. The solid line shows the fitted ordinary least-squared prediction for species as a function of increasing body mass, and the different shades of grey polygons are the 95% confidence interval for each prediction. Community-managed lands showed a negative trend with increasing animal body size.

4.4. DISCUSSION

In our study area, which spans the largest contiguous forest tract in the Eastern Himalayas, many animal guilds (based on diet and habitat use) showed a decline in abundance with increasing disturbance (Fig. 4.5). However, different guilds responded differently to the presence of roads and paths (Fig. 4.6). Furthermore, mammal species varied greatly in their responses to management regime (protected areas vs. community-managed lands; Fig. 4.9). In general, mammal species were more abundant in protected areas (although these differences were not significantly different). Species also show varying responses to roads and habitat disturbance (Figs. 4.6, 4.7); large species such as sambar and gaur tend to occur in more disturbed habitats away from roads and in protected areas. In general, species richness and abundance were higher in protected areas than in community-managed lands, although pair-wise comparisons (between each protected area and community-managed land) indicate that there was significant variation in the magnitude of difference across sites.

Key informants report a decline in larger-bodied species in community-managed land. Interviewees from protected-area lands do not report a decline in larger-bodied species. We acknowledge the limitations of this comparison, as the respondents in each area have differing profiles, as noted above. Although the interviewees from the protected area did not report a decline in larger-bodied species, their observations are supported by our field data. This clearly shows that protected areas are important for large herbivores such as sambar and gaur, and for top predators such as the tiger. For all of these species, our interviewees reported drastic declines in their abundance in community-managed lands. Large bird species, such as hornbills, also show drastic declines in community-managed lands.

Despite similarities in perceived trends and empirical data for certain species, we did not find a significant correlation between perceived abundance declines for species in protected versus community-managed lands. This could be because interview-reported declines were assessed over a 30-year period, and the present abundance status of many species in protected areas might reflect the signatures of past disturbances and extirpations. For example, Pakke Tiger Reserve was formerly a game sanctuary (Velho et al., 2012), and Eaglenest Wildlife Sanctuary has a history of logging and hunting (Srinivasan, 2013). They may have not been able to retain their entire original complement of species.

Given that there are multiple reserves within this larger landscape, future studies should focus on longer-term estimation of key faunal species to identify if and where there are source populations. If so, an understanding of dispersal constraints and functional connectivity (Vasudev et al., 2015) within the landscape might allow one to better predict the potential of protected areas and community-managed lands to regain some of their extirpated species.

Based on our informants, most of the faunal declines were believed to be caused by hunting, although the needs of a growing population, urbanisation and logging were also thought to be important. We found that for several targeted species, multiple motivations (for instance sustenance and recreation) drive hunting. Thus, attempts to attribute a single overarching motivation to hunt in the region may have limited value (Selvan et al., 2013; but see Sethi, 2013). For example, barking deer may be hunted for sport, and their meat may be consumed at home, shared in the village, or distributed at a festival depending on the time of the year. Barking deer products (usually made of skin or antlers) might also be used, gifted or sold, but are not generally destined for markets. For commercially valuable species, often hunted for body parts that are subsequently traded nationally and internationally—such as tigers and otters the motivation to hunt is more focused. For example, there are multiple incentives, including trade, to hunt species such as the Himalayan black bear. This species may be hunted for recreation, consumed as meat, used in traditional medicine or in skin products, whereas its gall bladder usually makes its way to illegal markets. Studies from Southeast Asia show that while most wildlife is traded locally, and the majority nationally (within country or state), there is still a substantial volume traded internationally (Nijman, 2010). Given that hunting is seen as an important threat to this landscape, the commercialisation of wild meat and species on many levels needs to be assessed.

We find that anti-poaching efforts in the lower altitudes of Pakke Tiger Reserve (which also have higher anthropogenic pressures; Velho et al., 2014; Appendix S16) are likely to have benefits for hunted mammals and birds. Moreover, the species richness and abundance are much lower in surrounding community-managed land than in the reserve itself. An analysis of the placement of protected areas showed that a majority of protected-area networks are biased towards inaccessible sites (in terms of slope and elevation); greater distances to cities and towns; and lower agricultural suitability (Joppa and Pfaff, 2009). However, the configuration and placement (away from villages) of other inaccessible protected areas may help to retain many species, even in the absence of active protection. This is similar to management trends across other protected areas (of which 40% showed major deficiencies), but were still able to contribute to biodiversity conservation (Levrington et al., 2010).

Furthermore, the matrices of community-managed lands around protected areas hold promise and potential for wildlife conservation. For example, the higher altitude community-managed lands around Pakke and Eaglenest have high species richness (Fig. 4.9), although animal abundances might be lower than in their respective nearby reserves. Although species richness was low in the community-managed land around Sessa Orchid Sanctuary, it still had higher species abundance compared with the adjacent protected area, indicating that there might be some pockets outside reserves where species are still found in high abundances. Notably, Sessa Sanctuary has many nearby roads that might increase anthropogenic pressures and depress its wildlife populations.

Contrary to our expectations, most species did not show strong responses to roads or trail networks, except for the canopy guilds (especially hornbills), sambar and gaur. The rapidly expanding global road network plays a key role in opening up otherwise inaccessible forest, which exacerbates wildlife declines because of the susceptibility of tropical species to hunting and habitat disruption (Dulac, 2013; Laurance et al., 2014). The effects of roads were also apparent at smaller scales, where annual deforestation rates increased from 1.1 to 3% over two study periods (Linkie et al., 2004). It is very likely that single-lane, often-unpaved roads, wherein sections are washed out and inaccessible during the monsoon season, are not typical of roads in the rest of the country or the world. More than 50% of the total road length (circa 1997 because more recent data are not available) in Arunachal Pradesh is non-paved (Singh, 2005).

Because of the strategic geopolitical importance of Arunachal Pradesh because of an increasingly strident China, the Indian government has recently accelerated plans to construct more roads in the state. The Trans-Arunachal Highway will expand the existing road network by over 2,400 km, with the first phase of completion being targeted for mid-2016 (Dey, 2013). An analysis of road building and agricultural production shows that placing more roads in biodiversity-rich yet agriculturally low-yielding areas, such as Arunachal Pradesh, could have negative impacts for biodiversity (Laurance et al., 2014). These impacts are likely to be exacerbated by the often-weak enforcement of environmental laws in such remote areas. The effects of roads may already be evident: patterns of lower abundances of large species already exist in protected areas near supposedly low-impact roads. We caution that proposed road expansion should be tempered with rigorous ecological and social research to model and predict the future impacts of new roads. Equally important is proactive land-use zoning (DeFries et al., 2010) to identify areas where roads should and should not go, based on a range of environmental and socioeconomic criteria.

To our knowledge, our study is the first to examine the differences in biodiversity values of protected areas and community-managed lands at multiple paired sites in the tropics. The possibility of finding community-managed lands that harbour significant biodiversity values should be explored further; as such lands could complement existing protected areas and maybe better than open-access areas (Shahabuddin and Rao, 2010). The State Government, through certain draft legislation (Arunachal Forest Act, 2014), seeks to regulate human extractive use of these community forests (unclassified state forests), and more importantly, to formulate rules for land-use management moving to a more centralised governance structure.

While it might be beneficial for the state and residents to work together, especially on hunting-related threats (Appendix S17), the existence of rule-based governance of resident tribes or existing land-use in community forests provides an opportunity and framework for conservation outside protected areas. If the reclassification of land were to be done unilaterally by the government and parceled into more formal reserves, this would undermine the importance of community-managed lands in the larger landscape. In Arunachal Pradesh, 62% of the forests are such community-managed lands (Menon et al., 2001). At the same time, active management in protected areas is likely to be beneficial, especially in areas that have high anthropogenic pressures. However, even in the absence of active management, protected areas still retain important biodiversity values on a larger scale.

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SUMMARY OF CHAPTER 5

My initial chapter identified the very broad challenges related to hunting in India, but this was largely explored from an ecological perspective. In this final chapter, I and a colleague use a combination of interview data to describe at length the different dimensions of hunting in north-east India. For this work I teamed up with Ambika Aiyadurai, an anthropology doctoral student at National University of Singapore, to understand the depth and breadth of hunting in north-east India. This chapter is largely descriptive, based on many years of fieldwork and notes, and we aim to create an integrated understanding of the historical, social, cultural, economic and biological factors that govern hunting in north-east India. This chapter also presents, from official gazettes, diaries and records, several historical accounts by early British naturalists and explorers who visited the region. Meeting and spending time with hunters from the Eastern Himalayas made me ponder whether there are generalities and similarities to other hunting cultures across the world. This field-based endeavour was meant to collect many voices, embed them in critical thought and create a flowing narrative.

There are many aspects of hunting in north-east India and many of these features are rapidly changing with time. Although there is great heterogeneity among cultural practices related to hunting, the economic motivations to target certain species are becoming increasingly similar. On the one hand, hunting may be influenced by livelihood issues. On the other, trade and commercialisation of species is a cause of increasing concern.

In north-east India, the strong cultural underpinnings in which hunting is embedded are very different from those seen in the rest of India. While religious identities are changing, these changing affiliations do not necessarily translate into a greater tolerance for wildlife or a change in hunting practices. The realm in which hunting operates in a community has therefore grown to include many other factors. What remains striking is the complex interplay of factors—including human livelihoods, markets, cultural beliefs and conservation effectiveness—relevant to the particular socio-economic setting we studied, as seen through the experiences of Pahi Meyor and many other hunters that feature in this final chapter.

CHAPTER 5

THE LAST HUNTERS OF ARUNACHAL PRADESH: THE PAST AND PRESENT OF WILDLIFE HUNTING IN NORTH-EAST INDIA

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5.1. INTRODUCTION

Pahi Meyor sold a leopard skin to a major in the armed forces. The asking price was not money but 15 cases of alcohol. Pahi got 180 bottles for just one fresh, shiny leopard skin[1].

Pahi belongs to the enterprising Meyor or Zakhring tribe, of about 300 people scattered in 15 villages close to the Indo-China border in Arunachal Pradesh, India (Aiyadurai, 2011b). In the frontier area where this Buddhist tribe lives, the vast illegal trade of leopard and tiger skins from India to Tibet is common knowledge. In fact, Pahi even possesses a compact disc and some brochures published by the Wildlife Protection Society of India, in which the Dalai Lama appeals to Buddhists to stop wildlife hunting. Pahi, upon his return from Delhi and still under the influence of Dalai Lama's plea, swore he would give up hunting and dispose of the skins and skulls he already possessed. But a year later, he was narrating the story of the army officer and the leopard skin.

For Pahi and other hunters in Arunachal Pradesh, the story is much more complex than the simple act of killing animals and trading for cash or barter. There are strong cultural underpinnings that may have localised effects and at larger scales they shift to the demand and supply side of trade. On spending time in the village, we realised the significance of wild meat for special events is especially noteworthy. Wild meat is offered as a bride price during weddings and regarded as a status symbol by the Miju Mishmi tribe (Aiyadurai, 2009). Orange-bellied squirrels are gifted by Adi men to their bride's family during marriage ceremonies in Arunachal Pradesh (Das and Shukla, 2007). Wildlife products are exchanged to gain good will and to establish or affirm relationships of patronage. The gifting of wildlife products is also common way to gain good will from senior government officers and elite members of society. Records show that in 1945, a British officer

1 Fieldwork conducted in January 2006 and August 2007 in Kibithoo circle in Anjaw district (Arunachal Pradesh). For more on the Meyor, see Aiyadurai (2012). The name of the hunter has been changed.

was gifted an otter skin by Mishmi residents[2]. These days, visiting government officers are presented with animal skins that are used as decorative items at their residences[3].

Residents have found new ways to create capital from wildlife products and this has been facilitated by the demand created by non-resident settlers and external market forces. In the case of the non-Arunachalis, it is market-based products and personal or professional favours that create this demand. For example, a non-Mishmi doctor bartered a bottle of Horlicks, a health drink that was bought at a subsidised rate from the armed forces depot, in exchange for various animal products, including wild meat. He exchanged another bottle of Horlicks for an otter skin, for which the hunter refused to take money[4]. Therefore, this cannot be seen as a simple gift-exchange practice alone; it is embedded in a cultural and political process that is being transformed by socio-economic changes.

Studies on hunting in India are on the rise (Velho et al., 2012), which is a reflection of the global push to acknowledge the seriousness of this issue. After all, illegal wildlife trade is reported to be amongst the most lucrative businesses in the world, coming in on the list only after illegal drugs and weapons trafficking. The increasing demand for bear bile, used in traditional Chinese medicine, drove hunters in a small village of about 100 houses in Arunachal Pradesh to kill 35

[2] Tour diary of B.H. Routledge, Sadiya Frontier, Dec 1945-Dec 1946. Mss Eur D1191/2. The British Library, London.

[3] Personal observations while conducting fieldwork in Anjaw district. It is not uncommon to see the drawing rooms of government officers with skins of blackbear (Walong, 2008), red panda (Hayuliong 2006) and linsang (Hayuliang, 2006), along with skulls of barking deer (Hayuliang 2006-7). For more examples of gifts see Aiyadurai (2009) and Aiyadurai (2011).

[4] Fieldwork conducted in Anjaw district during June-July 2009. A villager who worked for the electricity department (with the Arunachal Pradesh government) trapped two otters; he gave one otter skin to the doctor posted in the village that was 12 km from Hayuliong. The doctor later displayed the otter skin as a wall hanging in the drawing room. On visiting the same doctor in 2012 in Tezu (Lohit district) where the doctor was posted, his drawing hall was decorated with the same otter skin.

Himalayan black bears *Ursus thibetanus* in 2011 alone. Skilled hunters can kill up to 10 bears a year[5] (Velho, 2012); a big gall bladder (the source of bile) fetches up to Rs. 25,000 ($ 417 USD; 1 USD = 60 rupees) while smaller ones fetch between Rs. 10,000 (167 USD) and Rs. 12,000 (200 USD). Musk deer pods are sold for Rs. 10,000 per *tola* (a south Asian unit of mass which is standardised to 11.66 grams). The pods are not used locally but are sold to non-resident middlemen who illegally export them to international markets, eventually used to make perfume. While these two species have been hunted for several decades, the hunt for otter skins is reported to be a recent activity. With increasing demand for soft, waterproof skins in the international market, each skin often fetches a hunter anything between Rs. 8,000-10,000 ($ 134-167 USD). Traders from Burma and the neighbouring state of Assam come to Arunachal Pradesh to place orders for otters, and also provide serrated metal leg-hold traps to get them on the menu.

5.2. THE BUSHMEAT CRISIS

The rampant increase of wildlife hunting globally, even apart from that for trade, has prompted an international academic group to label the phenomenon a 'bushmeat crisis'[6].

Residents who live on the periphery of the forests and traditionally depend on locally available wildlife for food or trade may not see it in the same light. Hunting is seen as a mundane everyday activity in most parts of Arunachal Pradesh. Often, residents find it amusing that someone has come to study 'hunting', which they perceive as a non-issue. When in the field, rumours of our presence and purpose are always aplenty. We are reported to be from the medical department to provide

[5] Fieldwork from July to September 2012 in Rupa and Shergaon in West Kameng district (Arunachal Pradesh). For more on the Shertukpens, see Velho & Laurance (2013).

[6] Bushmeat crisis (http://www.bushmeat.org/). The Bushmeat Conservation task force is a consortium of conservation organizations and scientists that tries to understand how wildlife is threatened by commercial hunting for sale as meat.

vaccinations, clothes salespersons, government officials, spies, or even telephone salesmen when the word 'research' is mistaken for 'recharge' (for cellular phones). Many are convinced that we are there on false pretences, using hunting as a pretext to source out other information. Our binoculars are sometimes borrowed to look out at a distance – usually evoking comments on either how beautiful a species is or how good it would be to take binoculars on a hunt. It is sometimes enough to live in the village and show residents our animal field guides to convince them that we are indeed there to study wildlife hunting.

5.3. HUNTER STORIES

These conversations about hunting have remained undocumented in north-east India. One possible reason could be the limited interactions with the rest of India. Entry into the state is restricted by the Inner Line Permit (an official travel document issued by the government to allow inward travel of Indian citizens into the state for a limited period; was enacted by the British in 1873). Additionally, due to the geographical remoteness of Arunachal Pradesh, it has been relatively cut-off from mainstream economic and infrastructural development. As such, people remain dependent on traditional livelihoods and natural resources for their living. Key areas were connected by roads only after the vividly remembered occupation of this area by China in 1962. Now, defence personnel from all over the country are posted in the region for short periods on a rotational basis. Although there is limited interaction between residents and defence personnel, there is a clear asymmetry in the relationship. Residents are often employed as porters and guides as they are more familiar with the tough terrain and landscape.

Once army personnel gain access to these areas, for many army personnel there are no checks to prohibit the hunting of commercially important species such as musk deer. These personnel then form partnerships with non-Arunachalis from the trading community. These traders now have many shops across Arunachal, also a result of increase in road networks. In many of these shops they sell animal skulls, parts (such as musk deer pods) and skins and occasionally barter bottles of alcohol with defence personnel. This is becoming increasingly more common as the Indian Army increases its troops in Arunachal Pradesh.

Remoteness is not the only reason why people in this state discuss hunting so freely; there is a strong cultural element involved. In Asia, and especially north-east India, hunting is not a matter of economics and market forces alone. There are other social underpinnings, where hunting is need-based, with intimately interrelated cultural and socio-political demands. The traditional right to hunt is claimed by many different tribes across north-east India (Aiyadurai et al., 2010). The Apatani tribe regards bushmeat with multiple cultural connotations. General festivities include voluminous servings of barking deer *Muntiacus muntjak* and wild pig *Sus scrofa*.

In the neighbouring state of Nagaland, ritualistic offerings for weddings include three types of squirrels, while the Assamese macaque *Macaca assamensis* is sacrificed during the annual spring festival of Morum to propitiate their deity (Hilaludin and Ghose, 2005). According to the villagers, the amount of wild meat on offer has been significantly reduced over time (Aiyadurai, 2009). This is attributed to the decline of wildlife around villages, forcing tribesmen to travel farther, an undertaking that only skilled hunters can manage (Aiyadurai, 2007a). Markets have introduced alternatives to make up for any shortage in wild meat during weddings and village ceremonies. While some wild meat is mandatory for ceremonial purposes, the shortage is supplemented with dried sea fish such as Bombay duck *Harpadon nehereus* (called *bamla-maas* in vernacular, a name derived from the Bengali or Assamese 'bamlaoh,' brought from bigger cities and towns)[7]. While Bombay duck has now become common in rituals, it remains a supplement and not a substitute for wild meat.

[7] Fieldwork from 2007-2009 where participant observations were done during village ceremonies, in Chaglagam and Goillong circles of Anjaw district.

As our work continued, we found that different tribes across north-east India spoke of hunting in a common and open language. Spending time talking to villagers enabled us to understand the different aspects of hunting (Aiyadurai, 2011a)[8]. Conversation starters were plentiful thanks to the wild animal skulls and skins displayed in people's houses, sometimes neatly mounted on bamboo frames. This is a fairly common practice even today. For example, in Miju Mishmi areas in Eastern Arunachal Pradesh, houses and porches are decorated with the mounted skulls of prey like barking deer, wild pig, takin or gnu goat *Budorcas taxicolor* and bear (Aiyadurai, 2007a). Also on display are fans from pheasant or eagle-tail feathers among the Mishmi (Aiyadurai, 2007b; Aiyadurai, 2012) and Nyishi, respectively, head gear from hornbill casques, machete sheaths and shoulder belts made from capped langur and Asiatic black-bear skins which are commonly used by the Nyishi people (Aiyadurai and Varma, 2003; Aiyadurai, 2007a).

Wild meat also has significance both in sickness and in health across various tribes of Arunachal Pradesh. In parts of north-east India, meat from the Assamese macaque is believed to aid infant development, the gall bladder of the Himalayan black bear is touted to cure jaundice; the liver of hoolock gibbons *Hylobates hoolock* is believed to kill malarial parasites; while the harmless-looking hoopoe *Upupa epops* is believed to alleviate impotency among the Angamis. Sometimes it is the same force or attribute of a species that gives power to humans. For example, amongst the Aka tribes of East Kameng district, the bone marrow of mountain goats, the agile goral (*Naemorhaedus* spp.), is believed to cure fractures. As well, the bones of otters are rolled on the windpipe of a choking person to alleviate their distress[9].

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[8] This review paper provides a multidisciplinary understanding of wildlife hunting in north-east India (ecological, political and anthropological meaning).

[9] Forty semi-structured interviews conducted with the Koro and Hrusso Aka tribe in Palizi, Ramdha, Thrizino, Banah and Sopung (March and December, 2012).

5.4. DIFFERENT REALMS OF SCIENCE

Four years of pioneering observations made by the anthropologist Alex Aisher reveals a fascinating account of peoples' belief in forest spirits. He discusses how forest spirits influence the way that people interact with the ecosystem in the Nyishi community, the largest tribe of Arunachal Pradesh (Aisher, 2007). Similarly, the Miju Mishmi tribe believe that *shuttho* (mountain spirit) takes care of the mountains and the animals that reside there (Kri, 2008; Aiyadurai, 2009). These beliefs are similar to those in other parts of south-east Asia; the Kerinci people of Sumatra believe that wild animals have a spiritual 'herdsman' (Bakels, 2004) and for the Agta groups in the Philippines, hunting is described as the 'heart of their culture' (Estioko-Griffin and Griffin, 1981). To glean cultural insights on trends in animal populations and forest cover, more studies of peoples' perceptions of the forests in Arunachal Pradesh and other parts of north-east India, are needed.

The boundary between the human and the natural world is often blurred: humans are considered to be part of natural systems while animals, trees and rivers are believed to be 'people' with emotions and feelings. When visiting Mishmi households, it is common to see tar-blackened skulls of wild animals varnished by the blood of sacrificed domestic animals. The sacrifice of domestic livestock is necessary to appease spirits to protect the village from disease and famine. In exchange for domestic animals that are offered to spirits, the spiritual world provides wild animals to hunters. Central to this belief system is that spirits (both living and non-living) have 'souls'. The 'owner of the forest' is believed to embody the 'spiritual world'.

This relationship has been best summarized by British anthropologist Tim Ingold, who states that that hunting is not just a survival activity but also a 'world renewing process' that maintains the cyclical process of life. This corroborates studies from other parts of the world. For example, Ingold has found that among the reindeer herders of North America and Eurasia, it is believed that the dispositions of wild animals are controlled by spirits that release animals to hunters (Ingold, 1980). This represents a rite of renewal. The presence of animal guardians is reported among the Mishmi (Aiyadurai, 2009) and the Tukano Indians of north-west Amazon, and Yukaghirs of Siberia, hold similar beliefs. In addition to these guardians, shamans play a significant role, acting as powerful intermediaries between the human world and the spirit world.

In the many societies in Arunachal, shamans, who have dual role of village priests and traditional healers, are known to have special powers to communicate with the spirits. Shaman priests travel between two worlds negotiating with spiritual masters to recover the vitality which is perceived to be lost due to illness. In December 2012, a priest invited us to his house, in West Kameng, to see a box that enables him to acquire the power of all wild animals. To an inquisitive wildlife biologist, this box, with an assortment of talons, claws, beaks, fangs and skins of many animals, is like a treasure trove. Like others, this priest had first claim on all kills made by hunters; parts of top-predators such as tigers, leopards or clouded leopards are essential to maintain the ritualistic power of a priest[9]. Important priests have shoulder belts adorned with the maxillae and mandibles of large carnivores such as tigers, whereas less-powerful priests wear parts of smaller carnivores such as marbled cats. The presence of spirits in the house and farm is part of day-to-day talk about friendly and harmful spirits.

This cosmological exchange between forces of the human and spiritual world essentially drives the cultural tradition of hunting. It is starkly different in other parts of India, where cultural and religious prohibitions prevent the killing of protected plants and animals (Rangarajan, 2001). Across India, many wild animals are privileged with religious protection, including Asian elephants *Elephas maximus*, monkeys, Indian peafowls *Pavo cristatus* and blue bulls *Boselaphus tragocamelus*. However, in Arunachal Pradesh, some taboos and restrictions on animal hunting resonate louder than others with respect to wildlife conservation. For example, the yellow-throated marten *Martes flavigula* is not hunted and eaten by the Miju Mishmi. It is buried in the soil immediately if it gets caught in a hunting trap set for other animals. Similarly, the Miju and Idu Mishmi people (Lohit and Lower Dibang Valley) do not hunt the hoolock gibbon *Hoolock* spp., the only ape found in India (Aiyadurai, 2011a). Even sighting a gibbon is considered extremely ill-fated, especially for pregnant women, as it is believed to result in the death of the foetus (Aiyadurai, 2011a).

Among certain Buddhist tribes in western Arunachal Pradesh, killing animals is not permitted during the breeding season or the time of Chokar Puja, which falls between May and June of every year. This same region and religion, also includes the Monpa and the Shertukpen tribes of Tawang and West Kameng districts of Arunachal Pradesh. The Monpa tribe that lives above the tree line of the Eastern Himalayas follows this ban strictly. A few hundred metres below, the air becomes warmer for more than one reason. The tension between Shertukpen hunters and formalised religious rules is quite apparent. Their one-month hunting ban is under pressure from the hunting lobby to be reduced to 15 days (Velho and Laurance, 2013). Religious prohibitions on hunting that once extended to the Asian elephant, serow *Capricornis thar*, gaur *Bos gaurus*, and tiger *Panthera tigris* are slowly eroding. While the elephant is still revered by the majority, taboos related to gaur and tiger hunting are undergoing rapid change. For example, hunters who kill gaur ritualistically cut the tail off and attribute the kill to a predator such as an Asiatic wild dog *Cuon alpinus* or a tiger. Also, the blame is ritualistically taken by a member of a clan (that they perceive to be lower) of the same tribe. The resulting meat is not sold but distributed in the village to share the burden of sin. The existence of these taboos and practices makes a pitch for wildlife conservation easier among the Shertukpens. In sharp contrast, a few hundred meters below where a different tribe shares the same district, not even elephants are spared.

These social and moral scopes have, over the past few decades, become subject to further change with the arrival of Christianity, and increasing influences of Hinduism. The interactions between these new religious players, new forms of religions and residents have implications for the traditional beliefs systems. For example, religious sects of Hinduism such as the Art of Living and Brahmakumaris promote vegetarianism and teetotalism. They attempt to change the attitudes and behaviours of residents, which may lead to changes in their lifestyles. Though some may see this as a positive approach, the social impact can be serious. The preaching by these newly introduced religions (both Christianity and Hinduism) undermines the traditional belief systems and overlooks the already existing practices embedded in their daily lives.

Species that were previously protected by tribal hunting taboos may no longer enjoy protection under Christian mores. Interestingly, while spirits may no longer be worshipped and skulls may no longer occupy pride of place in the house, hunting still continues (Aiyadurai, 2011a). The impact and influence of religious conversions on indigenous belief systems related to wildlife conservation remains to be investigated and revisited in depth.

5.5. REASONS FOR HUNTING

As hunting practices undergo several socio-economic and political changes, scholars argue that the distinction between 'indigenous' and 'trade-related' hunting is now harder to define. A historical lens cast over the last 40,000 years of mammal hunting in tropical Asian forests shows evolving perspectives of hunting (Corlett, 2007). Before the advent of agriculture, hunters and gatherers relied on animals as a source of protein. Hunting continued in pre-industrial societies, even when communities began to cultivate crops. Now, hunting and trapping continues to play an important role in the lives of farming communities as part of their crop-protection strategies. Over the last 50 years, hunting for subsistence has been increasingly replaced by the hunting for markets.

Bigger pockets and markets are important factors that need to be investigated, even if the preference for wild meat remains constant. In Nagaland, wild meat is perceived to be a luxury commodity for high-income families. This preference for wild meat, in terms of taste and purity, is especially prevalent among people who have migrated to the cities and towns. As a result, wild meat costs up to five times that of domestic meat (Hilaludin and Ghose, 2005). Although wild meat and animal skins are traded for both local and global markets, the resident hunters themselves may not be directly involved with trade. A strong network supplies meat, skins, bones and body parts to desiring buyers.

To date, there has been a greater focus on unraveling the trade-related aspects of animals such as elephants and tigers, as well as birds captured for the pet trade. Several new species have been added to the list of animals traded. China has long been the destination for luxury market products in Asia, but the last 20 years has seen trade in live animals and animal parts in South-east Asia (Nooren and Claridge, 2001). There are no biological data to show what the future holds for commercially exploited species such as bears, pangolins, musk deers and otters in India. We still do not have a bigger picture of the effects of hunting these species in the wild; a small-scale study, within a tiger reserve, in Arunachal Pradesh shows that hunting for tiger trade might result in extirpation of the species (Datta et al., 2008). Evidence from another state in the north-east shows that localised hunting may have implications for global species decline of migratory birds. For example, in Nagaland, 120,000-140,000 Amur Falcons *Falco amurensis* are killed enroute during their annual migration from Siberia, via the Himalayas, to South Africa (Dalvi et al., 2013).

5.6. THE REACH OF GUNS

Equipment used for hunting has undergone a radical transformation; locally made traps have been replaced by homemade and factory-made guns. There is little doubt that gun hunting has more impact on large mammals than indigenous trapping, but it is important to consider the factors leading to this influx of guns.

Arunachal Pradesh has attracted a large number of visitors both during colonial and post-colonial times. From the very beginning of the 19th century, the Mishmi Hills have attracted all kinds of travelers: missionaries, botanists, surveyors, British political officers, bird watchers and traders (Bailey, 1912; Ali and Ripley, 1948; Kingdon-Ward, 1953; Heriot, 1979). Survey officers used the Mishmi Hills to reach the capital of Tibet (Lhasa), as it was supposed to be the shortest route for mapping the terrain (Marshall, 2005). The border areas shared with Tibet were surveyed to identify incursions by the Chinese, and this continues today with the militarization of the border by defence forces and intelligence agencies along the international border.

In colonial times, British officers presented gifts to win the support and cooperation of the tribal residents. While salt, rum, cigarettes, and iron and steel primarily used for making machetes, were among the various political presents given to villagers, second-hand guns were frequently gifted. B.H. Routledge, who visited the Mishmi hills as a political officer in 1945-46, writes in his tour diary that he took some 'old guns for sale to hill tribes'. Later he reports of a young Mishmi man who had a breech-loading gun with machine-gun attachment (0.30) cartridges collected from crashed American aircraft[10]. The villagers then manufactured these muzzle-loading guns locally. Routledge, the Political Officer of the Sadiya Frontier Tract in 1945-46, claimed that it was an amazing piece of work for a Mishmi to produce! F.P. Mainprice, on his way to Nilangat (Goilliong circle, Anjaw district) in 1943-44, observed two dozen Mishmi gun makers, mostly headmen[11].

[10] During World War II, the Allies lost hundreds of aircrafts in Arunachal Pradesh. The region's inhospitable terrain and unpredictable weather led to mechanical failure and aircraft crashes. According to one report, at least 400 US warplanes went missing in Arunachal Pradesh alone. A request from the US to resume the search for the remains of American pilots has created a renewed interest in the region internationally (http://zeenews.india.com/news/north-east/us-to-search-for-ww-ii-fighters-in-arunachal_778563.html).

[11] Mainprice was Assistant Political officer during Delei Valley Tour in 1943-44 (at present Anjaw district). See Tour Diary of F.P. Mainprice, ICS, Assistant Political Officer, Lohit Valley, Nov 1943 - May 1945. MssEurD1191/3. The British Library, London.

After India's independence, under the NEFA (North East Frontier Agency) administration, the government freely issued gun licenses in the 1950s for self-protection, to check inter-tribal feuds and to protect villagers against wild animals. This led to a rise in the number of gun users, who then became more efficient in hunting wild animals. The ammunition was purchased at the markets. In the past, gunpowder was prepared locally but this is no longer a common practice.

Guns gradually became an important asset; the possession of a gun became a symbol of great prestige and issuing gun licenses was an easy way to lure voters. Today, snare-trapping still continues but guns have accelerated the pace of hunting. With rifles and double-barrel breech-loading guns easily available in all major towns, guns are now the preferred tools for hunting. Many hunters exercise a choice in the type of weapon used when they go to hunt; a double-barrel breech-loading gun, with a short interval between rounds, is preferred when hunting bears, as they tend to fight back tenaciously even after being shot. In December 2012, one hunter recounted a bear hunt where the bear, shot up to 12 times, managed to escape[7]. A popular belief among hunters is that for every bear killed, at least six bears are injured and subsequently cannot be found[3].

Hunting using guns is considered to be macho, unlike trapping. Gun hunting itself can bring in more meat (larger animals). But, when compared with traps, guns have a narrow niche of harvest (usually large animals) and their use needs to take into consideration the cost of ammunition and the time available to hunters to actively search for animals. Trapping requires a certain amount of skill and knowledge about movement trails and frequent haunts of different animals. Traps are made from bamboo and plant fibres; metal wires are also used these days. The extra costs involved with gun hunting such as the purchase of ammunition, equipment, gun maintenance, and obtaining licenses serve as no deterrent.

With increasing human population growth, greater accessibility to remote forests, and the adoption of modern hunting methods and guns, the problems with hunting have become complicated. Species are being removed beyond sustainable limits in many places (Hart, 2000; Hill and Padwe, 2000) because of market demands for wild meat (Apaza et al., 2002; Fa et al., 2005). Greater wild meat consumption has come with improved hunting technology and penetration into remote forest areas (Robinson and Redford, 1991).

5.7. OUTLINING THE CONSERVATION CHALLENGE

Given such complexities, wildlife hunting cannot be purely viewed as a practice that will lead to the local or global extinction of wildlife species. In India, emerging information shows that of 114 mammals that are hunted, many are highly endangered and vulnerable to extirpation, especially in Arunachal Pradesh (Velho et al., 2012; Chapter 1). This region remains fascinating to explorers, anthropologists, and more recently wildlife researchers and conservationists. It spans two global biodiversity hotspots and has yielded the discovery of two new species: the Arunachal macaque (*Macaca munzala*), a new primate species; and the critically endangered Bugun liocichla (*Liocichla bugunorum*), a new bird species, in just the last decade (Athreya 2006; Sinha, et al., 2005). As large parts of Arunachal's forests are still unexplored, many more discoveries are expected, against a backdrop of rising challenges for conservation, including hunting. Thus the forests of north-east India bloom and wither with hope for wildlife conservation.

One of the noteworthy and hopeful conservation efforts in Arunachal Pradesh is that of Pakke Tiger Reserve. The key change for this reserve came in 2004 with the arrival of Tana Tapi, the Divisional Forest Officer from the Nyishi community that lives around Pakke. He initiated the upgrade of a 13 km anti-poaching road to a 41 km road, which runs east to west. Resources increased, from anti-poaching camps employing 19 people, to 27 anti-poaching camps employing 200 staff from the resident Nyishi community. The Assam-Arunachal border has been well secured, and organised poaching gangs have been controlled. Concurrently, he has managed to win people's support by working closely with civil society, women’s self-help groups, village elders and leaders.

The hunting of hornbills is rite of passage for Nyishi men and hornbill parts are used in their headgear. This has been addressed by several non-governmental organisations in consultation with village leaders, and is now a centerpiece of conservation efforts. Nyishis living in the lower reaches of Pakke work closely with non-governmental organisations to protect hornbill nests; they have devised fines for hunting hornbills and cutting nest trees and now use fibreglass hornbill beaks. The Forest Department pays *gaon buddas* (village heads) an honorarium to enforce their customary conservation laws for hornbills and other species. When women self-help groups provide information about any illegal activity, the village council pays them fifty percent of the fine amount. Funds that come to the Forest Department via the Compensatory Afforestation and Management Programme are channeled through Village Forest Development Councils that comprise members from each village. The social impacts of these efforts are yet to be studied, and the political dynamics are always in flux, but Pakke Tiger Reserve has become an example of the multifaceted efforts required to conserve forests and wildlife.

At the eastern end of Arunachal Pradesh lies the high-profile Namdapha Tiger Reserve where, over the last decade, various conservation-related projects have been attempted with little or no Forest Department presence on the ground. The employment of the Lisu people as field assistants, data recorders and guides was aimed at providing alternative livelihoods in the community in order to wean them away from hunting (Datta, 2007). The lack of roads, schools, and basic medical care were other pressing problems. Schools, medical care, handicraft and conservation-education programmes, where people pledged not to hunt wild animals, did not succeed (Datta, 2015).

It is very important to understand how residents view conservation, especially because conservation (whether through protected areas or community participation) is likely to be problematic because forest use and wildlife hunting are linked to the daily lives of the Arunachali people. Resident communities often see conservation projects as a kind of developmental strategy that would provide education, healthcare and improve the quality of life, in exchange for their co-operation and participation in conservation projects. It is still unclear whether civic and social welfare projects are effective at creating a good rapport with the community and achieving conservation goals. The evidence so far points to the important goal of creating a good rapport, but the sociological impacts for conservation remain untested (see reports in 2012 where residents fired guns at members of civil society and the Forest Department of Namdapha Tiger Reserve)[12]. Involving residents in conservation through community development projects may have good intentions, but they also require engaging with the socio-economic, cultural, political and historical factors affecting the use of natural resources.

Although some view poverty as an important driving force behind hunting and wildlife trade, affluent consumers, locally and across the world, provide the main fuel to the fire of wildlife trade. Focusing on projects and enforcing prohibitive laws related to hunting on a small scale may not always succeed, without consideration for the outside influence of global factors.

The 'human side' and 'governance side' of hunting is intertwined. A study done in Periyar Tiger Reserve, a mainland southern India protected area, shows that hunters were usually male, married and had very basic levels of education (primary school education or none) (Gubbi and Linkie, 2012). Given that there are fewer socio-cultural dimensions compared with north-east India, it may be plausible to reduce wildlife hunting through access to higher education, promotion of alternative protein use, and stricter law enforcement (Gubbi and Linkie, 2012).

[12] 'Namdapha Tiger Reserve under threat' (http://www.arunachaltimes.in/mar12%2017.html); but see also 'Law demands facts to settle any issue' (http://www.arunachaltimes.in/mar12%2021.html)

However in north-east India a clearer image will emerge when we seek to understand whether hunting is a way of life, a livelihood issue, a socio-cultural dimension of living, part of a trade network, or all these put together in varying degrees of complexity. It may not always be the actors but the interactions and space they share that makes it beneficial or detrimental for conservation. Identifying the causes (and not the symptoms) and integrating these in a multi-tiered framework of governance would benefit conservation. In the case of Pakke, key leaders from the resident community have created or been part of effective, inter-linked institutions: the Forest Department, village councils and conservation programmes bound with civil society.

There are other examples of commendable work that is being done to contain over-hunting in other parts of north-east India. The massive exploitation of Amur falcons has been reversed in Nagaland through a multi-pronged approach. With an estimated global population of a million Amur falcons, approximately 20,000 were hunted annually in Nagaland during their annual migration (Dalvi et al., 2013). In peak season, the number of hunted birds increases to 12,000–14,000 a day, and were consumed locally (Shashank Dalvi, pers. comm.) or sent to unknown destinations (Dalvi et al., 2013). Safe passage for these falcons is resulting from a combination of legislation and enforcement of existing wildlife-protection laws; creation of eco-clubs for children and teachers; radio-tagging of Amur falcons, wherein their arrival in southern Africa is conveyed to people in Nagaland; and the involvement of religious groups, conservation organisations, and residents (Shashank Dalvi, pers. comm.).

5.8. A FINAL WORD FROM PAHI

So, when we think of hunting in remote areas, it can no longer be described simply as indigenous hunting for subsistence. We need to know from more geographical and social scapes about whether hunting for the cooking pot is sustainable or not in India. Furthermore, the interaction between middlemen and resident hunters, for trade and business, is also part of a larger socio-economic process. For example, when a hunter brings home a gnu goat or a takin he and his family would consume part of it, offer it to border security staff during a ritual, sell a portion of the meat, display the skull in his house and exchange portions of the meat in conjunction with social obligations. This cannot be understood as simply subsistence versus commercial; resident versus outsider; or cultural versus non-cultural. The multiple forces that perpetuate hunting operate on different scales and levels, making the issue of hunting intriguingly complex.

There is not one simple answer about who predominantly hunts, why people hunt, what they hunt for and, more importantly, the solution to overhunting. As with the enterprising Pahi Meyor, we very often find that people are caught between markets, traditions and conservation. Pahi's barter of 15 cases of alcohol for a leopard skin illustrates this. With 15 cases, he earned 180 bottles of liquor. So, did he start a new business, sell these bottles at a higher price or barter the alcohol for more skins? None of these. He arranged a Sunday lottery in his little town: for each bottle, he made ten lottery tickets and sold them for Rs. 20 ($ 0.33 USD) per ticket. Whoever won the lottery won one bottle. This followed week after week for each bottle. With remarkable enterprise, he finished up earning Rs. 36,000 ($ 600 USD). His experience adds to the seemingly endless, multi-layered complexities of hunting for subsistence, and to the demands of emerging markets in the world beyond his home in the eastern Himalayas. As hunting practices are sustained by social and cultural trends and are increasingly blended together with larger-scale trade, these factors cannot be treated separately from those that operate within the community.

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CONCLUSION

The wet tropical forests of Arunachal Pradesh in north-east India span two global biodiversity hotspots (the Indo-Myanmar and Eastern Himalaya hotspots) (Myers et al., 2000). These forests are among the most biodiverse areas in the world. For instance, the bird diversity of the region is second only to that in the Andes (Price, 2012), and a new bird species, the Bugun Liocichla (*Liocichla bugunorum*), was only recently discovered from the area (Athreya, 2006). The area lies at the junction of different biogeographical regions and has extreme altitudinal and climatic gradients. It is mostly inhabited by tribes whose lives are linked to forests in multiple ways.

While Arunachal Pradesh is not limited by competition for land as yet because only tribes are allowed to own land, the pressures from hunting and harvesting of forest products are growing with road expansion and population growth. I studied forest use and the impact of this use on wildlife species in areas subject to differing human pressures. I compared accessible and inaccessible areas and areas under local community management with other areas under the control of government conservation agencies. My research revealed the extreme complexity of the situation and the need for more information on how different species of wildlife respond to different management regimes. Government protected areas must remain the mainstay of conservation efforts but community-managed areas could provide many complementary values if there is not overharvesting of wildlife that may be sensitive to hunting.

In this thesis, Chapter 1 is an India-focused synthesis of hunting-related studies across multiple taxa and geographical areas. I collated 143 studies that had mentioned hunting in India in one sense or another. I found that bushmeat hunting and poaching remains a significant threat to Indian wildlife, especially in Arunachal Pradesh state. Further, given the nascent state of research on wildlife hunting in India, the reported number of species affected by hunting is expected to increase, as more studies on hunting are conducted. Also, larger-bodied species have traits that make them more intrinsically vulnerable to hunting, but they are also more likely to be well-studied. I suggest that future studies should expand the focus on hunting to include a range of different-sized species at multiple locations.

I assessed hunting-related threats in each chapter of my thesis and showed that hunting and deforestation are particularly challenging in the lower reaches of the Pakke Tiger Reserve in eastern Arunachal Pradesh, circumstances that are exacerbated by ethno-civil strife (Velho et al., 2014; Appendix S18). Forest Department staff from Pakke Tiger Reserve believed that hunting-related threats to the reserve and adjacent areas stemmed from the ease of access to guns, where residents can procure muzzle-loading guns from insurgents for as little as $9 USD (Velho et al., 2014). They worried that natural-resource scarcity in the areas outside Pakke may lead to increased hunting, fishing, and logging pressures within the reserve. Guns were the main method that people use to hunt, although a small percentage employed snares and traps. Overall, hunting was perceived to be the major reason for decline of species, according to interviewees from all sites that I sampled.

In Chapter 2, my collaborators and I addressed social and health-related challenges to park management in Pakke Tiger Reserve, by focusing on the effects of malaria. I was able to investigate how malaria impinged on park management, by collating data and health records from local health centres and private pharmacies and augmenting these with records from the Forest Department and interviews with anti-poaching staff.

Malaria affected people in different ways. Seventy per cent of staff in Pakke were afflicted by malaria over a four-year period (Velho et al., 2011; Chapter 2), resulting in an estimated loss of 44,160 human-hours of patrolling effort, roughly equating to two of the 24 anti-poaching camps in the reserve being left empty. Future studies should attempt to assess whether there are links between peak malaria incidence in the wet season with poaching intensity.

In Chapter 3, my colleagues and I explored the role of community-managed lands and an adjoining protected area for the conservation of larger-bodied mammal species using multiple sampling methods (animal-sign transects, camera traps, and key-informant interviews).The protected area where the study was conducted was the Eaglenest Wildlife Sanctuary, an exceptionally biodiverse site in the Eastern Himalaya Biodiversity Hotspot.

From our sign-surveys and camera trapping, I found that Eaglenest Wildlife Sanctuary is important for larger-bodied species such as gaur and elephant, whereas the adjacent community-managed lands retain several smaller-bodied species of conservation concern, such as the red panda. At least at this one locale, I concluded that community-managed lands can have important biodiversity values that may enhance and complement those of protected areas. Some community-managed lands (such as the land around Eaglenest), I suggest, could have species richness and unique conservation values comparable to those of nearby protected areas. Future studies should extend to other taxonomic groups, such as birds, as well as medicinally important plants, both of which maybe important for peoples livelihoods in and around Eaglenest Wildlife Sanctuary. This is especially important given that 62% of Arunachal Pradesh's forests are located in community-managed lands and protected areas are often located within a matrix of community lands.

In India the material, cultural and symbolic associations with species are often higher and more intricate than the number of species in a given area (Jain, 1998). In this context I found that there were complex relationships that existed with species in and around Eaglenest Wildlife Sanctuary. Here I found that the taboos that prevented the killing animals were very variable across different resident communities, although some taboos such as those of killing elephants were more codified and consistent. Similar to other studies which have shown the benefits of rule-making for tree species (Persha et al., 2011), animals such as elephants may also benefit from taboos that prevent their being killed in this region. Changing economic and social contexts in community-managed lands, such as the decline of traditional hunting restrictions on species such as the gaur, and the impacts of these changes on biodiversity, require further study. Further, land-use and social norms maybe much more dynamic in these community-managed lands compared with protected areas.

A key finding from our interviews was that our interviewees perceived a general state of decline in biodiversity both within Eaglenest Sanctuary and in the adjoining community-managed lands, especially for large-bodied species. Otters, tigers, and leopards were perceived by residents to have exhibited the most drastic declines. All of these species are highly valued in the international wildlife trade and this maybe a key factor in their decline. Other studies have also shown that high-value items such as elephant ivory, rhino horn, tiger bones and pangolin scales are inevitably traded internationally (Nijman, 2010).

In Chapter 4, I assessed the efficacy of community-managed lands versus adjacent protected areas across four independent sites for a range of hunted mammals and for selected birds (pheasants and hornbills). This large-scale analysis is of relevance as resident communities control roughly equal areas when compared to gazette protected areas (Molnar et al., 2004). I collected data on species presences, and variables such as vegetation structure and human disturbance using standardized sign transects, with roughly half of these transects resampled during a second year.

Many sites in community-managed lands showed significant disturbance in areas occupied or visited by humans. I observed invasive plant species, cut stumps, a dense understory and low density of mature trees. Mammal species differed in their responses to land use across sites. The main observations from each study site were as follows:

EAGLENEST WILDLIFE SANCTUARY AND ADJOINING COMMUNITY-MANAGED LAND:

These paired sites had comparable species richness, although the overall abundance of mammal species was higher within Eaglenest compared with the community-managed land. Although there was no active ranger patrolling within Eaglenest, it benefited from the natural protection afforded by its remoteness from villages. The community-managed lands had fewer large-bodied species but sustained important populations of small-bodied species many with high conservation significance (Chapter 3). This underscores the importance of both strict protection and community management as complementary regimes for conservation, albeit for different sets of species.

SESSA ORCHID SANCTUARY AND ADJOINING COMMUNITY-MANAGED LAND:

Sessa Orchid Sanctuary had much higher species richness when compared with similar community-managed lands. However, this was the only location where the community-managed land had a higher relative abundance of mammals than did the protected area. One plausible reason is that although Sessa Orchid Sanctuary still retains high species richness, this protected area is threatened by illegal logging, agricultural encroachments and settlements. The existence of new villages and conversion of forests to agriculture is likely to have depressed mammal abundances.

PAKKE TIGER RESERVE (LOWER REACHES) AND ADJOINING COMMUNITY-MANAGED LAND:

At its lower reaches, Pakke Tiger Reserve had higher species richness and abundance compared with the nearby community-managed lands. In fact, this site had the highest species richness and abundance values across all protected areas and community-managed lands that I sampled. While lower altitudes may have higher mammal species richness, the reserve also benefits from the regular anti-poaching patrols undertaken by the Forest Department.

PAKKE TIGER RESERVE (HIGHER REACHES) AND ADJOINING COMMUNITY-MANAGED LAND:

The higher reaches of Pakke Tiger Reserve and their adjacent community-managed lands have comparable species richness and abundance values. This may be because in both management regimes, there are tracts of forests far from villages with relatively low human populations. However, hunting (in the absence of patrolling and protection) continues in both regimes.

In general, across multiple independent sites, protected areas tended to have higher mammal richness than did adjacent community-managed lands (Chapter 4). However species across regimes responded to land-use intensity (which was characterized by a disturbance gradient that ranged from agriculture to primary forests) in different ways. Unlike Gardner et al. 2008, I did not find that land-use intensity was more important than protection regime or vice-versa. I found that disturbance, protection and their interactive effects were important predictors of mammal and bird species abundances. In general, I concluded that protected areas are important for biodiversity in Arunachal Pradesh, although community-managed lands also had important site-specific value (Chapter 3 and 4). Furthermore, protected areas were important for large-bodied species such as gaur (*Bos gaurus*) and sambar (*Rusa unicolor*), which had higher abundances in protected areas compared with community-managed lands and were found further away from roads (Chapter 4). In the general landscape respondents reported that sambar and gaur had both declined drastically (as had tigers, which have been extirpated in the region).

Although certain large-bodied species such as sambar and gaur appeared to avoid the vicinity of roads other species did not show a negative response to roads. It remains unknown whether species move away from roads in response to hunters or if there is higher food availability away from roads. For mammals, more information is needed on the factors that govern species distributions with respect to habitat disturbance and distance to roads. This is especially important because roads threaten tropical forests and their biodiversity in different ways (Laurance et al., 2009). The impacts of roads could be from direct forest loss from clear-felling, species invasions (Walsh, 2004), increased predation risk (Laurance, 2004) and higher number of road-kills (Vijaykumar, 2001; Goosem, 2002). To date, the roads in Arunachal Pradesh are relatively sparse and used only with low intensity, with limited road widths and traffic volumes. For example, Eaglenest Wildlife Sanctuary during the peak tourist season may have just 15 cars passing through it each day.

This is, however, likely to change in the near future. The central government of India plans to improve road connectivity by inter-linking the state with major highways in this sensitive military area on the disputed frontier with China. In this context there has been accelerated investment in road building in Arunachal Pradesh and plans to expand the road network by 2,407 km, with the first phase of completion being targeted for mid-2016 (Dey, 2013). Such changes should be considered very carefully for they might have major impacts on human pressures such as hunting and habitat change in this biologically crucial region. The need for cooperation between India and China has been called upon to mitigate climate change, biodiversity and forest loss (Bawa et al., 2010).

In my final chapter, I collaborated with an anthropologist to evaluate hunting from social and anthropological perspectives. I found many parallels between the relationships that hunters have with animals in different parts of the world. For instance, the Tukano Indians of the Amazon and the Yukaghirs of Siberia believe in the presence of animal guardians, similar to the Mishmi tribe in Arunachal Pradesh state. Yet in other parts of India, I found, there were many differences in the motivation and extent of hunting compared with those in north-eastern India.

It would be interesting to further examine the influence of these distinct cultural and economic factors on attitudes to wildlife conservation and how and why they differ from those in the rest of India. A key area for future studies should be to compare and contrast the relative costs and performance of different strategies (especially ranger patrols versus outreach efforts) in achieving conservation outcomes. Such metrics also need to include the linkage of outcomes (in this case the response of mammals) to outputs such as intensity of patrolling.

The main conclusion of this thesis is that threats from wildlife hunting in north-eastern India are highly varied in space and are also likely to change over time. Hunting pressures are influenced by issues ranging from human health (malaria), which may compromise park management, to issues arising from conflicts related to ethnic identity and control of natural resources. These were superimposed on more 'standard' and well-known threats such as hunting and illegal logging that most forests across the world face. I found that solutions to some of these threats maybe relatively cheap, simple and effective – for example, providing mosquito nets to forest watchers to reduce the incidence of malaria. Other threats such as conflict over identity, ethnicity and militancy are so complex that their solutions go beyond the competence of park or natural resource management agencies and lie in the broader political arena.

While I highlight a combination of threats to wildlife operating in my study area, an important perspective is the multitude of opportunities that are available to deal with these challenges. On the one hand, mitigating some of these threats may require standard approaches to biodiversity conservation, such as protected areas and patrolling. On the other hand, community-managed lands may have important biodiversity values in some sites and cover a large area (~62% in Arunachal Pradesh).

While studies from across the world have focused on the financial, social, human, and political assets of community-based management (Bowler et al., 2012), there is still little information on the biodiversity assets of these areas. However, a review of community-conserved areas (CCAs) showed that they were less effective in conserving biodiversity compared with strictly protected areas but were more effective than open-access areas (Shahabuddin and Rao, 2010). The biodiversity metrics of past evaluations have largely focused on deforestation rates (Porter-Bolland et al., 2012), fire-frequencies (Nelson and Chomitz, 2011), vegetation responses (Agrawal and Chhatre, 2006) and a matched comparison on a single-species (Goswami et al., 2014). A literature review shows that the geographical focus of studies on community-based management has been predominantly in Asia (specifically Nepal and India), but thus far, this form of management has been associated with greater tree density and basal area and not with other specific environmental benefits (Bowler et al., 2012).

If community managed areas are to fill their potential role in conserving biodiversity, this needs to be achieved through some careful and well-designed strategies. The ability to identify, follow up and monitor threats that are often linked to people's lives and livelihoods is an important role that residents may play in community-management (Sheil et al., 2015). On the one hand, while this ability may be flexible and adaptive, on the other the capacity to identify, address and prevent these threats often depends on the situation and context (Sheil et al., 2015). Further, when scientists identify threats they are usually at multiple scales. While ecological studies measure and identify threats at the plot level, the usually seek to generalize at the landscape level. Social studies usually work at the village level but then seek to gain a wider understanding of resident communities. This mismatch of scale makes it difficult to formulate policy that encapsulates both social and ecological processes in a meaningful way. Mixed-method approaches could be a way to integrate ecosystem or forest health measures with different social and ecosystem management systems (Lund et al., 2014).

However, it may be possible to formulate policy whereby social and ecological processes are integrated into a framework of community-based management. Firstly, this requires forestry practices in Asia to encapsulate a broader understanding of human-managed ecosystems rather than being solely driven by the traditional silvicultural lens of management. Secondly, this may require looking at solutions across disciplines. For example, in agroforestry-knowledge systems, ecological and social processes have been merged in Nagaland state in north-east India and have been implemented quite successfully. Here, Village

Development Boards of as many as 35 ethnic groups use their value-driven institutional arrangements for land-use planning and fallow management (Ramakrishnan, 2006). Although there are some reservations as to how these have been implemented, similar opportunities exist for biodiversity conservation. For example, in Chapter 3, I found that the Tukpen Village Council has representation of every family with periodic meeting where fines are levied for a certain set of rules with respect to hunting, logging and fires. These mechanisms could be tapped and used more effectively, and their use ties into the larger theory of common-property resources where the benefits of rule-making and participation have positive outcomes for forest management (Persha et al., 2011).

Introducing such policies, rules and incentives that will encourage communities to conserve biodiversity requires innovation and further effort. Community-managed lands are no substitute for protected areas but they clearly could help to augment and complement their roles in the conservation of biodiversity and key ecological and environmental processes.

The main conclusion of this thesis is that threats from wildlife hunting in north-eastern India are highly varied in space and are also likely to change over time. Hunting pressures are influenced by issues ranging from human health (malaria) which may compromise park management to issues arising from conflict related to ethnic identity and control of natural resources. These were superimposed on more 'standard' and well-known threats such as hunting and illegal logging that most forests across the world face. I found that solutions to some of these threats maybe relatively cheap, simple and effective - e.g., providing mosquito nets to forest watchers to reduce the incidence of malaria. Other threats such as conflict over identity, ethnicity and militancy are so complex that their solutions go beyond the competence of park or natural resource management agencies and lie in the broader political arena. While I highlight a combination of threats from my study area, an important perspective is the multitude of opportunities that are available to deal with these challenges. On one hand, mitigating some of these threats may require standard approaches to biodiversity conservation, e.g.: protected areas and patrolling. On the other, community-managed lands may have important biodiversity values in some sites and are expanding (~62% in Arunachal Pradesh).

While studies from across the world have focused on the financial, social, human, political assets of community based management (Bowler et al., 2011), there is still little information on the biodiversity assets of these areas. However a review of community-conserved areas (CCAs) showed that they were less effective in conserving biodiversity compared with strictly protected areas but were more effective than open-access areas (Shahabuddin and Rao, 2010). The biodiversity metrics of past evaluations have been largely focused on deforestation rates (Porter-Bolland et al., 2012), fire-frequencies (Nelson and Chomitz, 2011) and vegetation response (Agrawal and Chhatre, 2006) and a matched comparison on a single species (Goswami et al., 2014). The geographical focus of studies on community-based management has been predominantly Asia (specifically Nepal and India), but thus far, this form of management has been associated with greater tree density and basal area and not with greater environmental benefits (Bowler et al., 2011).

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Appendix S1: Miscontrued dichotomies. Published in *Seminar*. This article highlights the increasing polarity in terms of how debates are framed in India: growth at all costs versus the environment. Conceptually, this echoes more focussed ideaological debates surrounding protected areas versus community-managed lands.

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Appendix S2: A two part series on forest management and wildlife science. Published in *Economic and Political Weekly*. This article highlights the present short-comings in forest management and the need to involve independent scientists in decision-making.

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Appendix S3: Part 2: Turning the page in wildlife science: conservation biology and bureaucracy. Published in *Economic and Political Weekly*. This article highlights how scientists can involve themselves more constructively in matters of forest governance.

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Appendix S4: Sidestepping science: India's 'Notional' Board for Wildlife. Published in *Economic and Political Weekly*. This article highlights how greater transparency is required to make forest governance more inclusive in India.

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Appendix S5: Reprint of Velho, N., Karanth, K. & Laurance, W.F. (2012). Hunting: A serious and understudied threat in India, a globally significant conservation region. *Biological Conservation* 148: 210-215.

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Short communication

Hunting: A serious and understudied threat in India, a globally significant conservation region

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ABSTRACT

Hunting is one of the greatest conservation challenges facing tropical wildlife. Wildlife in Indian tropical forests are vulnerable to hunting, although data on hunting impacts from the region are limited. We use a meta-analysis of 143 hunting studies from India to identify the species and geographic regions most at risk, and to assess their legal protection. We found evidence of hunting in 114 mammal species, with larger-bodied mammals being particularly vulnerable. Although 75% of all studies focused on mammals, few actually quantified hunting impacts. Further, among studies of all terrestrial vertebrates where hunting was mentioned, only 6% focused exclusively on hunting. With further research, we expect that the suite of species known to be exploited by hunters will increase. We conclude that the Eastern Himalaya and Indo-Myanmar biodiversity-hotspot complex is particularly vulnerable to hunting. Quantitative studies of hunting impacts are urgently needed across India, especially in this biodiversity-hotspot complex.

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Appendix S6: Reprint of Velho, N., Srinivasan, U., Prashanth, N.S. & Laurance, W.F. (2011). Human disease hinders anti-poaching efforts in Indian nature reserves. *Biological Conservation* 144: 2382-2385.

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ELSEVIER

Short communication

Human disease hinders anti-poaching efforts in Indian nature reserves

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ABSTRACT

Where hunting pressure is high, anti-poaching efforts are often crucial for protecting native wildlife populations in nature reserves. However, many reserves suffer from inadequate support and provisioning of staff, especially in developing nations. In Pakke Tiger Reserve in northeastern India, we found that malarial infection is a serious hindrance for front-line patrolling staff that limits the time they can spend in the field. We assessed the consequences of malaria both for local people and park staff in the general region and its indirect effects on wildlife protection. To accomplish this we compiled data from annual epidemiological records of malaria, the number of malaria cases and associated mortality, financial costs, and loss of time spent patrolling. Over a 4-year period (2006–2009), the majority (71%) of forest department staff in Pakke Tiger Reserve suffered from malaria. Malaria treatments cost park managers nearly 3% of their total budget and caused a net loss of 44,160 man hours of anti-poaching effort. The government forest and health departments involved in the employment and health of park staff have separate missions and responsibilities, yet our findings show that a multi-disciplinary approach to conservation is essential to avoid overall systemic failure.

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Appendix S7: Reprint of Velho, N. & Laurance, W.F. (2013). Hunting practices of an Indo-Tibetan Buddhist tribe in Arunachal Pradesh, north-east India. *Oryx* 47: 389-392.

Short Communication

Hunting practices of an Indo-Tibetan Buddhist tribe in Arunachal Pradesh, north-east India

NANDINI VELHO and WILLIAM F. LAURANCE

Abstract Hunting is a serious threat to Indian wildlife. We used semi-structured interviews to assess hunting practices, cultural contexts and village-level governance within a Buddhist Indo-Tibetan tribe in the biologically rich region of Arunachal Pradesh. A large majority (96%) of the 50 respondents preferred wild meat over domestic meat, and most hunted for recreation. Species such as the Asian elephant *Elephas maximus* are still considered taboo to hunters but other species that were once taboo (such as gaur *Bos gaurus*) are now hunted. A month-long ban was previously instituted to prohibit tribal hunting during the wildlife breeding season each year but this has now decreased to 16-days duration. A multi-level governance framework is needed to resolve a mismatch between national policy in India and grass-roots governance for managing wildlife hunting.

Keywords Arunachal Pradesh, biodiversity hotspot, bushmeat, hunting, tribal governance, India

This paper contains supplementary material that can be found online at http://journals.cambridge.org

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Appendix S8: The candidate model set used in the species-level GLMM analyses, with associated AICc and ΔAICc values. Columns 2 to 9 represent the predictors used in the model (with columns 7 to 9 representing interactions between predictors). A '+' sign indicates that the predictor (or interaction) was included in the corresponding model, and a '-' sign that it was not. Accordingly, Model 1, which includes all predictors and interactions was our global model, and performed best (ΔAICc = 0).

Model	Dist road	Disturbance	Regime	Repeat	Species	Dist road : Species	Disturbance: Species	Regime: Species	AICc	ΔAICc
1	+	+	+	+	+	+	+	+	1443.45	0
2	-	+	+	+	+	-	+	+	1453.250	9.79
3	+	+	+	+	+	-	+	+	1454.68	11.23
4	+	+	+	+	+	+	-	+	1486.92	43.46
5	+	-	+	+	+	+	-	+	1490.23	46.77
6	-	+	+	+	+	-	-	+	1500.23	56.77
7	+	+	+	-	+	+	+	+	1500.86	57.40
8	+	+	+	+	+	-	-	+	1501.85	58.39
9	-	-	+	+	+	-	-	+	1503.83	60.37
10	+	-	+	+	+	-	-	+	1504.94	61.48
11	-	+	+	-	+	-	+	+	1509.72	66.26
12	+	+	+	-	+	-	+	+	1511.70	68.24
13	+	+	+	+	+	+	+	-	1533.41	89.95
14	+	+	-	+	+	+	+	-	1539.71	96.26
15	+	+	+	-	+	+	-	+	1542.70	99.24
16	+	-	+	-	+	+	-	+	1546.27	102.81
17	-	+	+	-	+	-	-	+	1555.22	111.76
18	+	+	+	-	+	-	-	+	1557.24	113.78
19	-	-	+	-	+	-	-	+	1558.95	115.50

20	+	-	+	-	+	-	-	+	1560.64	117.18
21	+	+	+	+	+	+	-	-	1581.44	137.98
22	+	-	+	+	+	+	-	-	1584.51	141.05
23	+	+	-	+	+	+	-	-	1588.64	145.18
24	+	+	+	-	+	+	+	-	1589.72	146.27
25	+	-	-	+	+	+	-	-	1590.41	146.95
26	+	+	-	-	+	+	+	-	1595.06	151.62
27	-	+	+	+	+	-	+	-	1596.60	153.14
28	+	+	+	+	+	-	+	-	1598.24	154.78
29	-	+	-	+	+	-	+	-	1607.60	164.14
30	+	+	-	+	+	-	+	-	1607.83	164.37
31	+	+	+	-	+	+	-	-	1636.03	192.57
32	-	+	+	+	+	-	-	-	1638.080	194.62
33	+	-	+	-	+	+	-	-	1639.34	195.88
34	+	+	+	+	+	-	-	-	1639.58	196.12
35	-	-	+	+	+	-	-	-	1641.55	198.093
36	+	+	-	-	+	+	-	-	1642.28	198.80
37	+	-	+	+	+	-	-	-	1642.55	199.09
38	+	-	-	-	+	+	-	-	1644.35	200.89
39	-	+	-	+	+	-	-	-	1649.24	205.78
40	+	+	-	+	+	-	-	-	1649.42	205.96
41	-	-	-	+	+	-	-	-	1649.70	206.24
42	+	-	-	+	+	-	-	-	1650.81	207.35
43	-	+	+	-	+	-	+	-	1651.03	207.57
44	+	+	+	-	+	-	+	-	1653.06	209.61
45	+	+	-	-	+	-	+	-	1661.69	218.23
46	-	+	-	-	+	-	+	-	1662.29	218.83
47	-	+	+	-	+	-	-	-	1691.32	247.86
48	+	+	+	-	+	-	-	-	1693.24	249.78

49	-	-	+	-	+	-	-	-	1694.94	251.48
50	+	-	+	-	+	-	-	-	1696.51	253.05
51	+	+	-	-	+	-	-	-	1702.10	258.64
52	-	+	-	-	+	-	-	-	1702.73	259.27
53	-	-	-	-	+	-	-	-	1703.26	259.80
54	+	-	-	-	+	-	-	-	1703.82	260.36
55	-	+	+	+	-	-	-	-	2297.39	853.93
56	+	+	+	+	-	-	-	-	2298.78	855.32
57	-	-	+	+	-	-	-	-	2300.73	857.27
58	+	-	+	+	-	-	-	-	2301.63	858.17
59	-	+	-	+	-	-	-	-	2308.54	865.08
60	+	+	-	+	-	-	-	-	2308.65	865.19
61	-	-	-	+	-	-	-	-	2308.98	865.52
62	+	-	-	+	-	-	-	-	2310.01	866.55
63	-	+	+	-	-	-	-	-	2345.58	902.12
64	+	+	+	-	-	-	-	-	2347.39	903.93
65	-	-	+	-	-	-	-	-	2349.06	905.60
66	+	-	+	-	-	-	-	-	2350.52	907.06
67	+	+	-	-	-	-	-	-	2356.30	912.84
68	-	+	-	-	-	-	-	-	2356.96	913.50
69	-	-	-	-	-	-	-	-	2357.47	914.0
70	+	-	-	-	-	-	-	-	2357.97	914.51

Appendix S9: A popular article based on our camera trapping work in Chapter 3 in Eaglenest Wildlife Sanctuary. This article also shows some of the camera trap images obtained during our study. Published in *Sanctuary Asia Magazine*.

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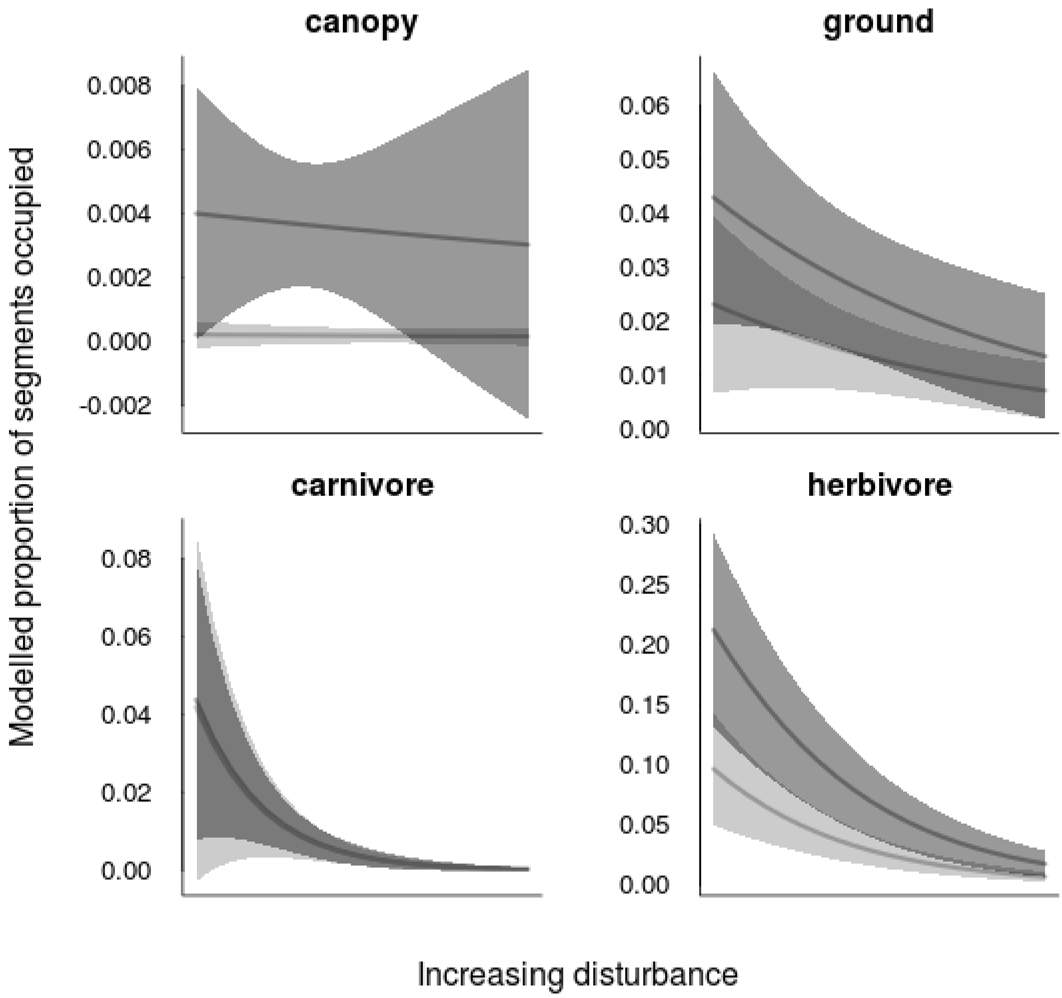
Appendix S10: The candidate model set used in the guild-level GLMM analyses in Chapter 4, with associated AICc and ΔAICc values. Columns 2 to 9 represent the predictors used in the model (with columns 7 to 9 representing interactions between predictors). A '+' sign indicates that the predictor (or interaction) was included in the corresponding model, and a '-' sign that it was not. Accordingly, Model 1, which includes all predictors and interactions was our global model, and performed best (ΔAICc = 0).

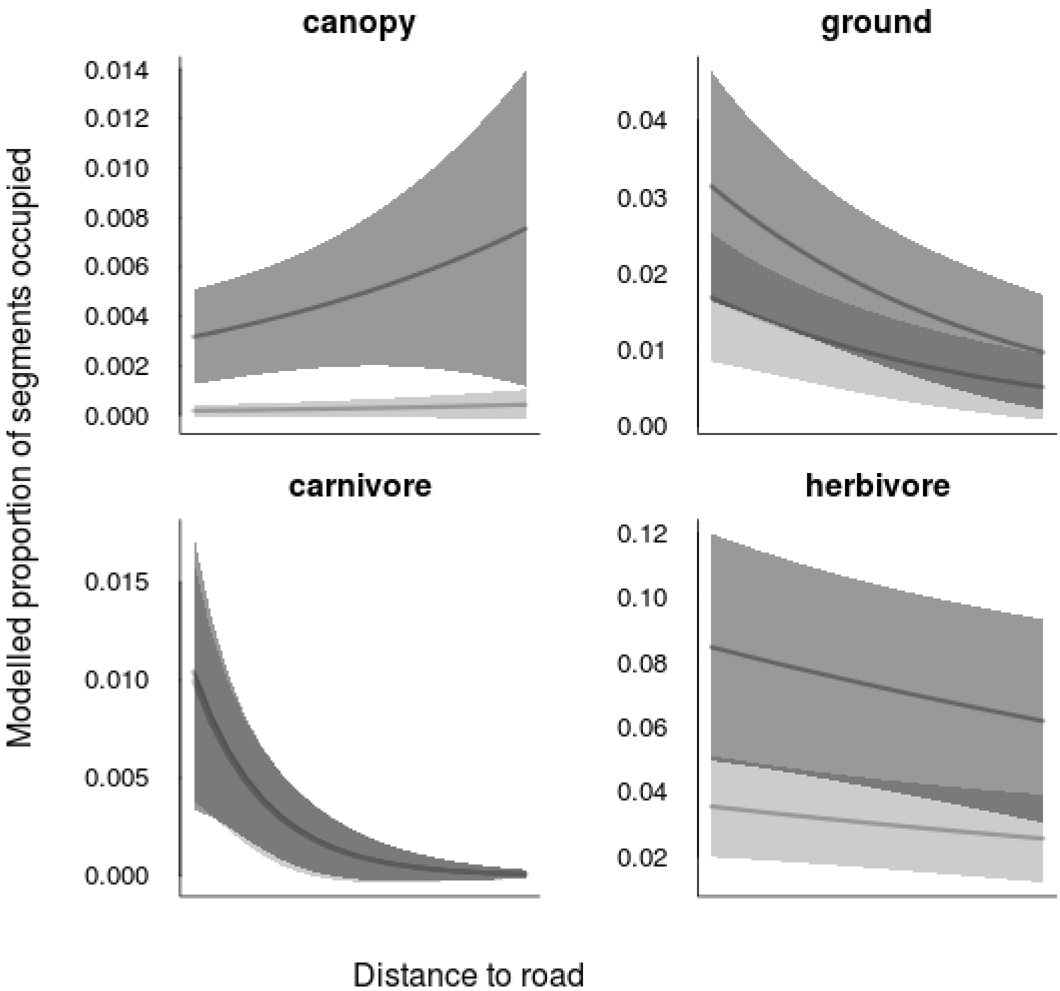
Model	Guild	Regime	Repeat	Dist road	Disturbance	Regime : Guild	Dist road: Guild	Disturbance: Guild	AICc	ΔAICc
1	+	+	+	+	+	+	+	+	6133.7	0
2	+	+	-	+	+	+	+	+	6141.1	7.4
3	+	+	+	+	+	+	+	-	6143.3	9.6
4	+	+	-	+	+	+	+	-	6150.7	17
5	+	+	+	+	+	-	+	+	6151.7	18
6	+	+	+	+	+	+	-	+	6158.1	24.4
7	+	+	-	+	+	-	+	+	6159.2	25.4
8	+	+	+	-	+	+	-	+	6164.1	30.4
9	+	+	+	+	+	-	+	-	6164.4	30.7
10	+	+	-	+	+	+	-	+	6165.5	31.8
11	+	+	-	-	+	+	-	+	6171.8	38.1
12	+	+	-	+	+	-	+	-	6171.9	38.2
13	+	+	+	+	+	+	-	-	6180	46.3
14	+	+	+	-	+	+	-	-	6186.4	52.7
15	+	+	-	+	+	+	-	-	6187.5	53.8
16	+	+	+	+	+	-	-	+	6190.1	56.4
17	+	+	-	-	+	+	-	-	6194.1	60.4
18	+	+	+	-	+	-	-	+	6196.2	62.5
19	+	+	-	+	+	-	-	+	6197.6	63.9
20	+	+	-	-	+	-	-	+	6203.8	70.1
21	+	+	+	+	+	-	-	-	6206.8	73.1
22	+	+	+	-	+	-	-	-	6213.2	79.5
23	+	+	-	+	+	-	-	-	6214.3	80.6
24	+	+	+	+	-	+	+	-	6220.6	86.9
25	+	+	-	-	+	-	-	-	6220.9	87.2
26	+	+	-	+	-	+	+	-	6227.4	93.7
27	+	+	+	+	-	-	+	-	6241	107.3
28	+	+	-	+	-	-	+	-	6247.8	114.1
29	+	+	+	-	-	+	-	-	6258.6	124.9
30	+	+	+	+	-	+	-	-	6259.5	125.8
31	+	+	-	-	-	+	-	-	6265.5	131.8

32	+	+	-	+	-	+	-	-	6266.4	132.7
33	+	+	+	-	-	-	-	-	6283.2	149.5
34	+	+	+	+	-	-	-	-	6284.1	150.4
35	+	+	-	-	-	-	-	-	6290.1	156.4
36	+	+	-	+	-	-	-	-	6290.9	157.2
37	+	-	+	+	+	-	+	+	6294.9	161.2
38	+	-	-	+	+	-	+	+	6304.8	171.1
39	+	-	+	+	+	-	+	-	6308	174.3
40	+	-	-	+	+	-	+	-	6317.9	184.2
41	+	-	+	+	+	-	-	+	6334.2	200.5
42	+	-	-	+	+	-	-	+	6344.1	210.4
43	+	-	+	-	+	-	-	+	6346.8	213.1
44	+	-	+	+	+	-	-	-	6350.3	216.6
45	+	-	-	-	+	-	-	+	6357.2	223.5
46	+	-	-	+	+	-	-	-	6360.3	226.6
47	+	-	+	-	+	-	-	-	6363.3	229.6
48	+	-	-	-	+	-	-	-	6373.7	240
49	+	-	+	+	-	-	+	-	6800.1	666.4
50	+	-	-	+	-	-	+	-	6811.4	677.7
51	+	-	+	+	-	-	-	-	6844.4	710.7
52	+	-	+	-	-	-	-	-	6846.9	713.2
53	+	-	-	+	-	-	-	-	6855.7	722
54	+	-	-	-	-	-	-	-	6857.9	724.2
55	-	+	+	+	+	-	-	-	8201	2067.3
56	-	+	-	+	+	-	-	-	8204.6	2070.9
57	-	+	+	-	+	-	-	-	8207.2	2073.5
58	-	+	-	-	+	-	-	-	8210.9	2077.2
59	-	+	+	-	-	-	-	-	8273.8	2140.1
60	-	+	+	+	-	-	-	-	8274.7	2141
61	-	+	-	-	-	-	-	-	8277	2143.3
62	-	+	-	+	-	-	-	-	8277.7	2144
63	-	-	+	+	+	-	-	-	8340.6	2206.9
64	-	-	-	+	+	-	-	-	8346.1	2212.4
65	-	-	+	-	+	-	-	-	8353	2219.3
66	-	-	-	-	+	-	-	-	8358.9	2225.2
67	-	-	+	+	-	-	-	-	8817.6	2683.9
68	-	-	+	-	-	-	-	-	8819.7	2686
69	-	-	-	+	-	-	-	-	8824.1	2690.3
70	-	-	-	-	-	-	-	-	8826	2692.3

Appendix S11: The relationship between the abundance of four mammal guilds (as estimated by the detectability-corrected proportion of transect segments occupied) and increasing disturbance of protected areas (dark grey) and community lands (light grey) across four paired sites combined. Solid lines represent fitted (predicted) values from the guild-level GLMM, and the lighter polygons show the 95% confidence interval associated with the modeled predictions. Trends from transects that were walked on the second sampling occasion are represented below.



Appendix S12: The relationship between the abundance of four mammal guilds (as estimated by the detectability-corrected proportion of transect segments occupied) and increasing distance from road in protected areas (dark grey) and community lands (light grey) across four paired sites combined. Solid lines represent fitted (predicted) values from the GLMM, and the lighter polygons show the 95% confidence interval associated with the modeled predictions. Trends from transects that were walked on the second sampling occasion are represented below.



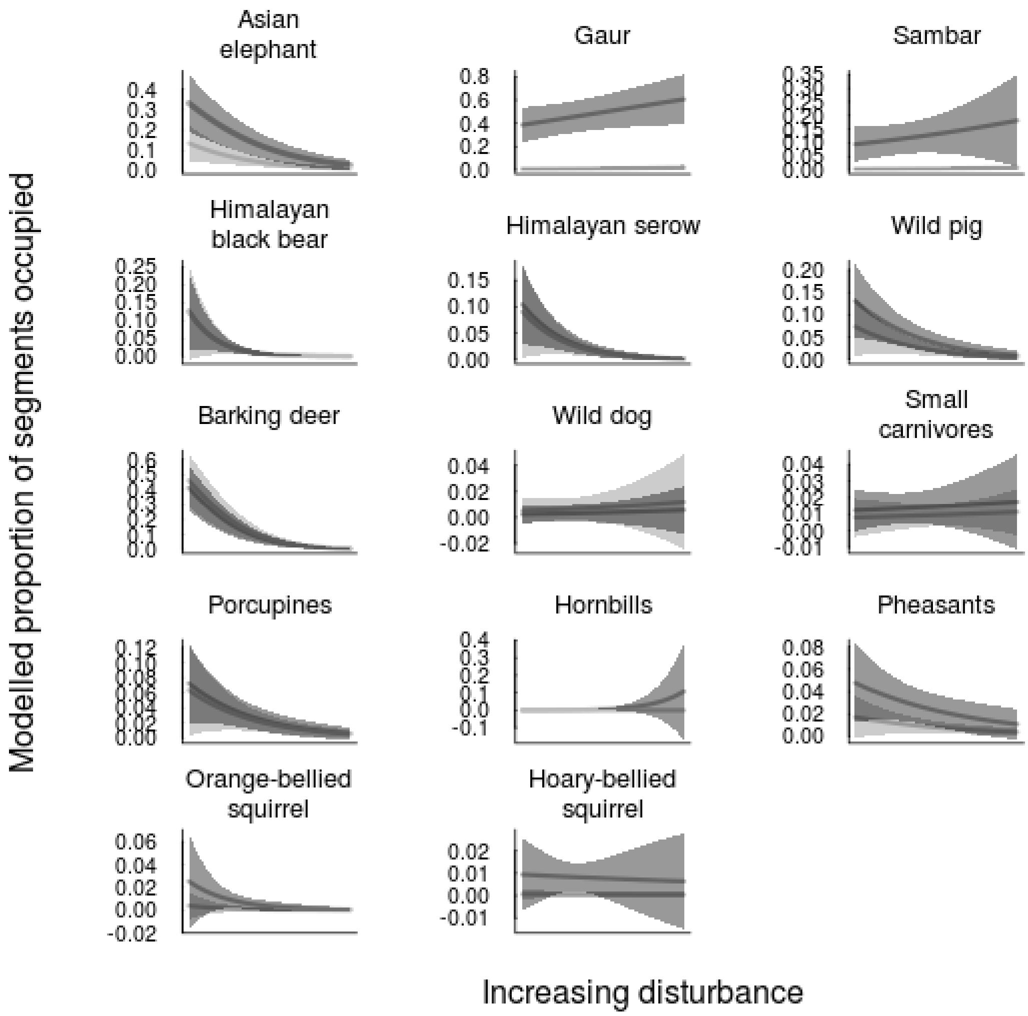
Appendix S13: The candidate species model set used in the species-level GLMM analyses in Chapter 4, with associated effect degrees of freedom, AICc and ΔAICc values. Columns 2 to 9 represent the predictors used in the model (with columns 7 to 9 representing interactions between predictors. A '+' sign indicates that the predictor (or interaction) was included in the corresponding model, and a '-' sign that it was not. Accordingly, Model 1, which includes all predictors and interactions was our global model, and performed best (ΔAICc = 0).

Mo-del	Regi-me	Rep-eat	Dist road	Distur-bance	Species	Regime: Species	Dist road: Species	Distur-bance: species	AICc	ΔAICc
1	+	+	+	+	+	+	+	+	4741	0
2	+	-	+	+	+	+	+	+	4749.1	8.2
3	+	+	+	+	+	+	+	-	4800.9	59.9
4	+	-	+	+	+	+	+	-	4808.9	67.9
5	+	+	+	+	+	+	-	+	4864.9	124
6	+	+	-	+	+	+	-	+	4870.7	129.8
7	+	-	+	+	+	+	-	+	4873.2	132.3
8	+	-	-	+	+	+	-	+	4879.3	138.3
9	+	+	+	-	+	+	+	-	4889.9	149
1+	+	-	+	-	+	+	+	-	4897.3	156.4
11	+	+	+	+	+	-	+	+	4947.6	206.7
12	+	+	+	+	+	+	-	-	4948	207.1
13	+	+	+	+	+	-	+	-	4954.2	213.3
14	+	+	-	+	+	+	-	-	4954.5	213.5
15	+	-	+	+	+	-	+	+	4955.4	214.4
16	+	-	+	+	+	+	-	-	4956.3	215.3
17	+	-	+	+	+	-	+	-	4962	221
18	+	-	-	+	+	+	-	-	4963	222
19	+	+	+	-	+	-	+	-	5035.9	294.9
20	+	+	-	-	+	+	-	-	5041.6	300.7

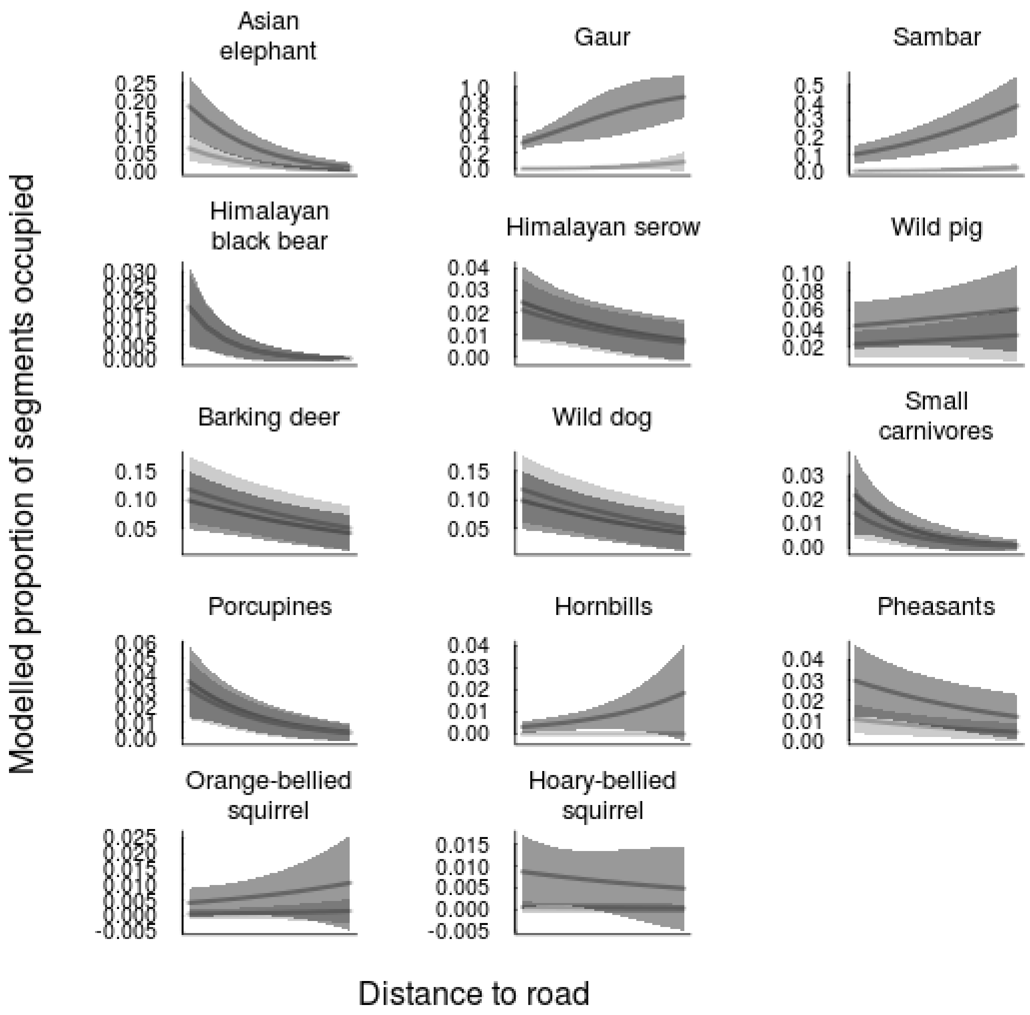
21	+	+	+	-	+	+	-	-	5043	302
22	+	-	+	-	+	-	+	-	5043.1	302.1
23	+	-	-	-	+	+	-	-	5049.2	308.2
24	+	-	+	-	+	+	-	-	5050.5	309.5
25	-	+	+	+	+	-	+	+	5069.1	328.1
26	-	+	+	+	+	-	+	-	5077	336
27	-	-	+	+	+	-	+	+	5078.9	337.9
28	-	-	+	+	+	-	+	-	5086.8	345.8
29	+	+	+	+	+	-	-	+	5111.9	370.9
30	+	+	-	+	+	-	-	+	5117.4	376.4
31	+	-	+	+	+	-	-	+	5119.9	379
32	+	-	-	+	+	-	-	+	5125.6	384.7
33	+	+	+	+	+	-	-	-	5128.9	387.9
34	+	+	-	+	+	-	-	-	5135.1	394.1
35	+	-	+	+	+	-	-	-	5136.9	395.9
36	+	-	-	+	+	-	-	-	5143.3	402.3
37	+	+	-	-	+	-	-	-	5204.8	463.9
38	+	+	+	-	+	-	-	-	5205.8	464.9
39	+	-	-	-	+	-	-	-	5212.2	471.3
4+	+	-	+	-	+	-	-	-	5213.2	472.2
41	-	+	+	+	+	-	-	+	5260.2	519.3
42	-	-	+	+	+	-	-	+	5270.9	529.9
43	-	+	-	+	+	-	-	+	5272.3	531.3
44	-	+	+	+	+	-	-	-	5278.4	537.5
45	-	-	-	+	+	-	-	+	5283.4	542.4
46	-	-	+	+	+	-	-	-	5289	548
47	-	+	-	+	+	-	-	-	5291.5	550.6
48	-	-	-	+	+	-	-	-	5302.6	561.6
49	-	+	+	-	+	-	+	-	5568.8	827.8

50	-	-	+	-	+	-	+	-	5580	839
51	-	+	+	-	+	-	-	-	5781.1	1040.1
52	-	+	-	-	+	-	-	-	5784	1043.1
53	-	-	+.	-	+	-	-	-	5793.1	1052.1
54	-	-	-	-	+	-	-	-	5795.7	1054.8
55	+	+	+	+	-	-	-	-	6980.6	2239.6
56	+	+	-	+	-	-	-	-	6986.3	2245.4
57	+	-	+	+	-	-	-	-	6987.9	2246.9
58	+	-	-	+	-	-	-	-	6993.8	2252.9
59	+	+	-	-	-	-	-	-	7051.8	2310.8
60	+	+	+	-	-	-	-	-	7052.8	2311.8
61	+	-	-	-	-	-	-	-	7058.5	2317.5
62	+	-	+	-	-	-	-	-	7059.4	2318.5
63	-	+	+	+	-	-	-	-	7122.5	2381.6
64	-	-	+	+	-	-	-	-	7132.3	2391.4
65	-	+	-	+	-	-	-	-	7134.5	2393.6
66	-	-	-	+	-	-	-	-	7144.8	2403.8
67	-	+	+	-	-	-	-	-	7598.6	2857.7
68	-	+	-	-	-	-	-	-	7601	2860.1
69	-	-	+	-	-	-	-	-	7609.7	2868.7
70	-	-	-	-	-	-	-	-	7611.9	2870.9

Appendix S14: The relationship between species abundance estimates and disturbance in protected areas (dark grey) and community-managed lands (light grey), across four paired sites combined. Solid lines represent fitted (predicted) values from the GLMM, and the lighter polygons are the 95% confidence interval associated with the modeled predictions. From left to right and top to bottom, species are arranged in order of decreasing body mass. These graphs represent trends from transects walked during the second sampling occasion.



Appendix S15: The relationship between species abundance estimates and road distance in protected areas (dark grey) and community-managed lands (light grey), across four paired sites combined. Solid lines represent fitted (predicted) values from the GLMM, and the lighter polygons are the 95% confidence interval associated with the modeled predictions. From left to right and top to bottom, species are arranged in order of decreasing body mass. These graphs represent trends from transects walked during the second sampling occasion.



Appendix S16: A popular article based on the conservation work around Pakke Tiger Reserve and the anti-poaching efforts that maybe useful for animal protection. Published in *Sanctuary Asia Magazine*.

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Appendix S17: A popular article based on our interview data in Chapter 4. This article highlights the changing contexts of hunting in north-east India. Published in *The Daily Pioneer*.

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Appendix S18: Reprint of Velho, N., Agarwala, M., Srinivasan, U. & Laurance, W.F. (2014). Collateral damage: impacts of ethno-civil strife on biodiversity and natural resource use near Indian nature reserves. *Biodiversity & Conservation* 23: 2515-2527.

Biodivers Conserv (2014) 23:2515–2527
DOI 10.1007/s10531-014-0735-1

ORIGINAL PAPER

Collateral damage: impacts of ethno-civil strife on biodiversity and natural resource use near Indian nature reserves

Nandini Velho · Meghna Agarwala · Umesh Srinivasan · William F. Laurance

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Abstract Civil conflicts often affect the control of natural resources, altering their access and use. Using a combination of questionnaires, remote sensing, and a review of articles in the popular print media, we investigated the impact of a protracted armed conflict on forest loss, livelihoods, and forest use near two globally important tiger reserves in northeastern India. Over a 23 year period, we found evidence of large-scale forest loss in the vicinity of Nameri and Pakke Tiger Reserves. Nearly all (99 %) interviewees opined that the ethno-civil strife was to blame for declining forest cover. Most interviewees identified 1990 as the year of onset of strife-mediated deforestation. This is partially supported by a review of print-media articles that reported conflict, violence, displacement, and the onset of large-scale migration in the previous year. According to respondents, ethno-civil strife has radically altered access to, and use of forests, by resident communities (causing economic hardship, increased costs, and reduced availability of essential timber products), and has also accelerated forest loss and increased poaching. We conclude that forests and wildlife

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in these protected areas are at immediate risk from ethno-civil strife. Urgent interventions are needed to reduce the environmental and societal impacts of civil strife in this biologically crucial region of India.

Keywords Forest cover · India · Insurgency · Logging · Militancy · Park management

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