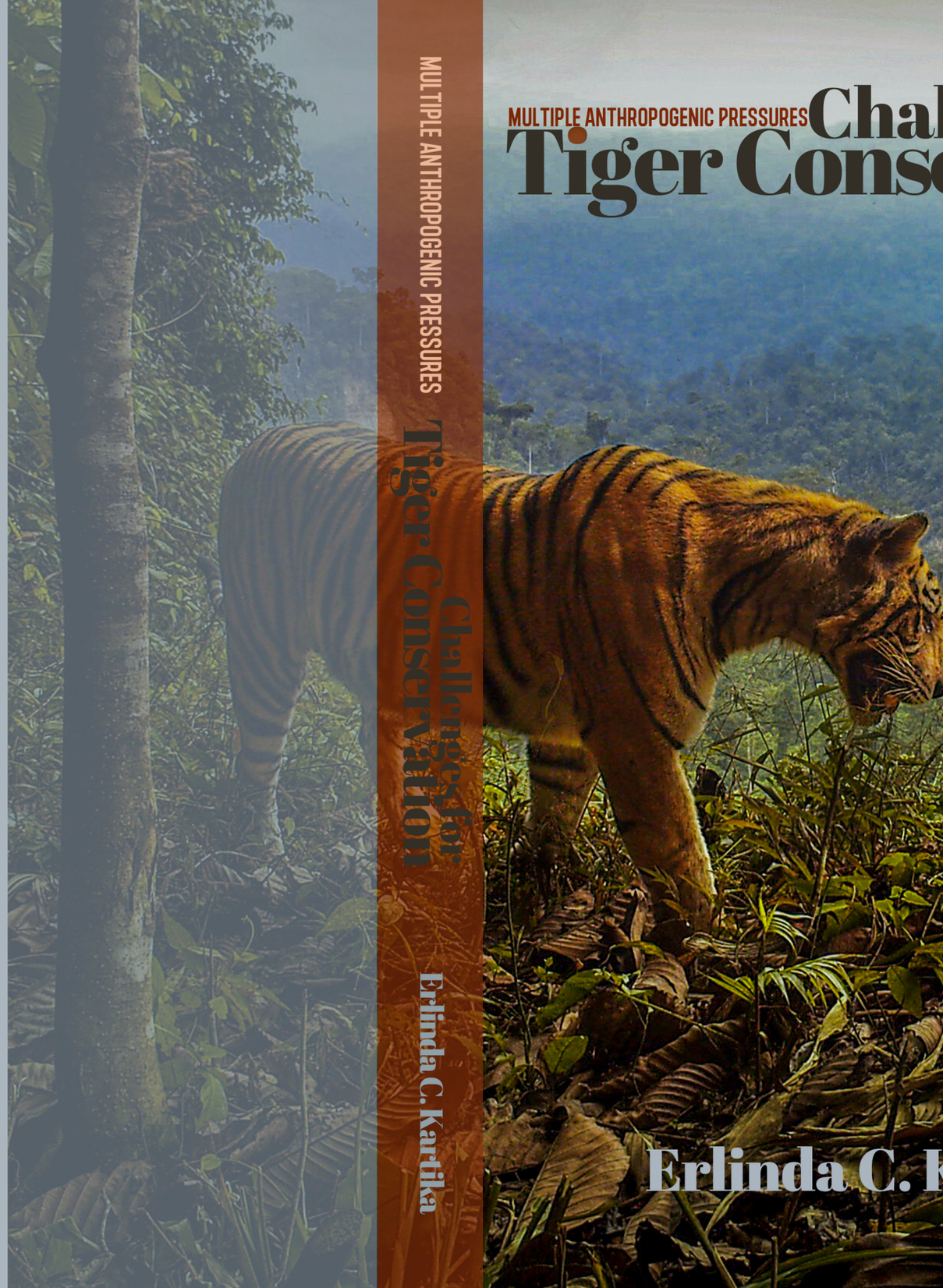

MULTIPLE ANTHROPOGENIC PRESSURES

Challenges for Tiger Conservation

Erlinda C. Kartika

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Challenges for Tiger Conservation

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Propositions

1. Focusing on the post-conflict fate of tigers will improve tiger conservation.
   (this thesis)

2. Merely taking into consideration traditional and local ecological knowledge is insufficient to conserve the Sumatran tiger.
   (this thesis)

3. Replacement of Marine Protected Areas by ecosystem-based management instruments effectively addresses marine biodiversity loss.

4. Global pandemics are social and political phenomena, caused by systemic failures in global governance, inequality, and unsustainable development.

5. Paper bags are more damaging to the environment than plastic bags.

6. Western dominance in science perpetuates global inequalities.

Propositions belonging to the thesis, entitled

Multiple anthropogenic pressures: challenges for tiger conservation

Erlinda C. Kartika
Wageningen, 27 June 2023

Multiple anthropogenic pressures: challenges for tiger conservation

Erlinda C. Kartika

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Multiple anthropogenic pressures: challenges for tiger conservation

Erlinda C. Kartika

Thesis

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Prof. Dr Arthur P.J. Mol,
in the presence of the
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Summary

English

Large carnivores face serious threats and are experiencing massive declines in their populations and geographic ranges around the world. Their large body size and high metabolic demand require large prey and expansive habitat, which make carnivores more vulnerable in a world that is now becoming more fragmented and more human dominated. Anthropogenic pressures, including habitat loss and fragmentation, retaliation killings and disease transmission from domestic animals, contribute to the declines and this makes the conservation of large carnivores very challenging. Using the Sumatran tiger (*Panthera tigris sumatrae*) as a model species, this study aims to understand how multiple forms of anthropogenic pressure namely human-tiger conflict, hunting, diseases and habitat change affect the carnivores. This study is a combination of empirical studies, analysing secondary data, and modelling.

Chapter 1 is the general introduction that presents the theoretical framework of this thesis, providing information on the conservation challenge of the focal species.

In **Chapter 2**, I analysed spatially-explicit, long term, island-wide human-tiger conflict data from Sumatra (Indonesia) to understand the scale of conflict, environmental factors determining the conflict, and the impact of the conflict for both humans and tiger. A total of 1192 human-tiger conflict reports were recorded between 2001 and 2019. The probability of conflict increased with human disturbance and decreased with distance from protected area and with elevation. During this period, 1419 livestock were killed or injured and 262 humans died or were injured. Within 18 years of the reported conflict, 181 tigers were removed from the local area of conflict, of which 129 were killed and 52 were sent to captivity, from which 10 were translocated. Promoting environmental education, livestock management and livestock insurance could minimize the impact of tigers conflicting with humans. To reduce the impact of the conflict on the tiger, fast response conflict mitigation from the nature conservation office, and disseminating the conflict protocol both to the staff and to local people, is deemed necessary.

In **Chapter 3,** I analysed the "human dimension" factors of the human-wildlife conflict, namely attitude, tolerance and emotion toward tiger. Using interview data from four areas with different types and impact of human-tiger conflict, I described the key determinants explaining the "human dimension" factors. I found that people's emotions were inversely correlated with their conservation attitude and with their tolerance towards tigers. We found that impact of the conflict explained the human dimension but not the frequency of the conflict experienced by individuals. Other factors determined the human dimension, including environmental education received by villagers, and the location of agricultural fields relative to the forest boundary. In this chapter I also calculated the financial impact of human-tiger conflict. Moreover, I compared how the impact of human-tiger conflict differed if I calculated direct impact on the affected individuals only and if I included the indirect impact across the community into the calculation. I found that calculating indirect impacts of the conflicts better helped explain their severity, specifically at the community level, and especially when humans were attacked. Hence, I suggest that an integrated program combining environmental education, and compensation for livestock and human losses, should not be aimed at individuals, but rather at the community; community involvement in handling the conflict could increase tolerance for tigers, thus contributing to tiger conservation.

In **Chapter 4**, I studied how local people perceived human-tiger conflict incidents and identified the factors that, according to them, caused the conflict, with special attention to cultural and spiritual values. I found that people explained the cause of the human-tiger conflicts as being more related to spiritual beliefs than to other factors. However, upon deeper analysis of the interviews, we discovered that holding such beliefs does not seem to inherently protect tigers. A decreased inclusion of tigers in local culture might weaken emotional connections between humans and tigers, resulting in reduced tolerance. Based on these results, I suggest that stricter livestock management in areas close to protected areas is crucial to prevent conflicts from occurring. I expect that future human-tiger conflict prevention and mitigation efforts will benefit most from education on tiger biology, ecology, and conservation status in high-risk conflict areas. Additional local capacity building and participation in conservation management might provide an opportunity to strengthen emotional connections of communities with tigers and support pro-conservation behaviours, even in times of conflict.

In **Chapter 5** I focused on the hunting of wildlife species that are typical prey for tigers in Sumatra. Here, I studied the extent of active and passive wild boar hunting in West Sumatra, with a focus on dog-assisted hunting practices, including target animal species, preferred hunting areas, and the motivation of the hunters for hunting, and also potential disease transmission by hunting dogs to game. I gathered data from social media, expert interviews, and a questionnaire-guided survey among hunters. I found that active and passive wild boar hunting widely occurred in Sumatra. Firearm and snare hunting occurred in all eight provinces in Sumatra (excluding the small coastal islands) while dog-assisted hunting occurred only in six provinces. We found that at least 1331 dog-assisted wild boar hunting events occurred in 2019 across the province of West Sumatra, on a regular basis. The dog-assisted wild boar hunting events mostly occurred on Sunday but did not exclude any other day of the week. Events involved 10-300 people, where each hunter brings 1 to 9 dogs. Dog-assisted hunting in West Sumatra mainly targeted wild boar (69 respondents), sambar deer (29 respondents) and to a lesser extent muntjac (8 respondents). Many dogs used for hunting are reportedly not vaccinated (35%), risking transmission of diseases like Rabies and Canine Distemper Virus to game and wild predators like the endangered Sumatran tiger, the clouded leopard, the golden cat, and various prey species. Hunting is inadequately regulated, rendering enforcement of these regulations impossible. The extent of wild boar hunting has as yet been unquantified but likely will have strong effects on the remaining wildlife populations. We call for proper quantification of hunting bags, and regulation, including the use and health status of dogs, to prevent disease transmission from dogs to wild animals and to protect remaining wildlife populations.

In **Chapter 6,** I studied the potential of pathogen spillover from domestic dogs to tiger. I concentrated on two factors that caused the spillover, e.g. the prevalence of pathogens in the host species in this case domestic dogs, and the interactions between dogs and wildlife. I collected blood samples and conducted laboratory analysis of Rabies Virus from domestic dogs in surrounding tiger habitat. I also conducted a questionnaire survey and interviewed 160 dog owners from eight villages within 5 km bordering the Batanghari Protected Forest. I found that most dogs have titer antibodies lower than the protective level of immunity against Rabies Virus for both vaccinated and unvaccinated dogs. Only <5% of respondents were familiar with Canine Distemper Virus, versus 75% with Rabies Virus. In West Sumatra, dogs were commonly used for hunting,

also within the Batanghari Protected Area. The high number of unvaccinated dogs for Rabies and Canine Distemper Virus increases the potential of spillover to carnivores such as tiger. To prevent the spread of diseases to wild carnivores, effective vaccination in combination with strict hunting regulations, law enforcement and education about the diseases and vaccination is needed.

Chapter 7 describes the effect of habitat changes on the occupancy of the Sumatran tiger. Here I am focusing my study on the response of tigers to different forest situations. Using camera traps, I conducted the study in three different areas, namely (i) secondary forest in the core area of Batanghari Protected Forest *versus* (ii) secondary forest neighbouring palm oil plantations, and (iii) secondary forest neighbouring mixed agriculture, to assess how differences in neighbouring habitat affect the occupancy of the Sumatran tiger. Using occupancy modelling, I found that tiger occupancy was twice as high in the secondary forest in the core forest area compared to areas neighbouring mixed agriculture and palm oil plantation. The results of this chapter suggest that neighbouring agricultural landscapes reduce levels of tiger occupancy compared to prime habitat.

In **Chapter 8**, I synthesise the results of this thesis and discuss the challenges of tiger conservation in Indonesia in the future. The ongoing habitat loss and human-centred development threaten the future of tiger and other wildlife. This puts into question how long the tiger can persist in the landscape that is ever more fragmented and human-dominated. Understanding ecological processes are notably important to prevent extinction of the species, but this thesis has also made clear that human dimension factors (beliefs and tolerances), environmental education, and local practices (large hunting parties with dogs, veterinary status) are at least as important. Effective management of natural resource by the authorities together with the participations of the people is key to success preventing the extinction of the tiger in Sumatra and likely other large carnivores elsewhere.

Ringkasan

Bahasa Indonesia

Kelangsungan hidup hewan karnivora berukuran besar menghadapi ancaman yang serius. Populasi dan jangkauan geografisnya menurun drastis di seluruh dunia. Dengan bobot tubuh yang besar dan kebutuhan metabolik tinggi yang memerlukan mangsa besar serta habitat yang luas, membuatnya makin rentan di bumi yang semakin terfragmentasi dan dikuasai manusia. Tekanan antropogenik, balas dendam, termasuk hilangnya habitat dan fragmentasi, serta penularan penyakit dari hewan domestik, berkontribusi kuat pada penurunan populasi mereka hingga membuat pelestarian terhadap karnivora besar ini sangat menantang. Dengan menggunakan harimau sumatra (*Panthera tigris sumatrae*) sebagai spesies model, penelitian ini bertujuan untuk memahami bagaimana bentuk-bentuk tekanan antropogenik yaitu konflik antara manusia dan harimau, perburuan, penyakit, hingga perubahan habitat yang mempengaruhi populasi karnivora. Studi ini merupakan perpaduan dari studi empiris, analisis data sekunder, dan pemodelan.

Bab 1, merupakan pendahuluan yang menyajikan kerangka teoritis dari tesis ini, memberikan informasi tentang tantangan status konservasi dari spesies yang diteliti.

Pada **Bab 2**, saya menganalisis data konflik antara manusia dengan harimau secara spasial, jangka panjang, dan mencakup seluruh pulau Sumatera (Indonesia) untuk memahami skala konflik, faktor lingkungan yang menentukan konflik, dan dampak konflik terhadap manusia dan harimau. Sebanyak 1.192 laporan konflik antara manusia dengan harimau tercatat antara 2001 hingga 2019. Kemungkinan terjadinya konflik meningkat akibat adanya gangguan manusia terhadap habitat harimau dan kemungkinan terjadinya konflik berkurang dengan jarak yang semakin jauh dari kawasan hutan lindung/konservasi dan dengan elevasi yang tinggi. Selama periode ini, 1.419 ternak mati atau terluka, 262 orang meninggal atau terluka. Dalam 18 tahun konflik yang dilaporkan, 181 harimau diambil dari area terjadinya konflik, 129 diantaranya dibunuh dan 52 dikirim ke penangkaran, di mana 10 nya dilepaskan kembali ke tempat lain. Meningkatkan pendidikan lingkungan, pengelolaan ternak, dan asuransi ternak dapat meminimalkan dampak konflik harimau terhadap manusia. Untuk mengurangi dampak konflik pada harimau, penanganan

konflik yang cepat dari Balai Konservasi Sumberdaya Alam (BKSDA), dan menyebarkan protokol konflik baik ke staf maupun masyarakat lokal dianggap penting.

Pada **Bab 3**, saya menganalisis faktor *human dimension* dari konflik antara manusia dan satwa liar, yaitu sikap, toleransi, dan kemarahan terhadap harimau. Dengan menggunakan data wawancara dari empat wilayah dengan jenis dan dampak konflik manusia dan harimau yang berbeda, saya menjelaskan faktor-faktor penentu utama yang menjelaskan faktor *human dimension*. Saya menemukan bahwa tingkat kemarahan masyarakat berbanding terbalik dengan sikap konservasi dan dengan toleransi mereka terhadap harimau. Saya menemukan bahwa jumlah kejadian konflik yang menimpa seseorang tidak memengaruhi sikap, toleransi dan kemarahan manusia terhadap harimau, namun dampak konflik memengaruhi sikap, toleransi dan kemarahan manusia. Faktor-faktor lain yang menentukan *human dimension*, termasuk pendidikan lingkungan yang diterima oleh warga desa, dan lokasi ladang pertanian ke batas hutan. Pada bab ini saya juga menghitung dampak finansial dari konflik antara manusia dan harimau. Selain itu, saya membandingkan bagaimana dampak konflik antara manusia dan harimau ini berbeda jika saya menghitung dampak langsung hanya pada individu yang terkena konflik dan jika saya memasukkan dampak tidak langsung yang menimpa seluruh masyarakat ke dalam perhitungan. Saya menemukan bahwa menghitung dampak tidak langsung dari konflik membantu menjelaskan tingkat keparahan konflik lebih baik, khususnya pada masyarakat, dan terutama ketika manusia diserang. Oleh karena itu, saya menyarankan bahwa program terpadu yang menggabungkan pendidikan lingkungan, dan kompensasi untuk kerugian ternak dan manusia, tidak seharusnya ditujukan kepada individu, melainkan kepada seluruh masyarakat yang terdampak konflik; keterlibatan masyarakat dalam penanganan konflik dapat meningkatkan toleransi terhadap harimau, sehingga turut berkontribusi pada konservasi harimau itu sendiri.

Di **Bab 4**, saya mempelajari bagaimana pandangan masyarakat lokal atas kejadian konflik antara manusia dan harimau serta mengidentifikasi faktor-faktor yang menurut masyarakat menyebabkan konflik itu terjadi, dengan menggunakan pendekatan nilai-nilai budaya dan spiritual. Saya menemukan bahwa orang menjelaskan penyebab konflik antara manusia dan harimau lebih berkaitan dengan keyakinan spiritual daripada faktor lainnya. Namun, setelah melakukan analisis lebih dalam dari hasil wawancara, saya menemukan bahwa memegang keyakinan spiritual tersebut

bukan semata hal penentu yang membuat orang secara langsung ingin melindungi harimau. Makin menipisnya folklor dan mitologi yang diyakini masyarakat tentang harimau dalam budaya lokal dapat melemahkan hubungan emosional-spiritual antara manusia dan harimau, yang mengakibatkan menurunya toleransi terhadap harimau. Berdasarkan hasil ini, saya menyarankan bahwa pengelolaan ternak yang lebih baik di daerah yang dekat dengan kawasan lindung sangat penting untuk mencegah terjadinya konflik. Saya berharap bahwa upaya pencegahan dan penanganan konflik antara manusia dan harimau kedepannya mengutamakan pendidikan tentang biologi, ekologi, dan status konservasi harimau di daerah konflik yang berisiko tinggi. Peningkatan kapasitas lokal dan partisipasi masyarakat dalam manajemen konflik dapat memperkuat hubungan emosional masyarakat dengan harimau serta mendukung perilaku pro-konservasi, bahkan dalam situasi konflik.

Di **Bab 5**, saya fokus pada perburuan satwa liar yang merupakan mangsa harimau di Sumatera yaitu babi hutan. Di sini, saya mempelajari sejauh mana perburuan babi hutan aktif (dengan menggunakan anjing dan senjata) dan pasif (dengan menggunakan jerat) di Sumatra, dengan fokus pada praktik perburuan menggunakan anjing. Beberapa hal yang saya teliti di bab ini termasuk di dalamnya adalah satwa apa saja yang diburu, area berburu yang disukai oleh pemburu, dan motivasi pemburu untuk berburu, serta potensi penularan penyakit oleh anjing buru pada satwa buruan. Saya mengumpulkan data dari media sosial, wawancara para ahli konservasi, dan survei yang dipandu kuesioner ke para pemburu babi. Saya menemukan bahwa perburuan babi hutan aktif dan pasif terjadi di seluruh Sumatra. Perburuan dengan senjata api dan jerat terjadi di semua provinsi di Sumatra (kecuali pulau-pulau kecil di pesisir), sedangkan perburuan yang dibantu anjing hanya terjadi di enam provinsi di Sumatra. Setidaknya 1.331 perburuan babi hutan yang dibantu anjing dilakukan secara rutin dan berkala terjadi sepanjang tahun 2019 di seluruh provinsi Sumatra Barat. Acara perburuan babi hutan yang dibantu anjing utamanya terjadi pada hari Minggu tetapi tidak mengecualikan hari lain dalam seminggu. Acara-acara ini melibatkan 10-300 orang, di mana setiap pemburu membawa 1 hingga 9 anjing. Perburuan yang dibantu anjing di Sumatra Barat utamanya menargetkan babi hutan (69 responden), rusa sambar (29 responden), dan kijang (8 responden). Banyak anjing yang digunakan untuk berburu dilaporkan tidak divaksinasi (35%), meningkatkan risiko penularan penyakit seperti *rabies* dan *canine distemper virus* pada satwa buruan dan predator liar seperti harimau sumatra, macan dahan, kucing emas, dan berbagai

spesies mangsa. Perburuan babi hutan tidak dilarang, juga tidak diatur di Indonesia sehingga pengawasan dan penegakan hukum terhadap perburuan ini menjadi sulit. Sejauh ini, dampak dari perburuan babi hutan belum terukur dengan baik, tetapi kemungkinan memengaruhi populasi satwa liar yang tersisa. Saya menyarankan pengukuran yang tepat terhadap hasil buruan, dan regulasi yang memperhatikan penggunaan dan status kesehatan anjing untuk mencegah penularan penyakit dari anjing ke satwa liar, serta upaya untuk melindungi populasi satwa liar yang tersisa.

Di **Bab 6**, saya mempelajari potensi penularan patogenik dari anjing peliharaan ke harimau. Saya fokus pada dua faktor yang menyebabkan penularan, yaitu prevalensi patogen pada spesies inang dalam hal ini anjing peliharaan, dan interaksi antara anjing dan satwa liar. Saya mengumpulkan sampel darah dan melakukan analisis laboratorium terhadap virus rabies dari anjing peliharaan di sekitar habitat harimau. Saya juga melakukan survei kuesioner dan wawancara dengan 160 pemilik anjing dari delapan desa dalam radius 5 kilometer sepanjang perbatasan Hutan Lindung Batanghari. Saya menemukan bahwa sebagian besar anjing memiliki antibodi titer yang lebih rendah dari tingkat kekebalan minimal untuk perlindungan terhadap *virus rabies* baik untuk anjing yang divaksinasi maupun yang tidak divaksinasi. Hanya kurang dari 5% responden yang mengenal Virus Distemper pada anjing, dibandingkan dengan 75% yang mengenal *virus rabies*. Di Sumatra Barat, anjing umumnya digunakan untuk berburu, juga di dalam Kawasan Lindung Batanghari. Banyaknya jumlah anjing yang tidak divaksinasi terhadap *virus rabies* dan *distemper*, meningkatkan potensi penularan penyakit tersebut ke karnivora seperti harimau. Untuk mencegah penyebaran penyakit ke karnivora liar, diperlukan vaksinasi yang efektif dan dikombinasikan dengan regulasi berburu yang ketat, penegakan hukum dan edukasi tentang penyakit dan vaksinasi.

Bab 7 menggambarkan efek perubahan habitat terhadap okupansi harimau Sumatra. Di sini saya memfokuskan penelitian saya pada respons harimau terhadap situasi hutan yang berbeda. Dengan menggunakan kamera jebak, saya melakukan studi di tiga area yang berbeda, yaitu (i) hutan sekunder di wilayah inti Hutan Lindung Batanghari dibandinkan dengan (ii) hutan sekunder di yang berbatasan dengan perkebunan kelapa sawit, dan (iii) hutan sekunder yang berbatasan dengan pertanian campuran, untuk menilai bagaimana perbedaan habitat sekitar memengaruhi okupansi harimau Sumatera. Dengan menggunakan pemodelan okupansi, saya menemukan bahwa okupansi harimau dua kali lebih tinggi di hutan sekunder di wilayah inti hutan dibandingkan dengan daerah

yang berbatasan dengan pertanian campuran dan perkebunan kelapa sawit. Hasil dari bab ini menunjukkan bahwa lanskap pertanian tetangga mengurangi tingkat okupansi harimau dibandingkan dengan habitat inti.

Pada **Bab 8**, saya mengelaborasi hasil-hasil dari tesis ini dan membahas tantangan-tantangan konservasi harimau di Indonesia di masa depan. Kehilangan habitat yang terus berlangsung dan pembangunan yang lebih berpihak pada manusia mengancam masa depan harimau dan satwa liar lainnya. Hal ini mempertanyakan berapa lama harimau dapat bertahan di lanskap yang semakin terfragmentasi dan dikuasai oleh manusia. Memahami proses ekologi sangat penting untuk mencegah kepunahan spesies, tetapi tesis ini juga menjelaskan bahwa faktor *human dimension,* kepercayaan dan toleransi, pendidikan lingkungan, dan praktik lokal (berburu besar-besaran dengan dengan anjing, status kesehatan satwa) setidaknya sama pentingnya. Pengelolaan sumber daya alam yang efektif oleh otoritas bersama-sama dengan partisipasi masyarakat merupakan kunci keberhasilan dalam mencegah kepunahan harimau di Sumatra dan kemungkinan pada karnivora besar lainnya di tempat lain.

Translated by: Fatris MF

Samenvatting

Dutch

Grote carnivoren worden geconfronteerd met serieuze bedreigingen en ervaren enorme achteruitgang in hun populatie aantallen en geografische verspreiding. Door hun lichaamsgrootte en hoge metabolische vereisten hebben ze grote prooien en een uitgestrekt leefgebied nodig. Dit maakt grote carnivoren kwetsbaarder in een wereld die steeds meer gefragmenteerd is en gedomineerd wordt door mensen. Antropogene drukfactoren, met inbegrip van verlies en fragmentatie van habitat, vergeldingsdood en ziekte overdracht van gedomesticeerde dieren naar wilde dieren, dragen bij aan de achteruitgang. Dit maakt behoud en bescherming van grote carnivoren erg uitdagend. In dit onderzoek wordt met behulp van de Sumatraanse tijger als model soort, onderzocht hoe diverse antropogene drukfactoren de carnivoren beïnvloeden. De antropogene drukfactoren betreffen conflicten tussen mensen en wilde dieren, jacht, ziektes en habitat verandering. Dit onderzoek betreft een combinatie van empirisch onderzoek, analyses van secundaire data en modeleren.

Hoofdstuk 1 betreft de algemene introductie waarin het theoretische kader van deze thesis wordt gepresenteerd. Hiermee wordt informatie verschaft over de uitdagingen die betrokken zijn bij behoud en bescherming van de tijger.

In **Hoofdstuk 2** heb ik ruimtelijk-expliciete, lange termijn data van conflicten tussen mensen en tijgers in heel Sumatra geanalyseerd, om te begrijpen wat de schaal grootte is, welke milieufactoren het conflict bepalen, en wat de impact van het conflict is op zowel mensen als tijgers. In totaal zijn 1192 meldingen van mens-tijger conflicten geregistreerd tussen 2001 en 2019. De kans op conflict nam toe met de mate van menselijke verstoring en nam af met de afstand vanaf beschermde gebieden en met hoogte. Tijdens deze periode zijn 1419 vee dieren gedood of verwond en 262 mensen zijn gestorven of verwond. Binnen 18 jaar na de conflictmelding zijn 181 tijgers verwijderd uit het lokale gebied waarin het conflict plaatsvond. Hiervan zijn 129 tijgers gedood en 52 zijn in gevangenschap geplaatst, waarvan 10 weer elders in de natuur zijn geplaatst. Het aanmoedigen van milieueducatie, beheer van vee en het verzekeren van vee kan de impact van tijgers die in conflict komen met mensen verminderen. Om de impact van conflicten op tijgers te

verminderen is een snelle mitigatie reactie vereist van de instantie die verantwoordelijk is voor natuurbeheer. Daarnaast wordt het verspreiden van het conflict protocol onder het personeel en de lokale bevolking noodzakelijk geacht.

In **Hoofdstuk 3** heb ik factoren binnen de menselijke dimensie van mens-dier conflicten geanalyseerd. Dit betreffen de houding, mate van tolerantie en emoties ten opzichte van tijgers. Met behulp van data verkregen uit interviews in vier verschillende gebieden, met verschillende typen en impact van mens-tijger conflicten, heb ik sleutelfactoren beschreven die de factoren binnen de menselijke dimensie uitleggen. De emoties van mensen waren omgekeerd gecorreleerd met hun houding ten opzichte van natuurbehoud en -bescherming en met hun tolerantie voor tijgers. De impact van het conflict verklaarde de menselijke dimensie, maar niet de frequentie waarmee individuen conflicten ervaarde. Andere factoren bepaalden eveneens de menselijke dimensie, met inbegrip van milieu educatie ontvangen door dorpsbewoners en de locatie van landbouwvelden in relatie tot de bosrand. In dit hoofdstuk heb ik ook de financiële impact van mens-tijger conflicten bepaald. Daarnaast heb ik vergeleken hoe de impact van mens-tijger conflicten verschilt als enkel de directe impact op het getroffen individu wordt bekeken ten opzichte van wanneer de indirecte impact op de hele lokale gemeenschap wordt meegenomen. De ernst van het conflict, vooral op het niveau van de gemeenschap, wordt beter verklaard als de indirecte impact op de hele lokale gemeenschap wordt meegenomen, met name als er mensen zijn aangevallen. Derhalve stel ik voor dat een geïntegreerd programma waarin milieu educatie en compensatie voor het verlies van vee en mensen worden gecombineerd, niet gericht moet zijn op individuen, maar op de gehele gemeenschap; betrokkenheid van de gemeenschap bij het omgaan met conflicten kan de tolerantie voor tijgers verhogen, en dus bijdragen aan behoud en bescherming van tijgers.

In **Hoofdstuk 4** heb ik onderzocht hoe lokale mensen de mens-tijger conflicten beleven, en factoren geïdentificeerd die, volgens hen, het conflict veroorzaakten. Hierbij is speciale aandacht besteed aan culturele en spirituele waarden. Mensen verklaarden de oorzaak van mens-tijger conflicten als zijnde meer gerelateerd aan spirituele overtuigingen dan aan andere factoren. Echter, na verdere analyse van de interviews, hebben we ontdekt dat het houden van dergelijke overtuigingen niet leidt tot inherente bescherming van tijgers. Een verminderde inclusie van tijgers

in lokale cultuur zou de emotionele connectie tussen mensen en tijgers kunnen verzwakken, wat resulteert in verminderde tolerantie. Op basis van deze resultaten, stel ik voor dat strikter beheer van vee in gebieden nabij beschermde gebieden cruciaal is om conflicten te voorkomen. Ik verwacht dat toekomstige inspanningen voor mens-dier conflict preventie en mitigatie het meeste profijt zullen hebben van educatie over de biologie, ecologie en beschermingsstatus van tijgers in gebieden met een hoog risico op conflicten. Tevens zou opbouwen van capaciteit en participatie in natuurbeheer en -bescherming een kans kunnen vormen om de emotionele connectie van gemeenschappen met tijgers te versterken, en gedrag dat pro-natuurbescherming is ondersteunen, zelfs in tijden van conflict.

In **Hoofdstuk 5** heb ik mij geconcentreerd op de jacht door mensen op typische prooi soorten van de Sumatraanse tijger. Ik heb de omvang van actieve en passieve jacht op wilde zwijnen in West-Sumatra onderzocht, waarbij de focus lag op de jacht met behulp van jachthonden. Factoren die onderzocht zijn betreffen de soort die bejaagd wordt, voorkeursjachtgebieden, de motivatie van jagers om te jagen en potentiële ziekteoverdracht van jachthonden naar wilde dieren. Ik heb informatie van sociale media verzameld, expert interviews gedaan, en een vragenlijst-gestuurde enquête gehouden onder de jagers. Uit de resultaten blijkt dat actieve en passieve jacht op wilde zwijnen veel voorkomt in Sumatra. Jacht met behulp van geweren en valstrikken komt in alle acht provincies van Sumatra voor (behalve op de kleine eilanden langs de kust), terwijl jacht met behulp van jachthonden in slecht zes provincies voorkomt. In 2019 hebben tenminste 1331 jachtpartijen met behulp van jachthonden plaatsgevonden in de provincie Wes-Sumatra, op regelmatige basis. Deze jachtpartijen met jachthonden vonden voornamelijk plaats op zondagen, maar andere dagen in de week zijn niet uitgesloten. Er waren 10-300 mensen bij betrokken, waarbij elke jager 1-9 jachthonden mee nam. Jacht met behulp van jachthonden richt zich in West-Sumatra op wilde zwijnen (69 respondenten), sambar hert (29 respondenten) en in mindere mate op de muntjak (8 respondenten). veel jachthonden zijn niet gevaccineerd, waardoor een risico ontstaat op transmissie van ziekten als Rabiës en Canine Distemper Virus naar wilde dieren, zoals de bedreigde Sumatraanse tijger, de nevelpanter, de goudkat en diverse prooi soorten. De jacht wordt inadequaat gereguleerd, waardoor handhaving van regelgeving onmogelijk is. De omvang van de jacht op wilde zwijnen heeft vooralsnog niet gekwantificeerde, maar waarschijnlijk sterke effecten op overgebleven populaties van wilde dieren. Wij pleiten voor een goede kwantificering van de

jacht, en voor adequate regelgeving, met inbegrip van het gebruik en de gezondheidsstatus van jachthonden. Hierdoor kan ziekteoverdracht van honden op wilde dieren worden voorkomen, en kunnen resterende dieren in het wild worden beschermd.

In **Hoofdstuk 6** heb ik de potentie van overdracht van pathogenen van gedomesticeerde honden naar tijgers onderzocht. Hierbij ligt de focus op twee factoren, namelijk de prevalentie van pathogenen in de gastouder (de hond), en de interacties tussen honden en wilde dieren. Er zijn bloedmonsters verzameld van gedomesticeerde honden in omliggend tijger habitat, en lab analyses uitgevoerd van het Rabiës virus. Ik heb ook een vragenlijst-gestuurde enquête gehouden en 160 hondeneigenaren geïnterviewd uit acht dorpen binnen 5 kilometer van het Batanghari Protected Forest. De meeste honden hebben titer antilichamen lager dan het niveau waarbij sprake is van immuniteit voor het Rabiës Virus, voor zowel gevaccineerde als ongevaccineerde honden. Slecht <5% van de respondenten waren bekend met het Canine Distemper Virus, in tegenstelling tot 75% met het Rabiës Virus. In West-Sumatra werden honden veel gebruikt voor de jacht, ook binnen het Batanghari Protected Area. Het hoge aantal honden dat niet gevaccineerd is voor Rabiës en Canine Distemper Virus, verhoogd de potentie voor ziekteoverdracht naar carnivoren zoals de tijger. Om de verspreiding van ziektes naar wilde carnivoren te voorkomen, is effectieve vaccinatie in combinatie met strikte regelgeving omtrent jacht, wetshandhaving en educatie over ziekte en vaccinatie benodigd.

In **Hoofdstuk 7** worden effecten van habitat verandering op de aanwezigheid van de Sumatraanse tijger beschreven. De focus ligt hier op de reactie van tijgers in verschillende bos situaties. Met behulp van cameravallen zijn drie verschillende gebieden onderzocht, namelijk (i) secundair bos in de kern van het Batanghari Protected Forest, (ii) secundair bos grenzend aan palmolie plantages, en (iii) secundair bos grenzend aan gemengde landbouw. Hierbij is onderzocht hoe verschillen in aangrenzend habitat de aanwezigheid van tijgers in het bos beïnvloedt. Met behulp van een aanwezigheidsbepaling (‘occupancy modelling’), bleek dat de aanwezigheid van tijgers twee keer zo hoog was in het secundaire bos in de kern van het beschermde gebied, als in de bossen die grenzen aan gebieden met gemengde landbouw of palmolie plantages. De resultaten uit dit hoofdstuk suggereren dat de aanwezigheid van gebieden met landbouw nabij het bos de aanwezigheid van tijgers verlaagt ten opzichte van uitgestrekte bosgebieden.

In **Hoofdstuk 8** breng ik de resultaten van deze thesis samen en bespreek ik de uitdagingen omtrent het behouden en beschermen van tijgers in Indonesië in de toekomst. Het voortdurende habitat verlies en de mens-gecentreerde ontwikkelingen bedreigen de toekomst van de tijger en andere wilde dieren. Hierdoor ontstaat de vraag hoe lang de tijger zich nog kan handhaven in een landschap dat steeds meer gefragmenteerd is en wordt gedomineerd door mensen. Ecologische processen begrijpen is erg belangrijk om het uitsterven van de soort te voorkomen. Echter, in deze thesis wordt duidelijk dat factoren binnen de menselijke dimensie (overtuigingen en mate van tolerantie), milieu educatie, en lokale gebruiken (grote jachtpartijen met jachthonden, gezondheidsstatus) minstens zo belangrijk zijn. Effectief management van natuurlijke bronnen door de autoriteiten, in combinatie met de participatie van de bevolking, is de sleutel tot succes bij het voorkomen van het uitsterven van de tijger in Sumatra. Dit geldt waarschijnlijk ook voor andere grote carnivoren elders.

Translated by: Marjolein Poelman

Contents

Chapter 1

General introduction

Large carnivores face serious threats and are experiencing massive declines in their populations and geographic ranges around the world in past two centuries (Ripple et al., 2014). Their large body size require large-bodied prey and expansive habitat, which makes thems more vulnerable in a world that is becoming ever more fragmented and more human-dominated (Gittleman, 2013, 1985; Gittleman and Harvey, 1982; Goodrich et al., 2022; Ripple et al., 2014). Anthropogenic pressures, including habitat loss and fragmentation, persecution (negative interaction between human and wildlife), utilization (in relation to poaching and prey hunting) and disease transmission from domestic animals, are known to negatively affect global carnivore populations (Chapron et al., 2008; Dinerstein et al., 2007; Gilbert et al., 2015; Hill et al., 2020; Ripple et al., 2014) and this makes the conservation of large carnivores very challenging.

In this thesis I embrace the definition of conservation science by Kareiva and Marvier (2012), which incorporates conservation biology into a broader interdisciplinary field that explicitly recognizes the tight coupling of social and natural systems. The consequence and societal goal of my thesis is to contribute to pursuing conservation within landscapes by acknowledging the relevance of several stakeholders, including the local public as interested party, scholars, governmental organisations and NGOs, paying attention to human rights and equity. The goal of conservation is to ensure the persistence of natural processes in the landscape, enabling the species to interact without going extinct due to damaging anthropogenic forces. Therefore, understanding the ecological processes and driving factors affecting the population dynamics of species is needed to enhance conservation efforts for ecosystems in general, and for vulnerable species in particular (Melbourne and Hastings, 2008; Shoemaker and Akçakaya, 2015). Investigation of the impact of anthropogenic pressures on their population dynamics and extinction risk is a key area for carnivore conservation (Adhikari et al., 2022; Bull et al., 2007; Hill et al., 2020).

For carnivores and many other species, population dynamics and extinction risks are determined by a combination of both intrinsic and extrinsic factors (Bull et al., 2007; Cardillo et al., 2005; Lacy et al., 2013). Intrinsic factors include body size, population density, genetic variation, and trophic level. Extrinsic factors include size and location of their geographical range, environmental factors and anthropogenic pressures. However, Collen *et al*. (2011) found that extrinsic factors (combined environmental factors and threats) are better determinants of

population decline than intrinsic biological traits. Many large carnivore populations are at an all-time low and these anthropogenic pressures will speed up the extinction of carnivores (Ripple et al., 2014).

The earth is now becoming more human-dominated landscape where the habitat loss and fragmentation of wildlife habitat appears unavoidable (Haddad et al., 2015). Once fragmentation occurs in a landscape, affected species experience population reductions and may split into smaller populations (Haddad et al., 2015). Fragmented populations have reduced gene flow and may experience reduced genetic variation that can lead to population extinctions (McManus et al., 2015).

Fragmentation also increases the potential of spreading infectious diseases to wild carnivores from domestic carnivores such as dogs (Whiteman et al., 2007). The potential of disease transmission from dogs to carnivores increases when dogs become one of their prey (Butler et al., 2004). In Africa (Cleaveland et al., 2007, 2000), India (Belsare, 2013), Argentina (Orozco et al., 2014), Brazil (Whiteman et al., 2007), Chile (Acosta-Jamett et al., 2011) and Russia (Gilbert et al., 2015), domestics dogs have negatively impacted wild carnivore populations through disease transmission.

Interactions with humans lead to conflicts and even retaliations towards carnivores (Ripple et al., 2014; Woodroffe et al., 2005a), affecting their populations (Ripple et al., 2014; Swanepoel et al., 2015). However, to what extent this retaliatory killing affects the population dynamics of carnivores remains unknown (Swanepoel et al., 2015).

Many studies related human-wildlife conflicts has been conducted on social issues and human dimension of the conflicts (Carter et al., 2012; Dickman, 2010; Hill, 2004; Madden, 2004; Nyhus, 2016) but, few studies have been conducted on the impact of retaliation killing (as a result of conflict) on the population dynamics of carnivores (Swanepoel et al., 2015). Those that have done so mostly used quantitative models to predict the demographic consequences of different mortality rates in carnivore populations (Ahearn et al., 2001; Swanepoel et al., 2015).

Among all carnivores, the tiger, *Panthera tigris* (Linnaeus, 1758), is one of the species that globally has a very small population size and has undergone a dramatic decrease in the past 100 years and still continues to decline until now (Goodrich et al., 2022). The estimated number of mature individuals in the wild now ranges from 2150 to 3150 (Goodrich et al., 2022) and the species occupies only 7% of its historical range (Figure 1) (Joshi et al., 2016; Sanderson et al., 2010; Walston et al., 2010). The population is also highly fragmented (Walston et al., 2010) throughout the Asian continent which has a dense human population and rapidly developing regions (U. S. Census Bureau, 2004). Rapid conversion of forest into agriculture, commercial logging and human settlement as a result of economic development brings great pressure on tiger habitats (Wilcove et al., 2013). As tigers preferentially live in forested areas compared to non-forest areas (Sunarto et al., 2012), the conversion of forest into other purposes will continue to make the conservation of tigers more and more challenging.

There are some factors that contribute to the population decline of tigers. Among all factors, human-caused mortality, i.e., hunting and retaliation killing, has been identified as a major threat contributing to the decline of tiger populations and their prey (Goodrich et al., 2022; Robinson et al., 2015). Other key factors are habitat loss and fragmentation (Joshi et al., 2016) and disease transmission (Gilbert et al., 2015).

Understanding these pressures and their impact on tiger populations is crucial for tiger management and conservation. However, our knowledge of how tigers are responding to multiple, simultaneous anthropogenic pressures remains limited. Using the Sumatran tiger as a case study, I investigated how multiple forms of anthropogenic pressure affect the Sumatran tiger, and I pay specific attention to anthropological issues which are likely key to stopping and reversing threats to the tiger population in Sumatra. This study is a combination of an empirical study, analysing secondary data and modelling.

In **Chapter 2,** I analysed 18-year government and NGO records on human-tiger conflict events in Sumatra to quantify the probability of conflicts and determine factors causing the conflicts. Through a modelling approach, using MaxEnt, I to find out the main determinant of conlicts

between tigers and people in Sumatra. In addition, and new to science, I established the fate of individual tigers that were linked to prior human-tiger conflict events.

In **Chapter 3,** I analyse the "human dimension" factors of the human-wildlife conflict namely attitude, tolerance and emotions toward the tiger. Using interview data from four areas that have different exposures of human-tiger conflict, I describe the key determinants explained as the "human dimension" factors, with emphasis on the impact of human-tiger conflict on loval society, as well as the role of environmental education

In **Chapter 4**, I go deeper into understanding the biocultural background of people in communities with differential human-tiger conflict experiences in central-western Sumatra. In particular, I aimed at establishing the role of carnivores in general and tigers in particular in local folklore and religion, to get a handle on the roots of the rather widely established practice of retaliatory killing.

Another anthropogenic pressure that study in this thesis is about tiger's prey hunting, in particular wild boar hunting in Sumatra (**Chapter 5)**. In this chapter I studied the extent of active and passive wild boar hunting in Sumatra and West Sumatra in particular. I focussed on dog-assisted hunting practices, including target animal species, preferred hunting areas, and the motivation of the hunters for hunting. I also considered potential disease transmission by hunting dogs to game using three types of data: (1) information from social media about dog-assisted wild boar hunting events in West Sumatra; (2) a questionnaire-guided survey among hunters around the Batanghari Protected Forest, West Sumatra; (3) expert interviews from provincial conservation offices about wild boar hunting practices in Sumatra.

In **Chapter 6,** I studied the potential of pathogen spillover from domestic dogs to tiger. The focus of this chapter is to find out the exposure of disease transmission from domestic dogs to tiger, with a focus on Rabies and Canine Distemper Virus. In this chapter I draw possible routes of disease transmission from domestic dogs to the Sumatran tiger.

In **Chapter 7,** I describe tiger occupancy in three different areas. Here I am focusing my study on the response of tigers to different forest edge situations. Using camera traps, I conducted the study in three different secondary forests, neighbouring (i) palm oil plantation, (ii) mixed agriculture and (ii) primary forest, to establish how these neighbouring habitat differences affect Sumatran tiger and natural prey occurrence, under the influence of human activities.

At last, in **Chapter 8**, I synthesise the results of this thesis and discuss the challenges of tiger conservation in Indonesia in the future. The ongoing habitat loss and human-centred development threatens the future of the Sumatran tiger and other wildlife. This puts into question how long the tiger can persist in the landscape that is now strongly human-dominated. Understanding ecological process are very important to prevent the extinction of the species, yet we also must consider human dimension factors to better understand the problem to reverse the current biodiversity decline. My discussion includes several recommendations to be put in place and I conclude that effective management of natural resources by the authorities, together with the active participation of the people inhabiting the complex landscape matrix is key to preventing the extinction of the tiger.

Chapter 2

The fate of tiger after conflict:

the island wide human-tiger conflict in Sumatra

Erlinda C. Kartika & Ignas M.A. Heitkönig

Abstract

Conflicts between humans and large carnivores are key issues in large carnivore conservation. Understanding the conflict from both human and carnivore side is important to seek ways of managing this conflict, but there is scant information on the fate of carnivores after the conflict. We analysed long term (2001-2019), island-wide human-tiger conflict (HTC) data from Sumatra, Indonesia, to understand the distribution and the drivers of this conflict, and the impact of the conflict on both people, livestock and tigers. A total of 1192 human-tiger conflict reports were officially recorded in that period, of which we established the fate of the tigers within 18 months after the conflict. The probability of conflict was higher with more human disturbance in ecosystem and was lower with distance from protected areas and with elevation. A total of 262 humans and 1419 livestock were reported killed or injured. In the same period, and within 18 months after HTC, most tigers escaped retaliation or follow-up action. A total of 129 tigers were killed, 42 were captured, and 10 tigers were translocated to another area. We suggest that promoting environmental education, livestock management to reduce tiger encounter and livestock insurance could minimize the impact of conflict with humans. To reduce the impact of the conflict on the tiger, fast response conflict mitigation from the conservation office, and disseminating the conflict protocol both to the staff and to local people is deemed necessary.

2.1. Introduction

Conflicts between people and large carnivores, including felids, have become urgent conservation issues worldwide (Ripple et al., 2014). Over 75% of the world's felid species are involved in and affected by human-felid conflicts (Inskip and Zimmermann, 2009). Being predators, felids are the most prominent species causing human-wildlife conflicts and are commonly considered as a threat to human safety and livestock (Nyhus, 2016). Felids are particularly predisposed to conflicts with humans because of their large home range and dietary requirements (Dickman, 2010).

Many studies on human-wildlife interactions emphasise the scale and impacts of the conflict from a human point of view but not from the wildlife's point of view (Bhattarai et al., 2019; Nyhus and Tilson, 2004; Perry et al., 2020; Thirgood et al., 2005). In the case of human-carnivore conflict most papers focus on the economic or psychological impact on humans following the carnivore's attacks on livestock or humans, while often reporting that retaliatory killing of the carnivore occurs (Aryal et al., 2014; Athreya et al., 2013; Kuiper et al., 2022; Miller et al., 2016). No studies focus on the fate of wildlife and carnivores in particular after human-carnivore conflicts. In this paper, we aim to shed light on the fate of tigers.

Wide-ranging conservation impacts of human-wildlife conflict point to an urgent need for effective solutions to reduce the killing of 'problem' wildlife (Woodroffe et al., 2005a). For effective human-carnivore conflict mitigation, understanding the drivers of the conflict is essential. Despite being highly complex and species- and site-specific, understanding the factors that are likely to affect hostility towards 'problem' animal is an important step towards effective mitigation (Dickman, 2012).

The tiger (*Panthera tigris*) is one of the felid species involved in and affected by conflicts with humans. People can lose their life and livestock while tigers face removal from their original habitat or even death because of lethal control (Nyhus and Tilson, 2004). Livestock predation and attacks on humans by tigers may lead to a negative attitude toward tigers. Fear and anger associated with the loss of livestock or human injuries and death make people less tolerant toward tiger and kill them in retaliation (Aryal et al., 2014; Carter et al., 2012; Karanth and Chellam, 2009).

Proximity to human settlements and a large human footprint are also drivers for the killing of carnivores (Hill et al., 2020; Lamb et al., 2020).

When tigers cause significant damage to human lives and livelihoods, it is common to respond by killing them, or at least that is the perception (Woodroffe et al., 2005a). Retaliation killing due to conflicts between humans and tigers is well-documented in some regions. For example, in Russia, retaliation killings accounted for 20-30% of tiger deaths between 1951 and the early 1990s (Miquelle et al., 2005). In many areas of South Asia and Southeast Asia, a high number of tigers have been legally killed or removed from the wild in response to conflict, with 2-4 tigers per year being killed or removed in some places (Kawanishi et al., 2010; Nugraha and Sugardjito, 2009; Smith et al., 2010). In Russia, 55 tigers were killed under permit between 1985 and 2002, mostly due to livestock predation or in defense of human welfare (Miquelle et al., 2005). Similarly, in Nepal, 25 tigers were removed between 1979 and 2006 because they had killed or threatened people in or near Chitwan National Park (Gurung, 2008).

The world's tiger populations continued to decline until about a decade ago (Sanderson et al., 2010; Walston et al., 2010). There currently are an estimated 2608-3905 mature tigers in the world, with some country-wide increasing, some stable, but often unknown or still declining population sizes, generally due to forest declines and agricultural expansion (Goodrich et al., 2022).

Of the three sub species of tiger that lived in Indonesia, namely Sumatran tiger (*Panthera tigris sumatrae*), Bali tiger (*Panthera tigris balica*) and Javan tiger (*Panthera tigris sondaica*), both the Javan tiger and the Bali tiger are extinct (Goodrich et al., 2022). In particular, the human-tiger conflict became the major driver for the extinction of the Javan tiger (Boomgaard, 2001). The Sumatran tiger is now the only sub species living in Indonesia and the population continues to decline in which human tiger conflicts contributed for this decline (IUCN, 2008). A recent report shows that the Sumatran tiger population stands at approximately 568 adult individuals (Wibisono, 2021) and that the population is still under immense threat. Considering this situation, reducing and preventing all causes of mortality of tiger appears to have become critical to successful tiger conservation (Goodrich et al., 2022). As human-tiger conflicts do contribute to the mortality of

tigers and thus to their continued population decline, this calls for a better understanding of the scale and the distribution of human-tiger conflict (HTC) data, to elucidate the main spatial and local causes of the conflict. The spatial pattern of human-wildlife conflicts typically does not occur randomly in space (Nyhus, 2016). This is because of the complexity of many aspects of human-wildlife conflict including wildlife behaviour and ecology, human dimensions, as well as characteristics of the area (Dickman, 2010; Madden and McQuinn, 2014; Nyhus, 2016). Predicting high risk future conflict areas will be beneficial to reducing the impact of conflicts (Behdarvand et al., 2014; Broekhuis et al., 2017; Goswami et al., 2015).

In this paper we analysed long-term (18 years) records of HTC conflict data from Sumatra, Indonesia, to understand (i) the spatial distribution of human-tiger conflicts and (ii) the impacts of the conflicts on people and on tigers. We discuss conflict management options to mitigate HTC and reduce negative impacts on the tiger population.

2.2. Methods

Records on human-tiger conflict

The study area consisted of mainland Sumatra. Eighteen years of records (2001-2019) related to HTC have been collected and compiled from the provincial office of the Ministry of Environment and Forestry (MoEF) and several NGOs working for tiger conservation, i.e., HarimauKita, World Wide Fund for Nature, Zoological Society of London, the Sumatran Tiger Trust, Fauna & Flora International, and the Wildlife Conservation Society. In total, 1192 unique records of HTC were filed during these years, i.e., excluding records of the same events recorded by different organisations. Within this dataset only 428 entries had GPS coordinates; the remaining records had only village name and type of conflict.

Assessment of the probability of HTC across Sumatra

To understand the spatial variability in HTC data, we modeled the conflict probability across Sumatra, based on reported data from the Ministry of Environment and Forestry and NGOs. In this analysis, we used Maximum Entropy Modeling (Maxent Version 3.4.4) to model the probability of conflict based on presence-only data. Freely available environmental data used for the analysis included the Human Footprint Index, distance to protected area, elevation, slope,

livestock density, and tree cover loss. Prior to running MaxEnt, the correlation coefficient matrix was compiled using the entire extent of all environmental variables using R package ENMTools. Two highly correlated variables were found, namely: 'elevation' and 'slope' (r=0.73). In the subsequent analyses we included elevation data, not slope; (see Supplementary S1). The independent environmental variables included in the models to understand HTC are listed in Table 1.

Table 1. Environmental variables used in the Maximum Entropy Modeling analysis

Environmental Variable	Value	Source
Human footprint index	Proxy for human disturbance of the natural ecosystem (range from 0 to 50)	(Venter et al., 2016a)
Distance to protected area	Kilometer	MoEF of Indonesia
Elevation	Meter above sea level	(Jarvis et al., 2008)
Livestock density	Total individuals (goat + cattle + water buffalo) (animals/km^{-2})	Robinson et al. (2007)
Tiger occupancy	Probability of tiger occurring in an area (range from 0 to 1)	(Wibisono et al., 2011)
Population density	Average human density within 10 km (number/km^{-2})	
Tree cover loss	average 10 km radius (%)	(Hansen et al., 2013)

The R package 'ENMeval' was then used to select the 'optimal' model settings for feature type and regularization parameter using the remaining non-correlated environmental variables (Muscarella et al., 2014). The evaluation suggested (ΔAIC~0) feature types L=linear and Q=quadratic to be used to run MaxEnt and regularization multipliers that increased incrementally with a value of 1. Using the same R package, we created a bias file based upon the presence points where most conflict occurred by creating kernel density (see supplementary file 2) assuming that these areas were the places easiest to sample. The bias points (or background data) were selected preferentially from areas of a high density of presence points (Phillips et al., 2009). The bias file has been found to improve model performance (Phillips et al., 2009; Stolar and Nielsen, 2015).

We used default settings with a maximum iteration of 500 and implemented a jackknife (i.e., 'leave-one-out') procedure. We attached a bias file that we created before and evaluated the variable chosen in the model by comparing AUC values. The AUC values ranged from 0 to 1, where a score of 1 indicates perfect discrimination, a score of 0.5 implies predictive discrimination that is no better than a random guess, and values <0.5 indicate performance worse than random (Merow et al., 2013).

The impact of the conflicts on humans and tigers

The HTC reports in the dataset were unique, but one report could follow on another one within a matter of days. For instance, one report could detail a livestock fatality while a subsequent one in the same village but a few days later could detail a human injury. Hence, independent records could be linked in time, and we took this into account in the analysis. The dataset contained records about the location and date of the conflict, whether a tiger attacked humans, livestock, or were only passing by (stray). Other records detailed location, date, and the fate of a tiger (killed, captured, translocated, or escaped) likely involved in one or more sequential HTC events up to 18 months before in the same location.

Characteristics and scale of conflict

To understand the characteristics of the HTC events we classified each one either as (1) from the human point of view or (2) from the tiger point of view.

From the human point of view, we distinguished three classes of impact:

(1) Stray tiger: the conflict was categorized as such if (a) a tiger roamed around the village, installing fear in people, or (b) people in the village coincidentally saw a tiger in or around a village which threatened them or their livestock, without making victims.
(2) Livestock depredation: the tiger attacked and killed or injured livestock.
(3) Human attack: the tiger attacked and killed or injured a person.

Whether a tiger was captured or died could often be linked to one or more sequential HTC events up to 18 months before in the same location. From the tiger point of view, the fate up to 18 months after conflict with people and/or livestock was categorised into:

(1) Escaped: the tiger likely involved in the conflict escaped from persecution.

(2) Killed: either by snare, poison, rifle or another device in the area of conflict by either villagers or poachers.
(3) Captured: the tiger was captured by conservation authorities in the conflict area and kept in the zoo.
(4) Translocated: the tiger was captured from the conflict area by conservation authorities, kept in a zoo or rehabilitation centre for a certain period, and was subsequently translocated to another area.

We quantified the impact of the conflict for the tiger through a tiger mortality index and through a tiger removal removal index as calculated below. The tiger mortality index is expressed as the number of tigers killed per conflict, either through poison, snare, or after initially being rescued by the conservation office.

$$\text{Tiger mortality index} = \frac{\text{number of tigers killed}}{\text{number of conflicts}} \qquad \textit{Equation 1}$$

The tiger removal index is expressed as the number of tigers being removed from its habitat per conflict, i.e., the tiger died or was captured and kept in a zoo or rehabilitation centre, without being translocated.

$$\text{Tiger removal index} = \frac{\text{number of tigers removed}}{\text{number of conflicts}} \qquad \textit{Equation 2}$$

All translocated tigers were excluded from the calculation of the tiger removal index.

2.3. Results

Human-tiger conflict probability distribution model and factors contributing to conflicts

High HTC probability appears to occur across the entire Sumatra mainland, but the conflict probability is highest in a central East-West band, and in several rather thin bands along several of the coastal hill areas (Figure 1).

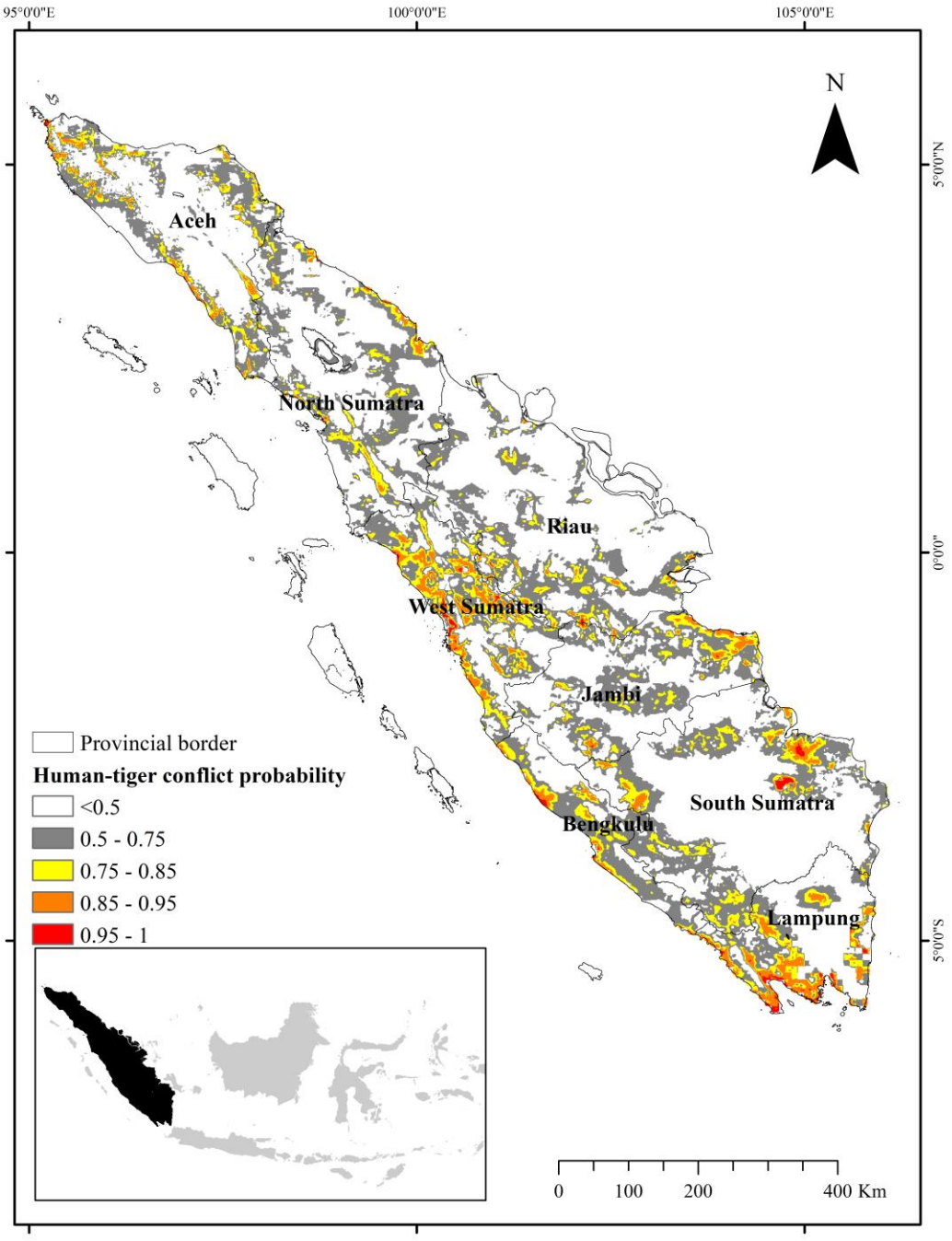

Figure 1. Predicted human-tiger conflict probability distribution on mainland Sumatra. Areas with yellow, orange and red colours have a high probability of conflicts. Thin black lines represent province boundaries. Inset: Sumatra, part of Indonesia.

Table 2. Selected environmental variables, their percent contribution to, and their permutation importance in the Maxent model for predicting HTC probability in Sumatra.

Variable	%Contribution	Permutation importance
Human footprint index (scale 0-50)	34.3	28.6
Distance to protected area (km)	29.7	35.2
Elevation (m a.s.l.)	20.4	13.5
Livestock density (individuals/km^{-2})	6	10.2
Tiger occupancy (probability 0-1)	5	3.6
Tree cover loss (%)	3.9	6.6
Human population density (number/km^{-2})	0.7	2.3

The human-tiger conflict distribution model across Sumatra performed well, with an average test AUC for the 10 replicate runs was 0.747 (sd = 0.055). Three environmental variables contributed considerably more than 10 percent to the probability distribution, namely: human footprint index (34.3%), distance to protected area (29.7%), and elevation (20.4%). Four variables had a permutation importance higher than 10 percent, namely: distance to protected area (35.2%), human footprint index (28.6%), elevation (13.5%), and livestock density (10.2%). Tiger occupancy, tree cover loss and human population density contributed no more than 5%, with a permutation importance well below 10% (Table 2).

The probability of conflict is high at close proximity to a protected area but dropped to about 0.2 at 30 km distance from a protected area (Figure 2a). The probability of conflict peaked in the range of 15-30 on a scale of 50 (Figure 2b).

The higher the area, the smaller the conflict probability (Figure 2c). HTC probability peaks around 3000-9000 livestock/km^{-2} (Figure 2d; NB livestock include chickens and pets). In terms of model fit, elevation plays a significant role in determining conflicts, with a contribution of about 20%. Tiger occupancy, tree cover loss and average human population density contribute little to the model, but removing these variables did not improve the model fit (AUC).

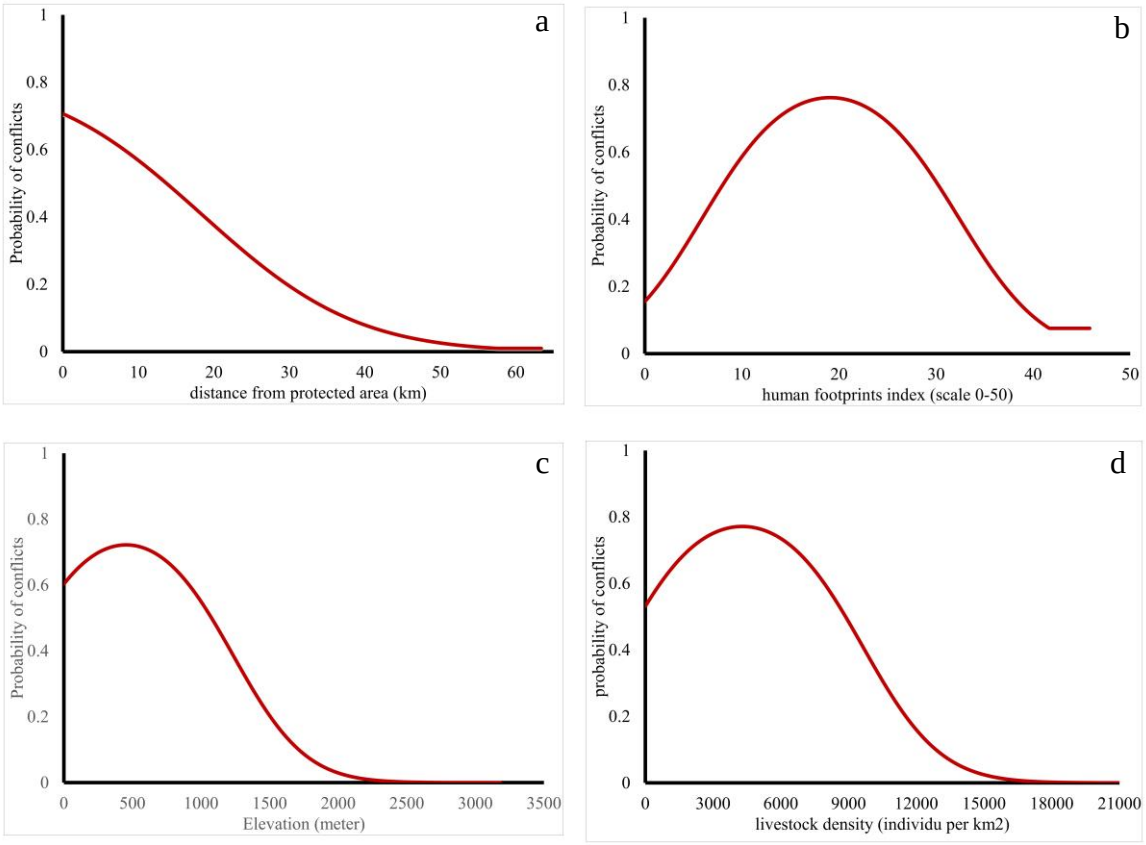

Figure 2. Response curves of four variables with permutation importance >10. (a) distance to protected area; (b) human footprint index; (c) elevation and (d) livestock density

Characteristics of the human-tiger conflict

In total, 1192 documented conflict data were recorded from all of Sumatra, of which 1052 reports detailed the impact on humans. Most conflict reports involved attacks on livestock (41%), closely followed by stray tigers (39%), while attacks on humans amounted to 20%. Another 138 records detailed the fate of tigers without mention of the impact on humans.

The impact of the conflicts

Human victims

In total, there were 260 human casualties (135 dead and 125 injured) within the 18-year period, amounting to ~15 people/year. Most attacks on people occurred in agricultural fields (31%) and in forest areas (30%), 7% in a plantation (either oil palm or forest plantation) and 2% on the village border. 28% of the data entries had no information on where the attack occurred.

Livestock depredation

Livestock depredation was the most commonly reported conflicts and caused direct economic loss. Over the eighteen-year period a minimum of 1419 livestock or pets were reportedly killed by tigers (Table 3). The highest number of livestock attacked were goats, with 644 goats killed or injured, followed by 231 cattle killed or injured by a tiger.

Table 3. Numbers of documented livestock/pets attacked by the tiger in Sumatra (2001-2019)

Livestock/pets	**Total**
Goats	644
Cattle	231
Dogs	212
Chickens	195
Water buffaloes	126
Other species	11
Total	1419

The fate of tiger after conflict

Most tigers (n = 1011) escaped and were not captured or killed after a reported HTC. Out of the 181 tiger victims that were documented, 129 individuals died, 42 tigers were sent to a zoo or other captive facility, and an additional 10 tigers were translocated after capture. Many of the documented tigers were involved in one or more conflict situations in the prior 18 months. Table 4 provides a recapitulation of the types of conflict in which these tigers were involved before becoming victims of the conflicts.

Table 4. Fate of tigers in eighteen-month period after reported human-tiger conflict. Stray = tiger walked in or near village, installing fear; Livestock = tiger attacked livestock; Human = tiger attacked a person. The type of HTC included events which occurred within a few days of each other in the same area.

Type of human-tiger conflict	Died	Captured	Translocated
Stray	6	8	2
Stray+livestock	26	8	2
Stray+human	2	3	
Stray+livestock+human	8		
Livestock	35	6	4
Livestock+human	18		
Human	15	10	1
Not specified	19	7	1

Figure 3 shows the tiger mortality index and tiger removal index per year over the course of the study period. In 2015, the tiger removal index was 0.44 (i.e., 44% of tigers that were involved in conflicts were captured and removed from their habitat). In the years 2008, 2009 and 2010 the number of conflicts was highest, with 104, 147 and 160, respectively, whereas the tiger removal and mortality indices peaked much later, in 2015. The tiger mortality and the tiger removal indices appear correlated and varied together over time, but were not clearly linked to the variation in the number of HTC reports (Figure 3).

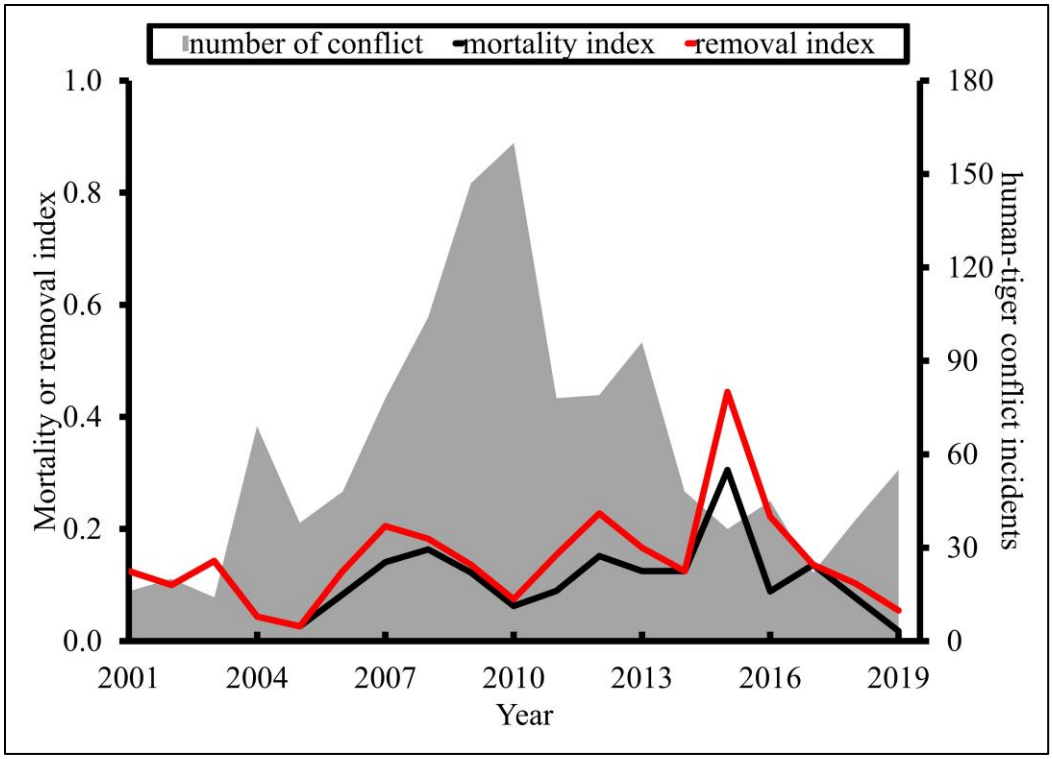

Figure 3. Tiger mortality and tiger removal index per year between 2001 and 2019 on Sumatra.

2.4. Discussion

The probability of conflict was higher in areas with a medium human footprint index, and decreased gradually when (i) further away from a protected area and (ii) with higher elevation. The 18-year conflict reports showed a strong impact on both people and tiger, with 260 human fatalities or injuries and 1419 livestock killed or injured and. 181 documented tiger fates within an 18-month time window after HTC included 129 kills, 42 remaining in captivity and 10 being translocated.

In Sumatra, tiger attacks on humans mostly occur when people were engaged in activities in the forest or near forest edges, particularly with agriculture and estate crops. This broadly corresponds to areas with intermediate levels of disturbance, including expanded crop lands and urban development (Venter et al., 2016a). The highest occurrence of human attacks was in the Central-East Sumatran provinces of Jambi and Riau, where also the highest percentage of forest change was recorded from 2003 to 2013 (Figure 4). Although tree cover loss contributed little to the

Maxent model for predicting HTC probability (3.9%) and had a low permutation importance (6.6%, Table 2), forest cover decreased and the extent of oil palm plantations increased in all provinces of Sumatra over the period 2003-2013 (MoEF, 2016; Figure 4). Also, the extent of mixed agriculture - which includes rice, rubber, coffee and cocoa - tended to increase in most provinces, except in North Sumatra where oil palm plantations increased most. In the province of Riau, the mixed agriculture area increased to 112%, and Jambi and Riau are also the provinces with the largest number of smallholder oil palm plantations (Badan Pusat Statistik, 2013). In smallholder oil palm plantations and mixed agriculture areas people usually visit their crop fields alone or in very small numbers, likely making themselves more vulnerable to tiger attack (Seidensticker and McDougal, 1993).

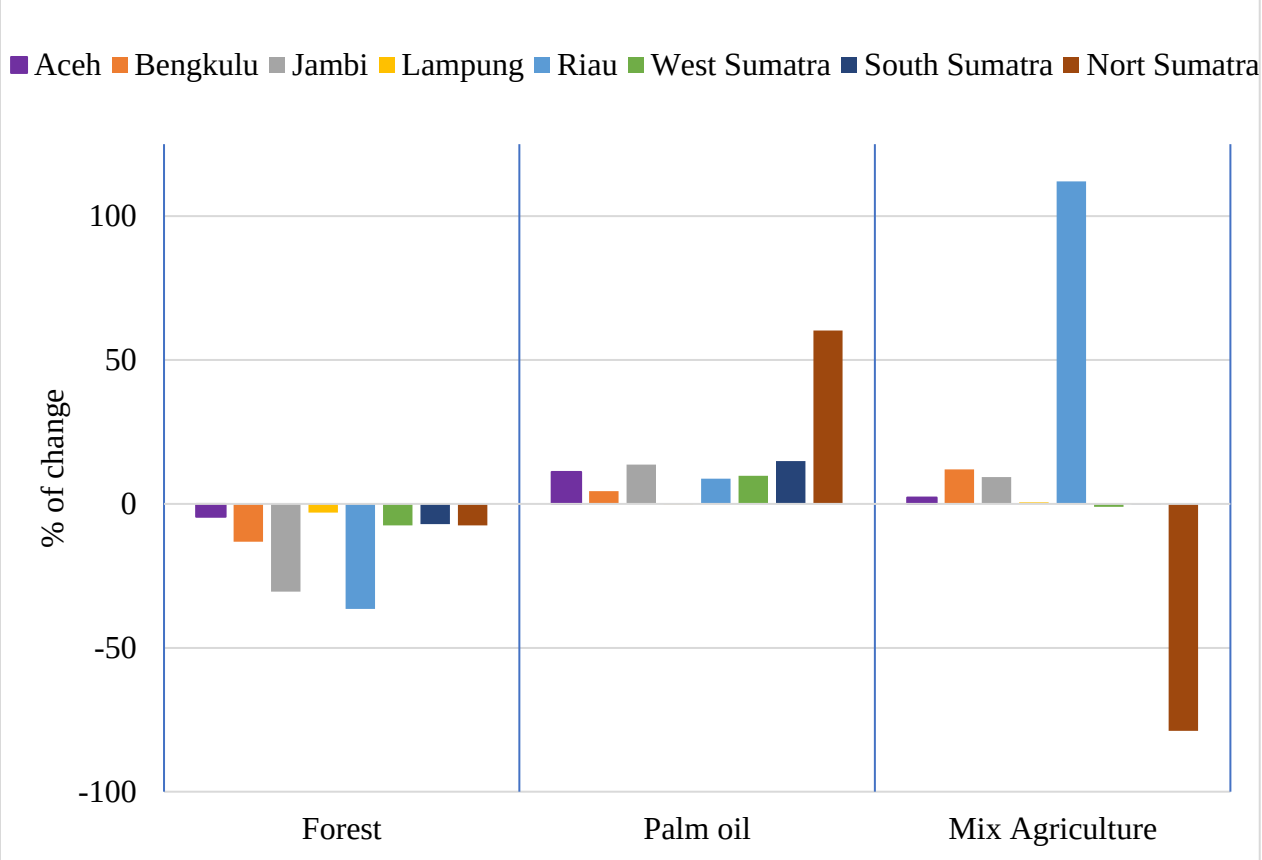

Figure 4. Percentage of land use change per province: forest, mixed agriculture and oil palm plantation from 2003 to 2013 (Ministry of Environment and Forestry, 2016)

Livestock attacks and stray tigers occur most prominently (summed at 80%) in the HTC reports, although the modelling analysis suggests that livestock density contributes little (6%) towards

explaining HTC probability (Table 2). This can be explained by the fact that (1) livestock density as used in the modelling includes a large array of small animals, including chickens which typically occur in large numbers and pets (Table 3), and that (2) livestock is poorly managed in most areas in Sumatra. In fact, the most valuable animals like cattle, water buffaloes and goats, of which households keep only one or a handful of individuals, are not kept in a proper cage but left outside on a rope or without constraint. In West Sumatra, people are known to often leave water buffaloes to forage inside the forest neighbouring dwellings and villages without a guardian; those animals will only be checked upon once in a month or even less (ECK, personal observations). These practices undoubtedly increase the chance of valuable livestock being attacked by tigers, and they are also linked to the poor livelihoods of smallholder farmers.

Keeping livestock without proper enclosure or other type of protection attracts stray tigers to approach dwellings and villages. Large carnivores catching free ranging domestic livestock requires less energy than catching wild prey (Woodroffe, 2000). Increasing local people's awareness on livestock management (Eklund et al., 2020; Miller et al., 2016) along with campaigning or even providing subsidies to build proper protection mechanisms for livestock may significantly reduce HTC in conflict prone areas. Creating and guarding proper enclosures for livestock close to tiger habitat, where the probability of tiger encounters is high, will reduce conflicts (Eeden et al., 2018; Holland et al., 2018) and improvements in livestock management do not need to be costly.

Livestock victims and stray tigers accounted for almost half (i.e., 61 out of 129) tigers being killed, whereas all conflicts including human victims accounted for fewer (i.e., 43) reliatory tiger kills (excluding tiger kills without prior conflict reports) (Table 4). Similar observations on retaliatory killings are reported from Kenya, for example, where Maasai pastoralists will kill a lion after livestock predation (Ontiri et al., 2019). Bad management of conflict including a slow response from the conservation office could also trigger people to resort to retaliatory killing, as was found in the case of leopard attacks in South Africa (Viollaz et al., 2021). There are several cases observed in Sumatra, where villagers called a tiger shaman or even a poacher to capture or kill the tiger when the governmental authorities did not respond to reports from villagers (ECK, personal observation).

Mortality of carnivores can have consequences well beyond the loss of individuals. Removal of adult males might result in infanticide by immigrating males and in reduced reproductive rates (Goodrich et al., 2008). High mortality of adult female tigers can result in reduced reproductive rates, cub and sub-adult survival, and reduced population growth rates (Goodrich, 2010; Goodrich et al., 2008).

Only 10 tigers were translocated after being rescued between 2001 and 2019 (Table 5). Resolving tiger conflicts by removing them from their habitat is likely ineffective and could lead to other conflicts. For instance, there is currently a conflict with wild boar in Sumatra, which has led to the perceived need for hunting them to control their population (see Chapter 5 in this thesis). Removing a tiger from a certain area could actually increase the population of wild boar, increasing farmers' crop losses. The presence of a tiger is not only important for controlling the number of wild boar, but also for suppressing their reproduction (Gaynor et al., 2019; Laundré et al., 2010). The removal of predators has been proven to be an ineffective way to resolve similar conflicts in many other areas too (Lennox et al., 2018). This calls for different, more effective approaches to reduce human-carnivore conflicts.

In line with other studies we support the need to develop a human-carnivore coexistence strategy if large felids like the tiger are to be conserved (Carter and Linnell, 2016). In Sumatra there is room to include (1) faster and more effective tiger response by the conservation office, (2) education on environmental and tiger ecology, and (3) improvement of livestock management, including livestock insurance for farmers. In terms of (1) tiger response by the conservation office there is a protocol to handle human-tiger conflicts without delay (P.48/Menhut-II/2008). However, the implementation of the protocol is still lacking especially on the implementation of the decision tree for choosing best methods for handling the conflict, where removal of the animal is the last option for conflict management. Many staff members in the conservation office are not aware of this decision tree, but even if they are aware, affected villagers almost always ask the officer in charge to capture the carnivore involved in the conflict, particularly if it is a tiger. Considering (2) education on tiger ecology and behaviour, smallholder oil palm plantation owners and other smallholder farmers appear to yield large gains from effective education programs which include guidance on entering forests and protection of valuable livestock, resulting in a reduction of HTC,

in part through increased tolerance toward the tiger (see also Chapter 3 in this thesis). This is in line with research by Carmi et al. (2015) and Sponarski et al. (2016). In terms of (3) livestock management and insurance, the government of Indonesia has recently launched a livestock insurance program to mitigate farmers from sudden death of livestock from diseases, theft or accidents (Ministry of Agriculture, 2022). The insurance is largely subsidized by the government, also supporting farmers from a large predator depredation impact.

While we have no doubts about the quality of the data we used in our analyses, the original data were mainly recorded if the conservation office or NGO was involved in rescue or conflict mitigation. The wildlife rescue unit, either from the conservation office or an NGO will only go to conflict sites when there is a report from the conflict area (which could come from local people, police, or army). Tigers are considered dangerous animals, so when conflicts involve human casualties or large and valuable livestock, they are normally reported faster than in the case of a stray tiger. If conflicts are not reported, they will not be recorded in the database. Hence, the actual number of casualties and fatalities on the side of people, livestock and tiger could be higher than reported by us over the 2001-2019 period.

In conclusion, the analysis of HTC across Sumatra reveals higher probabilities of conflict near forested areas, especially in forest margins and agricultural areas neighbouring forests, linked to deforestation and associated land-use changes. Translocation of tigers appears to be an inefficient and costly procedure to mitigate conflicts. Human and livestock casualties as well as tiger losses can be strongly limited by proper livestock management, adequate conflict response actions, a livestock insurance scheme and environmental education.

Supplementary S1. Correlation matrix for variables used in maxent

SPECIES	tiger.asc	avloss.asc	avpop10km.asc	distpa.asc	elevation.asc	footprints.asc	livestock.asc	slope.asc
tiger.asc	1	-0.10215	-0.10056	-0.07314	0.037758	-0.1354	-0.10527	0.087625
avloss.asc	1	1	-0.14333	0.312029	-0.47531	-0.08442	-0.27029	-0.45624
avpop10km.asc	1	1	1	0.054217	-0.09969	0.497093	0.476704	-0.09379
distpa.asc	1	1	1	1	-0.41868	0.22885	-0.00986	-0.42096
elevation.asc	1	1	1	1	1	-0.29082	-0.05255	0.725153
footprints.asc	1	1	1	1	1	1	0.456414	-0.29329
livestock.asc	1	1	1	1	1	1	1	-0.07188
slope.asc	1	1	1	1	1	1	1	1

Chapter 3

Impacts, costs and human dimensions of human-wildlife conflicts in West Sumatra, Indonesia

Erlinda C Kartika & Ignas M.A. Heitkönig

Abstract

Human–wildlife conflicts contribute to declining wildlife populations. To effectively address and reduce these conflicts, an understanding of their characteristics is required, including an assessment of how deeply the conflicts impact human communities. We focus on the impacts, impact-derived costs, and human dimensions of conflicts between humans and Sumatran tigers (*Panthera tigris sumatrae*). A semi-structured interview was conducted with 128 respondents from four villages in West Sumatra, Indonesia, which have experienced contrasting types of human-tiger conflict. In the case of tiger attacks on people, direct impacts affected only 3.3% of community members, but when including indirect impacts, >96% of community members were affected in many ways, strongly amplifying the direct individual impacts. The costs reflected the impacts. Direct costs were limited to the affected individuals or families, while indirect costs were mainly felt at community level, including huge opportunity costs such as lost income due to time away from the fields. Our analysis of the human dimensions of the conflict found that people's emotions were inversely correlated with their conservation attitude and with their tolerance of tigers. We found that calculating indirect impacts of conflicts helped explain their severity, specifically at the community level, and especially when humans were attacked. Our study suggests that an integrated program combining environmental education, and compensation for livestock and human losses, should not be aimed at individuals, but rather at the community level; community involvement in handling the conflict could increase tolerance for tigers, thus contributing to tiger conservation.

3.1. Introduction

Conflicts between humans and wildlife have become critical threats to wildlife conservation and have received increasing attention from conservation biologists (Ripple et al., 2014). This issue includes a wide range of species and is likely to escalate (Dickman, 2010). Some taxa have the potential to cause harm and damage to humans and their property (Strum, 2010). For example, crop-raiding by elephants in Africa and Asia (Shaffer et al., 2019), livestock depredation by carnivores (Treves and Karanth, 2003), attacks on humans by tigers (Nyhus and Tilson, 2004), disease transmission to livestock or humans (Cripps et al., 2019; Nyhus, 2016) and opportunity costs, where people lose economic opportunities as a result of the presence of wildlife (Thirgood et al., 2005) are costs that may occur as a result of living alongside wildlife.

The impacts of human-wildlife conflict can be categorized into direct and indirect impacts (Thirgood et al., 2005). Direct impacts are the physical or structural impacts that refer to directly quantifiable losses as a result of human-tiger conflict, such as livestock depredation, crop damage and personal injury or family loss. Indirect impacts are the subsequent or secondary results of the initial impact, such as time and money spent in preventing tiger attacks, time of disrupted school attendance, and opportunity costs. Both direct and indirect impacts may drive people to establish defenses and anticipatory behavior to protect their lives and their properties (Hazzah et al., 2009) which lead in turn to cautious or negative attitudes toward wildlife and eradication of wildlife around villages (Ontiri et al., 2019).

To manage negative interactions between humans and wildlife in conflict situations, an emphasis on the wild animals and their habitats, such as building fences, only has proven to be inadequate (Lischka et al., 2018). In the last decades, wildlife managers have gradually expanded their scope to incorporate a “human dimensions” approach which emphasizes describing, understanding, predicting and changing human thoughts and actions toward wildlife (Marchini, 2014). Understanding concepts that underlie the process of transforming human thought to actions, such as value, belief, risk, perception and acceptance, psychology, attitude and norms, tolerance and the relationships among them, can be beneficial for managing human-wildlife conflicts (Carter et al., 2012; Struebig et al., 2018).

Carnivores are prominent in human-wildlife conflicts and are commonly considered a threat to the safety of people and their livestock (Eeden et al., 2018). The common response when carnivores cause serious damage to people and their livelihoods is retaliatory killing. This reaction has led to the extinctions of several carnivore populations (Woodroffe et al., 2005b), including three subspecies of the tiger (*Panthera tigris sondaica*, *Panthera tigris balica* and *Panthera tigris virgata*). These species became extinct partly as a result of human–tiger conflict (Treves and Karanth, 2003). The Sumatran tiger (*Panthera tigris. Sumatrae*) faces the same extinction threat. Mortality of tigers due to human-tiger conflict is usually a major factor in the decline (Linkie et al., 2008). Currently, only 400-500 Sumatran tigers are estimated to remain in the wild (Linkie et al., 2008). Approximately 700 tigers were killed in Sumatra between 1860 and 1900, and during the same period, approximately 170 people were killed by tigers (Boomgaard, 2001). Data from 1978-1997 show that in Sumatra, 146 people were killed and 30 injured, approximately 250 tigers were killed, and 870 livestock were documented to have died as a result of tiger predation (Nyhus and Tilson, 2004). In other parts of Sumatra, retaliation against tigers continues. Conservation of the Sumatran tiger requires an understanding of human-tiger conflicts, including the "human dimensions", necessary to develop effective conflict mitigation strategies (Carter et al., 2012; Marchini, 2014; Struebig et al., 2018).

In this study, we aimed to (1) identify types of direct and indirect impact incurred in human-tiger conflict incidents in West Sumatra, (2) quantify both the direct and indirect costs incurred by local people, (3) examine whether the frequency of conflict together with its impact shape the human dimensions of the conflict (e.g., emotions, intention to kill tigers, tolerance and attitudes toward the tiger), and (4) identify key determinants explaining these human dimensions.

3.2. Methods

Study area

West Sumatra province has an area of 42,012 km^2 and covers 9.6 % of Sumatra, with a human population of approximately 5.3 million, or 127 people per km^2 (Badan Pusat Statistik, 2018). The research was conducted in four sites in West Sumatra, as shown in Figure 1. We selected our four study sites, all within two kilometers distance of a protected area, and all except one with a history of attacks by tigers on humans and/or livestock. Based on 2005-2012 data from the Ministry of

Environment and Forestry, we selected two sites that had experienced tiger attacks on humans (HA+), one of which also suffered livestock depredation, and two sites without human attacks (HA-), one of which also suffered livestock depredation.

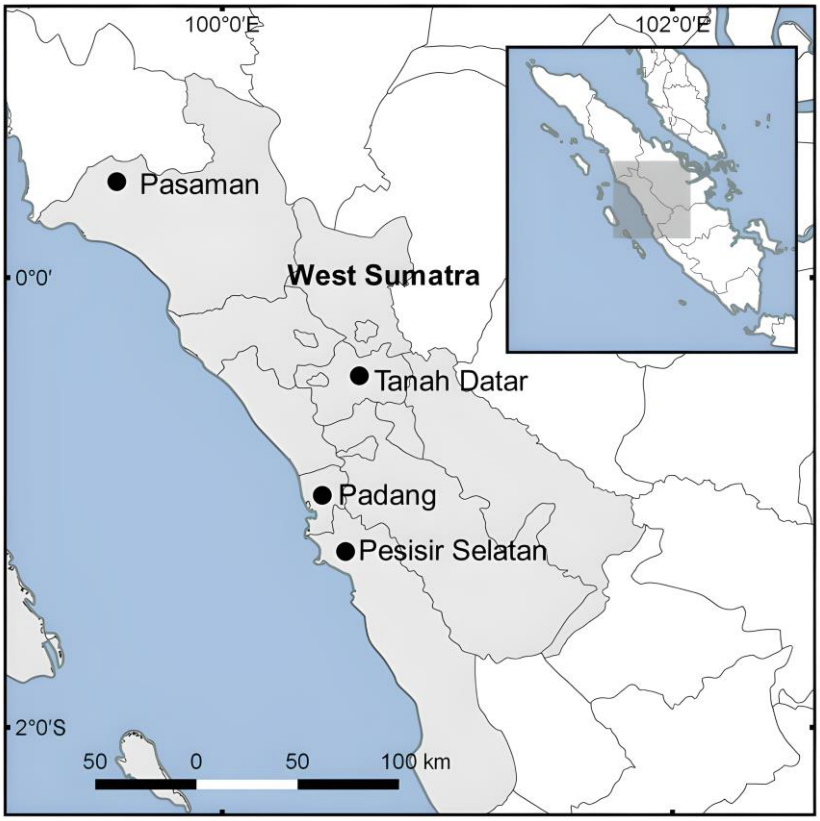

Figure 1. West Sumatra province and the four study sites. The map of Sumatra island (inset) shows the location of West Sumatra province (grey shaded area). The detailed map shows the location of the four surveyed villages**.**

The four study sites are Padang, with livestock depredation and human attacks (code =LD+HA+); Pesisir Selatan, with livestock depredation but no human attacks (code = LD+HA-); Pasaman, without livestock depredation but with human attacks (code = LD-HA+) and Tanah Datar, without any conflict (code = HA-LD-). The villages turned out to represent the two main human clans in the region: the Minangkabau (the largest clan in West Sumatra) and the Mandailing clans. For the remaining text in this document, the study sites will be referred to using the site codes mentioned above.

Field survey

Permission to conduct interviews in the study area was granted by the Ministry of Environment and Forestry, with permit number SI.823/BKSDA Sumbar-1/2012. Prior to interviewing local villagers, oral permission was obtained from the respective village leader. Oral informed consent in standardized format and the general purpose of the study were provided to each interviewee. Consent was obtained by having the interviewee state that s/he agreed to participate in the survey. The data were anonymized prior to the analysis.

During September to December 2012, a survey was conducted in a total of 128 households in the four study sites. A semi-structured interview was used to collect data using a written questionnaire as a guide (Supplementary S1). The interviews were conducted in an informal way using local languages. The questionnaire was tested and then modified where necessary through a pilot study of 10 respondents in site LD+HA-; we excluded these pilot study data from our analysis. The final questionnaire consisted of six main sections: demographic characteristics of respondents; tiger and human–tiger conflict experiences; impacts of the human-tiger conflict; costs associated with the human–tiger conflict; human dimensions of the human–tiger conflict (i.e., attitude, tolerance and emotions related to the intention to kill the tiger), and human–tiger conflict resolution.

Before conducting the surveys, a meeting with the head of each village was held to identify each household (the sampling unit) in the village that had experienced livestock predation and/or human attacks by a tiger. In the area where conflict did not happen (LD-HA-) respondents were chosen by walking around in the village and randomly choosing households. All households which had experienced human-tiger conflict(s) were interviewed. Other respondents were chosen on the basis of the order in which they were encountered as we walked through the village, visiting each compound in turn while maintaining the same proportion of men and women.

Data analysis

The costs of human-tiger conflict

Respondents were asked to mention what kind of damage they had incurred from the human-tiger conflict. We categorized and listed the impacts mentioned by respondents into direct and indirect impact. The costs of the human-tiger conflict refer to financial costs of the impacts of the conflict.

The costs were also categorized into direct and indirect costs. All direct costs were calculated by converting livestock loss to the current market price of livestock. Impacts were summarized and arbitrarily classified into five impact classes, relative to the average income per month of respondents (where Indonesian Rupiahs (IDR) 1 500 000 are worth € 100). These classes were as follows: small impact (< IDR 700 000), moderate impact (IDR 700 001-1 500 000), large impact (IDR 1 500 001-10 000 000), and severe impact (>IDR 10 000 000). All human victims were categorized as a severe impact.

To compare between direct and indirect costs, calculations of the indirect costs focused only on the opportunity costs. The opportunity cost is income that would have been earned if the presence of wildlife had not precluded particular activities. Here we tabulated the number of days villagers were excluded from going to the forest and/or working in the fields as a result of fear of tigers, multiplied by their average daily income. The opportunity cost was calculated by the equation:

$$Opportunity\ cost = d * I \qquad \textit{(Equation 1)}$$

Where is d= the number of days lost by not going to the forest and I = respondent's average income per day. The indirect costs (opportunity costs), now also expressed in monetary value, were classified similarly to the direct costs, as above. To compare the indirect costs suffered between groups, a Kruskal-Wallis analysis was applied.

Data respondents from site LD+HA+ and LD+HA- were used in the analysis of opportunity costs. Here we asked a specific question about how many days the respondents did not go to the forest or the fields. Calculations were based on livestock depredation incidents in 2010 and human attacks in 2008, as those were the most recent incidents that people could still remember clearly. For other indirect costs we presented the estimated costs (minimum and maximum) based on the indirect impacts mentioned by respondents.

Human dimensions of human-tiger conflict

To examine the human dimensions of human-tiger conflict, questions related to ecological knowledge, attitudes, tolerance, and emotions toward tigers were asked and scored as explained below:

Knowledge: Knowledge of tiger ecology was measured by asking five closed questions to respondents. Respondents who answered correctly were scored as 1, incorrectly as 0. The level of knowledge was calculated as the sum of all scores. For analysis purposes, the level of knowledge was then categorized into low (score 0-1), medium (score 2-3) and high (score 4-5).

Attitudes and tolerance towards tigers: To examine people's attitudes to conservation of tigers, several questions based on wildlife value orientation (Fulton et al., 1996) were asked. Responses were scored into five categories: 0.2 (no support for tiger conservation) to 1 (firm support for tiger conservation). The respondents' conservation attitude values were summarized by calculating a mean value for all conservation attitude statement scores. The same method was used when examining respondents' tolerance towards tigers in human-tiger conflict situations.

To compare the conservation attitudes and tolerance toward tigers between sites, a Kruskal Wallis and a *post-hoc* analysis (Mann-Whitney U test) was performed. These analyses were also performed to compare conservation attitudes and tolerance based on demographic data and knowledge about tiger ecology.

*Emotion***:** Emotions were assessed on the basis of one question about what the respondent would do if a tiger were to attack livestock or a person in their village in the future. Responses were classified into four levels of emotion: (1) not angry, if the response was to repel the tiger or to do nothing to it; (2) slightly angry, if the response was to ask the government to capture the tiger, or to capture the tiger and send it to the zoo; (3) angry, if the response was for the community to capture the tiger (this response usually leads to retaliation towards the tiger); (4) very angry, if the response was to kill the tiger.

The level of environmental education, and the frequency of conflicts in the villages were obtained from the Ministry of Environment and Forestry data.

To establish which factors influenced the emotion, the conservation attitude and tolerance towards tigers, a Principal Component Analysis (PCA) was conducted, using Canoco 5 software, with the following environmental factors as supplementary variables: (i) personal experience of human-tiger conflict; (ii) level of impact of the conflict; (iii) knowledge about tiger ecology; (iv) gender; (v) frequency of conflict in the village in the previous 5 years; (vi) ethnicity; (vii) distance of agricultural fields to the forest edge (boundary); and (viii) the number of environmental education programs carried out in the village in the last 5 years.

3.3. Results

Impacts of human-tiger conflict

Respondents stated that uncompensated direct impacts involved attacks on both livestock and humans. In the case of livestock attacks, direct impacts included livestock killed or injured. Livestock attacked by tigers included cattle, buffalo, sheep, and chickens. Apart from livestock, tigers also attacked dogs. In addition to direct impacts, livestock attacks also led to a series of indirect impacts, including time spent guarding livestock, lost economic opportunity income because of the presence of tigers (opportunity costs), increased demand for wood to build enclosures to protect livestock, which lead to illegal logging, and increasing demand for cash to build the new enclosures.

In the case of human attacks, respondents stated that direct impacts included human fatalities or injuries, while indirect impacts included opportunity cost, psychological trauma, and other factors. Figure. 2 provides a summary of direct and indirect impacts associated with human-tiger conflict incidents in West Sumatra province, as reported by respondents in this study.

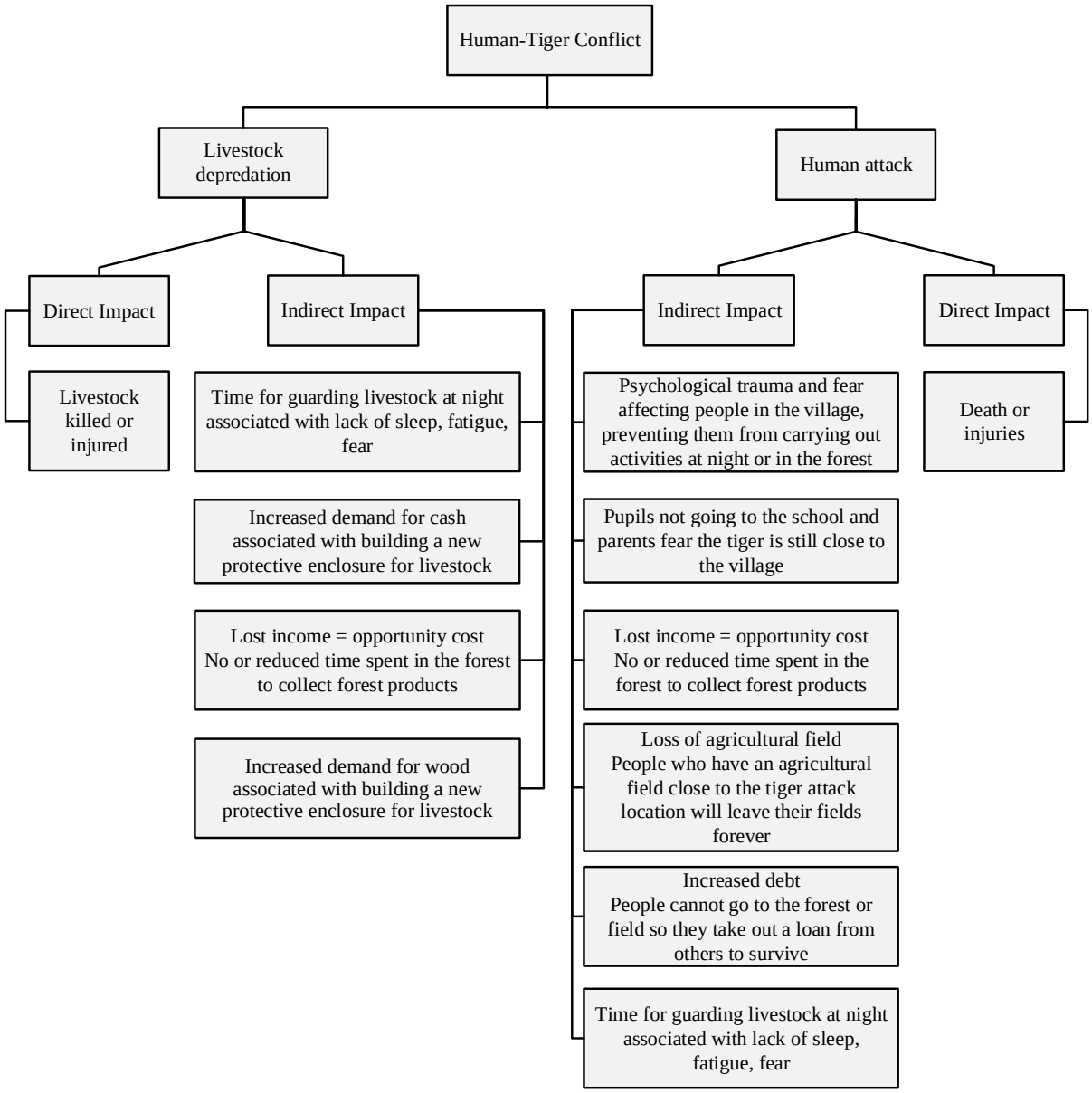

Figure 2. Summary of direct and indirect impacts incurred as a result of human-tiger conflict incidents in West Sumatra, Indonesia.

Direct impacts of human-tiger conflict

We recorded a total of 45 incidents of livestock depredation and 5 fatal human attack incidents by tigers in sites: LD+HA-, LD+HA+ and LD-HA+. A majority (53.7%) of respondents had experienced large direct losses in human-tiger conflicts, while 19.5% had experienced small direct losses. A total of 17.1% of respondents experienced severe direct losses and fewer than 10% of respondents experienced moderate direct losses (n=41).

Indirect impacts of human-tiger conflict

The degree of fear caused by tigers in relation to human-tiger conflict incidents was different for each respondent; as a result, the indirect impact perceived per person was different. Days lost going to the forest or agricultural fields as a result of human-tiger conflict were significantly higher in the case of attacks on humans (median=60, n=98) than in the case of livestock predation (median=7, n=68) (Mann-Whitney U=110, $p<0.001$). Men lost significantly fewer days (median=3, n=39) than women (median=7, n=29) (Mann-Whitney U=254, $p<0.001$); this difference was entirely due to the loss of livestock, because in the case of human attack, there was no significant difference between men and women in the median of lost days.

In three of the study sites (LD+HA+, LD+HA- and LD-HA+), 61.2% (n=98) of the respondents claimed that, as a consequence of the latest human-tiger conflict incidents in their villages, they had to take loans from other people in order to survive (61%). They could not go to the forest and agricultural fields out of fear, and they also did not have any savings to live on. Some people also tried to survive by selling their livestock (16%), depending on aid from the government (12%), tried to find other incomes (9%) and sought refuge in another area (1%).

In two study sites, LD+HA- and LD-HA+, schools were closed for some time after a tiger attack in the village. If a human-tiger conflict took place, teachers and parents were typically afraid and anxious that the tiger would attack their children. In site LD+HA-, they closed the school, and pupils were allowed to study at home for a week after a teacher found tiger footprints near the school. In site LD-HA+, two people were killed by a tiger. All villagers were very scared and did not allow their children to go to school. The teachers at the school were from another village and were too scared to come to this site. As a result, there were no school activities for almost a month in site LD-HA+.

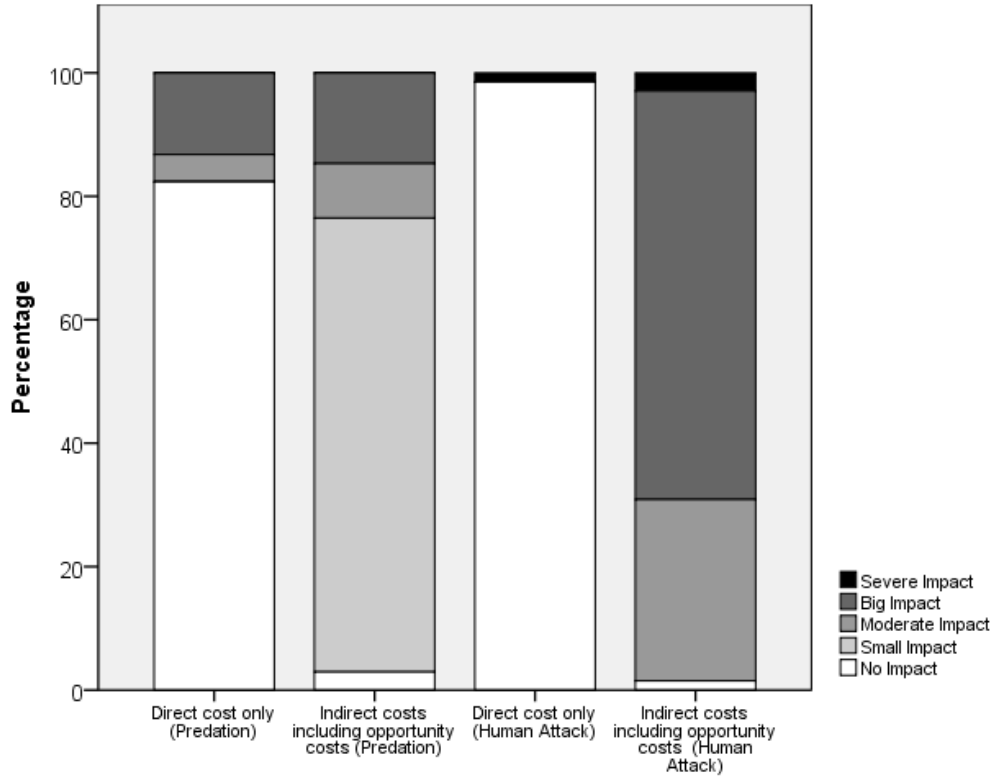

Figure 3. Comparing the reported impact severity of direct costs only and indirect costs, including opportunity costs, in study areas in cases of livestock depredation and human attack

The cost of human-tiger conflict

The direct costs for livestock depredations included expenses for veterinary care of the livestock, and the cost of replacing livestock losses. In case of human attack, the direct costs included medical expenses for treating the injuries, and expenses for burying the dead (Table 1). The direct costs were mainly incurred at the individual level, where the conflict was directly experienced. The indirect costs were incurred both at the individual and at the community level (see Table 1 for details).

Comparing impacts of direct and indirect costs (opportunity costs) on people's livelihoods

In 2010, there were several incidents of livestock depredation by tigers (n=13) in LD+HA- and LD+HA+ throughout the year. Sometimes, the tiger visited the village without attacking livestock. This situation made some people afraid and they decided to stay at home rather than going to the forest.

If only the direct costs of human-tiger conflict related to livestock depredation are considered, 82.4% of respondents (n=68) reported not having any impact at all. Yet, when also considering the indirect impacts of human-tiger conflict, only 2.9% of the respondents reported not having any impact (Fig. 3). With regard to an incident of human attack that occurred in 2008 in site LD+HA+, when one person was killed by a tiger, there is a similarly large contrast between direct and indirect costs perceived by the respondents (Fig. 3). Almost all respondents (96.7%; n=30) stated that they were not directly impacted by human-tiger conflict (human attack). However, if indirect impacts were included, 70% of the respondents experienced a large impact and only 3.3% experienced no impact.

Table 1. The costs of human-tiger conflict in cases of livestock depredations and human attacks (1 EUR = ~15,000 IDR). Amounts reflect the cost per incident

Type of conflict	Direct cost			Justification	Indirect cost			Justification
	Type of cost	Minimum (IDR)	Maximum (IDR)		Type of cost	Minimum (IDR)	Maximum (IDR)	
Livestock depredation	Livestock replacement	3,000,000	18,000,000	The price for a sheep or a dog is around IDR 3,000,000 and for a buffalo is around IDR 18,000,000	Overtime salary to guard livestock at night	350,000	1,500,000	The villagers will guard their livestock for 7-30 days after an incident. If the tiger comes only once, people usually guard their livestock for a week, but in the case of repeated tiger visits, they will guard their livestock up to 30 days
	Veterinary care	300,000	2,000,000	Depends on how many days the veterinarian takes care of the injured animals	Buy wood and other materials to build a strong enclosure	3,000,000	10,000,000	Cost depends on the size of the enclosure, related to the number of livestock
					Lost income (opportunity cost)	-	1,500,000	Number of days forest/agricultural field cannot be visited; average income is IDR 50,000 per day
					Cost of repelling the tiger by tiger shaman	5,000,000	20,000,000	Depends on how many days the shaman stays at the village and on the reputation of the shaman
Total Cost		**3,300,000**	**20,000,000**			**8,350,000**	**33,000,000**	

Type of conflict	Direct cost			Justification	Indirect cost			Justification
	Type of cost	Minimum (IDR)	Maximum (IDR)		Type of cost	Minimum (IDR)	Maximum (IDR)	
Human attack	Burial	0	1,000,000	In some communities, people cooperate to bury the dead body; in other communities there are costs for the burials.	Overtime salary to guard livestock at night	350,000	1,500,000	See above.
	Ceremony	2,500,000	25,000,000	Most families will hold the ceremony every 10 days within 100 days, but some families will only do the ceremony on day 3, 7, 40 and 100, with an average cost of 2,500,000 for each ceremony	Buy wood and other materials to build a strong cage	3,000,000	10,000,000	See above.
	Medical treatment	0	15,000,000	The medical treatment can be 0 if the victims are dead or if they have insurance. The average treatment cost per visit is 1,000,000	Trauma healing – If the trauma persists, then the government must allocate money for treatment	5,000,000	15,000,000	The value is mainly based on the travel cost for the government officer to the village.
					Interest from loan that people take to survive	-	1,800,000	Generally, people take out a loan for 12 months (average monthly income is IDR 1,500,000) with an interest of 10% per year

Type of conflict	Direct cost			Justification	Indirect cost			Justification
	Type of cost	Minimum (IDR)	Maximum (IDR)		Type of cost	Minimum (IDR)	Maximum (IDR)	
					Lost income (opportunity cost)	-	18,000,000	Based on 0-360 days forgoing visits to the agricultural fields or forest; average income is IDR 50,000 per day
					Travel cost to the city for refuge and/or to find another job	-	5,000,000	Depends on where people move. If they move to Jakarta (capital city) then they will spend the max amount of cost
					Buy new agricultural land, or cost to clear land for agriculture	-	50,000,000	Price for a piece of land that can be used to plant rice that can fulfil people's needs
					Cost to repel the tiger by the tiger shaman	5,000,000	20,000,000	See above
Total cost		**2,500,000**	**41,000,000**			**13,350,000**	**121,300,000**	-

Human dimension of human-tiger conflict

Severity of impacts, levels of environmental education, and frequency of human-tiger conflict in the village all seemed to play an important role in explaining the human dimension variables of emotion, conservation attitude and tolerance. Knowledge, gender and personal experience of human-tiger conflict played a minor role in explaining human dimension variables. The eigenvalues of axis 1 and axis 2 were 0.64 and 0.18, respectively, thus together capturing 81.6 % of the total variance in the data (Fig. 4).

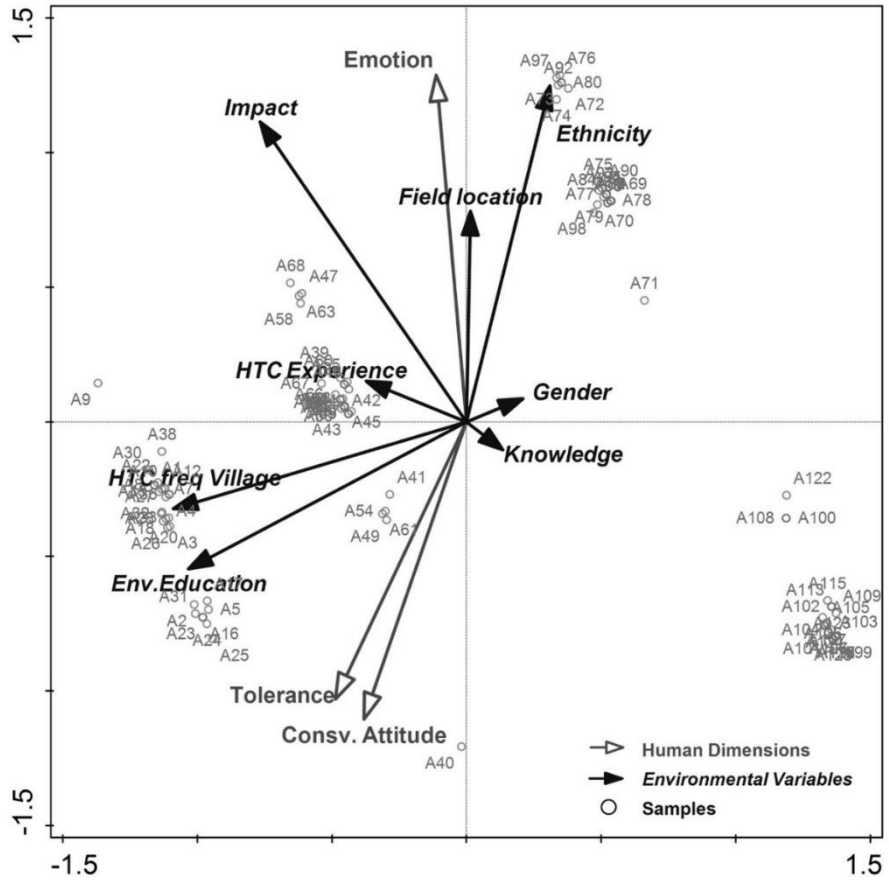

Figure 4**.** Principal component analysis (PCA) of human-tiger conflict experience, human-tiger conflict frequency in the village, impact, knowledge about tiger ecology, gender, field location, ethnicity and intensity of environmental education in the village (all environmental variables, solid vectors), with supplementary variables of conservation attitude, tolerance and emotion (intention to kill tiger) (human dimensions, open vectors) from 109 respondents (light grey) in four villages, West Sumatra, Indonesia. Eigenvalue of axis 1 = 0.64 and of axis 2 = 0.18 (sum of all Eigenvalues = 1.00).

The perceived severity of human-tiger conflict impacts was strongly and positively correlated with emotion and negatively correlated with tolerance and conservation attitudes. This means that the more severe the perceived impacts, the lower the tolerance and conservation attitude, and the more emotion (anger) was shown toward tigers. Environmental education was highly positively correlated with human-tiger conflict frequencies in the village, meaning that education program followed the occurrence of conflicts. People who had agricultural fields closer to the forest tended to be more emotional and intolerant towards tigers in comparison to people who had agricultural fields far away from the forest.

Knowledge

A total of 56% of respondents were categorized as having medium knowledge of tiger ecology and conservation. One-third (33%) of respondents had a high level of knowledge and 11% of the respondents had a low level of knowledge about tiger ecology and conservation. The median of self-declared knowledge about tiger ecology for all respondents (n=109) was 3 and was comparable among the four villages (Kruskal-Wallis X^2= 1.740, df=3, p=0.628).

Conservation attitude towards tigers

Overall, respondent's median of conservation attitude towards tigers was 0.66. The two sites which never experienced human attack incidents had significantly higher conservation attitudes toward tigers (sites LD+HA- and LD-HA- had medians around 0.74), compared to sites which experienced human attack incidents, (sites LD+HA+ and LD-HA+ had medians around 0.57) (Kruskal-Wallis X^2= 39.622, df=3, p<0.001).

Conservation attitude was not significantly different among respondents with regard to gender, field locations, knowledge about tiger ecology, and direct individual experience of human-tiger conflict through losing a relative or livestock depredation.

Tolerance towards tigers

Respondents' tolerance towards tigers was significantly different between respondents with regard to agricultural field location. Similar to the results for conservation attitudes, the two sites that had never experienced human attack incidents also had significantly higher tolerance towards tigers

(sites LD+HA- and LD-HA- had medians of 0.8), compared to sites that experienced human attack incidents, (sites LD+HA+ and LD-HA+ had medians around 0.3) (Kruskal-Wallis X^2= 22.589, df=3 p<0.001). Respondents who had agricultural fields close to or inside the protected area had significantly lower tolerance scores (median=0.3; n=52) compared with respondents having fields close to the village, i.e., further from the protected area border (median=0.6; n=56) (Mann-Whitney U= 1009, p=0.004,). Tolerance towards tigers was not significantly different among respondents who differed in gender, knowledge of tiger ecology, and direct experience of human-tiger conflict (livestock depredations or losing family members or relatives).

The median global score of tolerance toward tigers among overall respondents was low: 0.4. There was a positive correlation between conservation attitude and tolerance (Pearson correlation: r=0.618, p<0.001).

Emotion

A total of 60% of respondents (n=41), who had direct experience with tiger attacks through human or livestock fatalities mentioned that they wanted to kill the tiger, directly by themselves (26%) or with help from the community (34%). A large minority of respondents (40%) said that they would do nothing because they were scared of tigers.

3.4. Discussion

Our results show that including indirect costs can help explain the impacts of human-tiger conflict across the community more precisely. Calculating direct impact only severely underestimates the magnitude of the impacts of human-tiger conflicts on the people in affected villages. In the human dimension factors, we found that tolerance towards tigers in the case of human-tiger conflict was positively correlated with conservation attitude and negatively correlated with emotion (i.e., the intention to kill tigers in retaliation). These human dimension factors correlated with field location, frequency of human-tiger conflict in the village, the severity of impacts experienced by the respondent, and the intensity of environmental education programs in the village. Studies that are based on direct impacts tell only part of the story and indirect impacts are needed to complete the story of human-wildlife conflicts.

Impact of human-tiger conflict

Human-tiger conflict may refer to livestock predation or attacks on humans or to people's fear of being injured or killed by a tiger that has become a resident close to a village. The impacts of livestock depredations and attacks on people are not only felt by the owners of the livestock or the victims' families but are amplified to everyone in the village. Stories about man-eating tigers in the past (Boomgaard, 2001) and direct experience of tiger attacks make people scared of tigers.

Farmers and pastoralists have little or no possibility for alternative livelihoods, and predation on livestock, especially on more-valuable livestock, can be catastrophic for individual farmers. The financial impact of these losses can be considered large in relation to a farmer's income. For people who have a monthly income of IDR 1.5 million (€100) or less, losing one sheep (valued at IDR 800 000 (€53)) to tiger predation means those people are losing half their monthly income. Losing a water buffalo means a financial loss of IDR 18 million (€1 200) or twelve times their monthly income. For smallholder farmers and livestock owners, livestock represents a large financial resource, and losing one or more animals represents a major financial loss that causes financial difficulties for these individuals, as was evident by the various emergency measures they took in response to losses.

Human-tiger conflicts involving human fatalities are a significant challenge for affected relatives, and for all community members as well. The victim's family experiences direct and indirect impacts at the same time, often including large opportunity costs. The condition is made worse if the victim's family cannot go to the forest or agricultural fields for a long time. This situation can increase the family's debt if the family members decide to borrow money from others. Children also come under more pressure to help their family to earn money.

At the community level, the impacts of human-tiger conflict are mainly indirect impacts. Opportunity costs arising from human-tiger conflicts affect the entire community. Opportunity costs result from people's anxiety about tiger attacks, which makes them more likely to stay at home than go to the forest or their agricultural fields. The presence of a tiger in the vicinity of the village may result in measurable economic impacts on the villagers, because fear of the tiger may prevent villagers from pursuing normal daily activities. The total opportunity cost was higher in

the case of tiger attacks on humans than in the case of livestock predation. Similarly, Gore et al., (2005) also found that after a human was killed in a bear attack, people's perception of risk of being attacked by bears increased. The perception of risk might have differed between individuals and between gender (Gore et al., 2005); this may explain study results which found that, in the case of livestock attacks, the days lost through not going to the forest or agricultural fields were lower for men than for women.

The costs of human-tiger conflicts seem to be low when only the direct costs are calculated, but there are huge indirect costs that arise from these conflicts. In the case of human attack, for example, a long list of indirect costs emerges, tripling the cost. Apart from the opportunity costs that have been described before, guarding livestock during the conflict situation incurred costs for overtime salary if the livestock owner hired people to guard the livestock (Barua et al., 2013). Another indirect cost incurred by the human-tiger conflict is the cost of repelling the tiger by a shaman. Expenses are high and the villagers must share the cost with all community members. People in the study area believe that the tiger shaman can keep tigers away from the village (McKay et al., 2018).

Human dimensions of human-tiger conflict

There is no single solution to mitigate human-tiger conflicts, but many studies indicate that including human dimension factors are crucial for the long-term survival of tigers (Baruch-Mordo et al., 2009; Nyhus, 2016). This study reveals that emotions (intention to kill tigers in retaliation) are negatively correlated with conservation attitudes and tolerance toward tigers. People with low conservation attitudes tend to have high emotion score values. However, previous experience with human-tiger conflict and knowledge of tiger ecology seems to only have a small influence on shaping human dimension factors.

The amount of environmental education is higher in areas that have more frequent human-tiger conflict incidents, presumably because environmental education programs were implemented after a human-tiger conflict occurred. This was confirmed by local conservation office staff in West Sumatra, who stated that environmental education programs were allocated more to areas that experienced more conflicts (Rusdiyan P. Ritonga, personal communication, May 2018). Thus,

environmental education contributes to tolerance and positive conservation attitudes with respect to tigers. This result was also found with Andean bears (*Tremarctos ornatus*) in Ecuador; after receiving environmental education, people's attitudes and behavior toward the species changed positively (Espinosa and Jacobson, 2012). Environmental education has also had a significant positive impact on people's attitudes towards coyotes around Cabot Trail in Canada (Sponarski et al., 2016).

We found that the tolerance of people who had agricultural fields close to a protected area was much lower in comparison to people who had more distant agricultural fields. Thus, if a human-tiger conflict occurs, the people who have agricultural fields far from the protected area would probably only reduce the amount of time they stay in their fields, while people who had agricultural fields close to protected areas would probably not go to their fields at all, but would simply stay at home. Not going to their fields means potential loss of income. Therefore, the opportunity cost incurred in this situation is higher, which makes people less tolerant of tigers.

Ethnicity also seems to play an important role in shaping human dimension factors. During observations in the field, we found that people from the Minangkabau ethnic group had very strong traditional beliefs in relation to tigers, as evident from the many stories about them. The Mandailing ethnic group on the other hand had almost no stories about tigers in their traditions and beliefs. Hence, cultural attitudes seem to play a role in shaping innate tolerance of tigers by Minangkabau people across generations (McKay et al., 2018). In addition to the stories, the tiger also has a special place in the Minangkabau ethnic group, where people call the tiger "Inyiak" or "Datuak", while in the community these two terms are used for the most respected person in the community. Elsewhere in Indonesia, the Banten ethnic group, also has traditional beliefs about forest guardian spirits, where this belief influences people's behavior towards wildlife and the forest, wherein people believe that harming or killing water monitors *Varanus salvator* and/or reticulated pythons *Python reticulatus* brings bad luck (Uyeda et al., 2016). The traditional beliefs of people in the Sundarbans, Bangladesh also have direct effects on their tolerance of tigers (Inskip et al., 2016). In East Africa, cultural norms and traditional beliefs were also found to reduce antagonism towards problem animals (Dickman, 2012).

The median score of respondents' conservation attitude was higher than the median score of their tolerances. This means that people were aware of the importance of tigers in their lives but would nonetheless prefer to kill the tiger if it were to threaten them, rather than leaving the tiger alone because of its benefits for their lives. These benefits are related to local wisdom, where the local people believe that the tiger can guide them to find their way if they get lost in the forest. However, when it comes to choosing between killing a tiger to ensure safety from an attack or keeping the tiger alive for its benefits as a "guide", people typically choose safety first.

The knowledge of local people about tiger ecology and conservation in the study area was categorized as "medium," and this knowledge contributed little to shaping human dimension factors. Similar to this result, Carmi et al. (2015) found that environmental knowledge only explained 6% of people's behavior towards the environment, and they found that knowledge did not directly shape people's behavior, but that it was an external mediating variable in shaping people's attitudes. One example of an external mediating variable was shown by Marker & Dickman (2004) who found that some of the apparent success in improving attitudes towards cheetahs was achieved through implementing widespread environmental education programs, which had a particular focus on knowledge about cheetahs.

Contrary to our expectations, the frequency of human-tiger conflict experienced did not explain the human dimension factors, but the impacts of human-tiger conflict experienced strongly explained these factors. For example, people were less angry toward tigers in cases of frequent attacks without human losses than in the case of one fatal attack. Naughton-Treves & Treves (2005) also found that tolerance toward wildlife was shaped more by actual impacts than by the frequency of conflicts perceived by individuals. Similar to our result, Inskip et al. (2016) also found that negative experiences with tigers did not directly affect the tolerance level of people in the Sundarbans, Bangladesh.

Gender did not seem to play an important role in shaping human dimension factors; men appear to be just as scared of tigers as women. Although some studies have shown that gender is a key variable in explaining differences in attitudes (Alexander et al., 2015; Carter and Allendorf, 2016) most studies found that gender played no role in explaining differences in attitudes toward wildlife.

The median value of tolerance was much lower than the median value for conservation attitude. Therefore, management practices should focus on increasing people's tolerance for tigers. From this research we found that environmental education programs are important to increase people's tolerance toward wildlife. Compensation of public loss is one of the important measures found to be effective in a significant reduction of lion killing in Kenya (Bauer et al., 2017). In Bangladesh for example, combining compensation for losses with community engagement has been working as a combined approach to reduce retaliatory killing of tigers (Nasir Uddin, personal communication, May 2018). But compensation schemes have yet to be considered in human-tiger conflict management approaches in Indonesia.

With these findings, the paper contributes to understanding what the role is of indirect impacts incurred in human-wildlife conflicts by concluding that these indirect impacts should not be ignored. Therefore, studies on human-wildlife conflicts should quantify both direct and indirect costs incurred by local people. The paper also enhances our understanding that the human dimensions of the conflict (e.g., emotions, intention to kill tigers, tolerance and attitudes toward the tiger) is shaped by the frequency of conflict together with its impact. The impact of human-wildlife conflict not only affected people who lost their property because of the conflict, but also affected all the community members. Therefore, a compensation program which only aimed to compensate direct victims would not be enough to reduce the anger of people towards wildlife. Compensation should also be targeted at the entire community, especially in the event of human attacks.

Supplementary S1.

Questionnaire about the HumanTC in Sumatra

Village :
Location :
Size :
Date :
Distance house from the forest:

READ: *Hello, I am a PhD student from Wageningen University, The Netherland. I am here to conduct my research and want to ask about human tiger conflict. I would like to tape record our conversation, so that I can get your words accurately. If at any time during our talk you feel uncomfortable answering a question please let me know, and you don't have to answer it. Or, if you want to answer a question but do not want it tape recorded, please let me know and I will turn off the machine. If at any time you want to withdraw from this study please tell me and I will erase the tape of our conversation. All the answers that you give me will only be used for this research project. I will not record you name and/or address so all your answers are private and confidential. I will not reveal the content of our conversation beyond myself and people helping me whom I trust to maintain your confidentiality. I will do everything I can to protect your privacy, but there is always a slight chance that someone could find out about our conversation*

Are you happy to complete this survey? (tick (√) if YES; cross (X) if NO)	
Do you allow me to tape record our conversation? (tick (√) if YES; cross(X) if NO)	

Personal Information

(a) Sex : male/Female
(b) Age
(c) Education
(d) ethnic
(e) How many people live in your household? (+ family history if relevant for tigers)
(f) Income per month (Rupiah-Indonesian currency)?
(g) How long did you live in this area?
(a) What do you do?
(b) Do you have livestock?
(c) What kind of livestock do you have? And specify
(d) Do you have agricultural field?
(e) Is your agriculture field inside or adjacent to the forest (protected area)?
(f) Number of acres owned? What type of crops grown in your agricultural field?

List of animal which could be potentially harmful to crop or livestock

1) Wild boars
2) Long tail macaque
3) Rat
4) Sun bear
5) Tapir
6) Crocodile
7) Deer (Sambar deer)
8) Snake
9) Tiger
10) Cloud leopard

What kind of damage experience caused by those animal?

Experience with Sumatran tiger,

(a) Have you ever seen a Sumatran tiger in the wild before?
(1) Yes (2) No If yes continue to (b) if no go directly to (c)
(b) How many times you saw a Sumatran tiger in the wild?
(c) Do you see more tiger now than in the past?
(d) Do you think the number of problem with tiger increase no? if yes why?
(e) What do you think of the fact that there are tigers around your area?
(f) Are you afraid with tiger? Why/why not?
(g) Are there any stories or legends about the tiger?
(h) Do you lose your livestock because of other reason? If yes, what is it and how many?

Conflict (frequency, direct impact and indirect impact)
Direct impact

1) Predation

(a) Did you ever have trouble with Sumatran tiger?
(b) Have you ever have livestock damages caused by Sumatran tiger? How many times? What kind of livestock damage?
(c) How do you know if the damage is caused by Sumatran tiger?
(d) How much money (if you count) the livestock damaged caused by Sumatran tiger (in rupiah –Indonesian currency) (+ ask them how they calculate this)
(e) When did it happen? (date/year, time (day or night))
(f) Where did it happen? (In the village/in the agriculture field/in the protected area/…?)

(g) How do you feel when you lost your livestock at that time?
(h) What do you want to do with the tiger at that time?

2) Human Attack

(i) Have you or your family ever been attacked by a Sumatran tiger? What kind of attack?
(j) When did it happen? (date/year, time (day or night))
(k) Where did it happen? (In the village/in the agriculture field/in the protected area/…?)
(l) Was the household situation different after conflict happen?
(m) How do you feel when you or your family attacked by tiger at that time?
(n) What do you want to do with the tiger at that time?

Indirect Impact

(a) If the HTC occur will you stay at home for long day and not go out during the night? If yes for which period?
(b) If the HTC occur can you go to the forest or agricultural field? Will you lose your income if HTC occur? How much? And for how long? Months or years?
(c) If the HTC occur will you stay awake during the night?
(d) If HTC occur will you guard your livestock during the night? For how long you will guard your livestock until you think the situation is save?
(e) If the HTC occur will your children go to school? If no, why? And for how long they will not go to school?

Resilience and Vulnerability

(a) After damage caused by a tiger in your livestock how long you can replace your property loss?
(b) After damage caused by the tiger in your family how long it takes to live as usual?
(c) Are communities helping you after the damage caused by the tiger?
(d) Is the helping from communities helpful for you?
(e) Do government gave you compensation/insurance when you got any damage from a tiger? If yes how much?
(f) Is the compensation/insurance helpful for you?
(g) Do have family (outside your household) who help you to give you living cost every month/day?
(h) Is lose your livestock or other properties caused by the tiger make you and your family feels like lose everything? Why or why not?
(i) Is go to the forest (farming, herding cattle, collecting non forest timber product, collecting fuel wood) the only source income for your family?
(j) How do you keep your livestock during the night?
(k) Do you graze livestock in protected area?
(l) How often you go to the forest? And for how long you stay there?
(m) What time you going home if you go to the forest?

Attitudes toward Sumatran tiger

Choose one number that expresses your opinion

Strongly disagree **strongly agree**

1 2 3 4 5 6 7

(a) the presence of Sumatran tiger is good for my agriculture field (+)

1 2 3 4 5 6 7

(b) If there are more tiger so that less wild boar (+)

1 2 3 4 5 6 7

(c) The presence of Sumatran tiger in my village will make better life (+),

1 2 3 4 5 6 7

(d) Sumatran tiger near my home would increase my quality of life (+),

1 2 3 4 5 6 7

(e) it is okay to poach the tiger (-),

1 2 3 4 5 6 7

(f) Sumatran tiger commonly harm humans (-),

1 2 3 4 5 6 7

(g) If the tiger come to the village the tiger should be killed (-)

1 2 3 4 5 6 7

(h) It is important to conserve the tiger (+)

1 2 3 4 5 6 7

(i) I like the tiger because if I sold the tiger all part of their body is very expensive (-)

1 2 3 4 5 6 7

(j) I will help government to resolve HTC in my village (+)

1 2 3 4 5 6 7

(k) I would feel personally at risk if Sumatran tiger exist in my village, so that I will support people who kill the tiger (-)

1 2 3 4 5 6 7

(l) I am afraid of Sumatran Tiger, so that better if there is no tiger in West Sumatra (-)

1 2 3 4 5 6 7

Conflict resolution

(a) Do you know how to avoid predation from tiger toward your livestock? What did you do to reduce livestock predation from tiger(s)?

(b) Do you know how to avoid attack from a tiger when you are in the forest? What did you do to avoid tiger attack to you?

(c) What do you think the best solution to reduce livestock predation by tiger?

(d) What do you think the best solution to reduce tiger attack to people?
(e) What do you think the best solution for tiger that come to the settlement and kill the livestock or attack to the people?
(f) In your opinion who should solve the problem with tiger?
(g) In your opinion, Should people be compensated for their losses?
(h) Who should arrange/pay this compensation?
(i) Do you think you need more information about how to avoid HTC?
(j) In case of one of the conflict above (depredation, attack people) what do you think was the reason for this incident?
(k) Do you blame the tiger for this?
(l) What did you do to reduce the impact of HTC?
(m) What do you think about the following possible solutions for livestock depredation? Which one is the best solution?
    1. Compensation in rupiah for livestock predation
    2. Compensation with replacing livestock which is killed by tiger
    3. Placing livestock in a better and strong cage
    4. Guarding livestock
    5. Barriers (electric fencing around the village)
(n) What do you think about the following possible solutions for human attack? Which one is the best solution?
    1. Insurance for human attack
    2. Education
    3. Using face mask while people go to the forest
    4. Resettlement
(o) What do you think about the following possible solutions for tiger? Which one is the best solution?
    1. Translocation
    2. Deterrents (repealing tiger with light and loud noises)
    3. Lethal control
    4. Maintain prey availability for tiger in the forest to prevent tiger come to the settlement

Knowledge about tiger and HTC

(a) 100 years ago, West Sumatra contained a large population of Sumatran tiger,
    (1) Yes (2) No (3) don't know
(b) The number of Sumatran tiger sightings in West Sumatra has increased during the past decade,
    (1) Yes (2) No (3) don't know
(c) Sumatran tiger exist throughout Sumatra island,
    (1) Yes (2) No (3) don't know

(d) Sumatran tiger is protected by law
(1) Yes (2) No (3) don't know
(e) The mainly prey of Sumatran tiger is wild boar
(1) Yes (2) No (3) don't know
(f) Sumatran tiger live solitaire
(1) Yes (2) No (3) don't know
(g) Female Sumatran tiger will taking care for the cub
(1) Yes (2) No (3) don't know
(h) If the tiger come and make problem in your settlement you must report it to government
(1) Yes (2) No (3) don't know
(i) Tiger will active to look for their food during the night or early morning
(1) Yes (2) No (3) don't know

Beliefs (religion and local wisdom)

(a) Base on your religion is that allow for you to kill the tiger
(1) Yes (2) No (3) don't know
(b) If person kill the tiger, is he/she sin?
(1) Yes (2) No (3) don't know
(c) Base on local / customary law is that allow for you to kill the tiger?
(1) Yes (2) No (3) don't know
(d) If person kill the tiger, should he/she get punishment from the community?
(1) Yes (2) No (3) don't know
(e) Are there any changes in people's beliefs about Sumatran tiger compared between people in the past and present day?
(1) Yes (2) No (3) don't know

Response from Government to handle HTC

(a) Do you know where you should report HTC?
(1) Yes (2) No (3) don't know
(b) Is it easy for you to report HTC to government?
(1) Yes (2) No (3) don't know
(c) If you reporting HTC to government they will come to your place to handle HTC not more than 1 day after the report
(1) Yes (2) No (3) don't know
(d) Government ways to solve the HTC are good enough
(1) Yes (2) No (3) don't know

A dance group in Minangkabau poses in front of a tiger skin, 1890 (source: KITLV)

Chapter 4

Uncovering the local wisdom of Sumatran communities in understanding human-tiger conflicts

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Abstract

Traditional and local ecological knowledge plays an important role in reducing human-wildlife conflict including identifying the cause of conflict, identifying conflict hotspots, encouraging coexistence. Sumatran communities have a history of explaining the causes of human-tiger conflicts (HTC) with traditional ecological knowledge (TEK) including folklore and spiritual beliefs. How strongly such beliefs are currently held and how this affects post-conflict behaviour towards carnivores remains unclear. Having a detailed understanding of the social context in which human-wildlife conflicts occur is increasingly recognized as an important, bottom-up aspect of wildlife conservation. Semi-structured interviews with local communities were performed in two areas that have experienced different levels of HTC. We assessed to what extent spiritual beliefs and environmental effects are used to describe the causes of HTC and if holding spiritual beliefs determines the chance of engaging in retaliatory killing of tigers. Although communication with local inhabitants about Sumatran tigers is impeded by a lack of local knowledge, we found that spiritual beliefs related to HTC were held by 74% of our respondents. We also found that low HTC experience may result in the loss of spiritual beliefs, but holding spiritual beliefs did not seem to provide tigers with higher levels of protection. Interviews showed that there was little local agreement on the effect of environmental variables on HTC, although the importance of forest destruction was indicated by 57% of our respondents. We conclude that a decreased inclusion of tigers in local culture might weaken emotional connections between people and tigers, possibly resulting in reduced tolerance.

4.1. Introduction

A reduction in size and quality of natural habitat and associated decreased food availability may increase the occurrence of human-wildlife interactions and hence the potential for conflicts (Soulsbury and White, 2016). Conflicts include crop raiding (e.g., by elephant, wild boar, bear), and predation on livestock and even attacks on humans (e.g., by tiger, lion, jaguar, bear). Large carnivores in particular have wide ranging behaviour (Boitani and Powell, 2012) which brings them more often into conflict with humans (Ripple et al., 2014). In response, humans may kill the wildlife in retaliation, to prevent economic losses or to reduce the level of threat and fear (Aryal et al., 2014). The latter may reduce wildlife population levels to non-viable numbers and social structures or behaviour within the population may be altered negatively (Aryal et al., 2014; Inskip et al., 2014; Woodroffe et al., 2005b).

Carnivores are commonly considered as a threat to human safety and livestock. The negative perception of human to carnivores due to conflicts can have negative impact on carnivore populations (Inskip et al., 2016; Ripple et al., 2014), whereas conservation and human well-being are best served by interventions capable of mitigating Human Carnivore Conflict (Inskip and Zimmermann, 2009; Miller et al., 2015).

Van Eeden et al.'s (2018) meta-analysis on the management of conflict between large carnivores and livestock found that guardian animals and lethal carnivore control most effectively reduced livestock losses. Financial incentives promoted tolerance of large carnivores in some settings and reduced retaliatory killings, but coexistence strategies appeared to gain most from being location-specific, while incorporating cultural values.

Cultural backgrounds play a role in mitigating HCC. Bagchi and Mishra (2006) found that a pastoral community in Nepal experiencing greater levels of livestock losses was comparatively more tolerant towards the snow leopard than another nearby pastoral community. They explained this discrepancy by the presence of a conservation-incentive program and by a larger dependence on cash crops rather than on livestock as a source of income at the former site, making it more tolerant of the snow leopard. The Lion Guardian project trains and supports community members to protect dwindling lion populations in Kenya (Hazzah et al., 2014). It applies traditional conflict-

mitigation techniques and builds tolerance for lions by explicitly incorporating Maasai community cultural values and belief systems. In one area, the project reduced large-carnivore killing by 100% while in another area, when protection was combined with financial incentives, killing was reduced by 98% (Hazzah et al., 2014).

The critically endangered Sumatran tiger (*Panthera tigris sumatrae*) is one of the species facing declining populations due to conflicts (Goodrich et al., 2022). To prevent the extinction of the Sumatran tiger, addressing the conflict is important and both ecological and social factors need to be considered (Struebig et al., 2018). The understanding of a species from ecological factors, i.e., behaviour, the dispersal of offspring, age, presence of disease or injury, prey depletion and landscape characteristics, is important because this can offer data what affects predation on domestic animals and thus can identify prone area of conflicts so that mitigation budget can be directed to the areas (Miller et al., 2015; Tilson and Nyhus, 2010). In addition, and as indicated by the papers cited above, social factors like traditional ecological knowledge (TEK) and local ecological knowledge (LEK) are important because the conservation success of carnivores is determined by emotional connection of local people living with the species (Dheer et al., 2021).

Sumatran communities have a history of explaining the causes of human tiger conflicts (HTC) with TEK including folklore and spiritual beliefs (McKay et al., 2018). How strongly such beliefs are currently held and whether these affect post-conflict behaviour of people remains unclear. Having a detailed understanding of the social context in which human-wildlife conflicts occur is increasingly recognised as an important aspect of wildlife conservation. In this study we investigated, through semi-structured interviews, whether spiritual beliefs contribute to explaining post-conflict behaviour towards tigers.

4.2. Methods

Study area

Interviews were carried out in two areas located at the border of Batanghari Protected Forest which is part of Kerinci-Seblat tiger conservation landscape in the province of West-Sumatra (Figure 1) in November and December 2018. This tiger conservation landscape is one out of two priority tiger conservation areas on Sumatra as it contains >25 breeding females and is embedded in a

larger landscape with the potential to contain 50 breeding females (Luskin et al., 2017). No tigers were reported present to the Ministry of Environment and Forestry in area one since 2005, whereas tiger presence had been reported three times in area two since 2005. These reported incidents consisted of two livestock attacks (in 2011 and 2018) and one tiger being snared which escaped (in 2011).

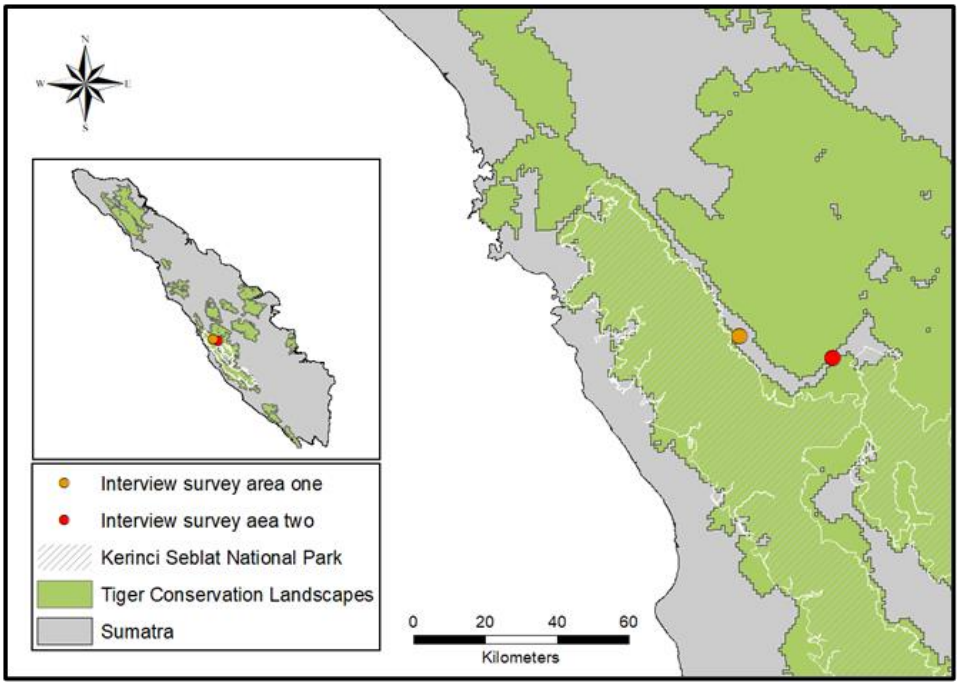


Figure 1. Interview survey area one (orange dot, left) and area two (red dot, right) in West-Sumatra, bordering Kerinci-Seblat National Park (hatched) and enclosed by the Kerinci-Seblat tiger conservation landscape (green).

Interview surveys

The study consists of semi-structured interviews in two locations within this area to assess to what extent spiritual beliefs and other factors played a role in post-tiger conflict behaviour. A total of 63 villagers were interviewed. Following pilot interviews and subsequent revisions, the interview leader (JM) and one of two local assistants/translators approached potential respondents whilst walking through the villages during daytime. Villagers were invited to participate in an interview with a duration of approximately 30-45 minutes regarding local culture, the relationship between humans and tigers (*harimau*) and the perceived causes of HTC. Prior to the start of an interview, the following definition of HTC was presented: tigers attacking humans and/or livestock in the forest or in the village, and/or entering villages.

The semi-structure interviews contained four parts (supplementary file S1). Part one consisted of (i) two open questions regarding the perceived causes of HTC, (ii) the perceived effect of environmental variables (supplementary file S2) on the occurrence of HTC through multiple-choice questions using 14 picture cards, and (iii) an open question on the presence of any additional factors not previously discussed that might increase the probability of HTC. In part two (iv) personal information was obtained and (v) first hand or second-hand encounters with *tigers* were described. Part three consisted of (vi) questions regarding knowledge of/ believing in (additional) tiger beliefs and/or myths (open and prompted questions), and (vii) villagers' post-conflict behaviour. The fourth and final part (viii) tested respondents' knowledge of *tigers* and (ix) their capability to distinguish and name five different felid species that occur on Sumatra using colour photos, and lastly (x) questions on knowledge of tiger population size, distribution, threats and diet.

Written notes were taken during the interview and voice recordings were made when allowed. Interviews were transcribed and ATLAS.ti 8.4.14 was used for qualitative and quantitative data analyses of questions that included references to spiritual beliefs. Per question answers were categorized and coded into common themes which were then grouped into code-groups describing spiritual, non-spiritual, or other explanations. Code-document tables were used to analyse the inclusion of spiritual, non-spiritual or other causes of HTC for each question per respondent. As statistical tests we employed Chi-square tests on count data comparing two groups, and McNemar's test on paired nominal data.

Ethics statement

Permission to use data in the study area was granted by the Livestock Department office of West Sumatra Province with number: *423/2212/sekr.2017*, and the ethical approval was granted by the social science ethics committee of Wageningen University, with approval number *09131098.*

4.3. Results

Respondent demographics

The respondents in area one included 17 men and 15 women with a mean age of 48 (range: 23-99), and area two included 16 men and 15 women with a mean age of 46 (range 18-80). All

respondents held the Muslim belief and 97% identified themselves as belonging to the Minangkabau ethnic group. The majority of the respondents had lived their entire life in the direct neighbourhood or at the interview location itself (57%), 17% indicated they had lived at another location within <25km of the interview site previously but did not specify any prior location or place of birth, and 25% were born or had lived >25km away.

Tiger identification and knowledge

Without distinguishing between the sampled areas, twenty-one different species names were given to the five felid pictures shown (excluding the general names 'harimau', wild/large cat 'macan' and cat 'kucing'). Twenty-nine respondents (46%) distinguished the Sumatran tiger as a separate species by using a name that at least included the word 'harimau' and by using a name that was not used for any other species. Names given include 'harimau sumatera' (n=13), 'harimau' (n=12), 'harimau asli' (n=2; original tiger) and 'harimau indonesia' (n=2). Other names given include 'harimau' when also given to at least one other species (n=25), lion (singa; n=5), 'harimau kumara' (n=1), 'harimau/macan' for all species (n=1), or a 'normal male tiger' 'harimau biasa jantan' whilst describing the golden cat as the 'normal female tiger', and unknown (n=1). Out of the 34 respondents that did not identify Sumatran tigers distinguishably, 22 respondents identified both tiger and clouded leopard (*Neofelis nebulosi*) as 'harimau' (35% of total), and overall, the name 'harimau' was given 116 times (37%).

Respondents from both areas widely indicated (67%) not knowing about tiger population trends; others thought populations were decreasing (25%), increasing (6%) or remained constant (2%). Fifty-nine respondents (94%) indicated that tigers occurred on Sumatra, whereas three respondents (5%) were not sure about their occurrence on Sumatra and one person who identified all but the golden cat as 'harimau', said they do not occur on Sumatra at all. Thirty-nine respondents (62%) indicated not knowing about their occurrence or absence on other Indonesian islands at all but other islands where tigers were thought to occur included Kalimantan (n=19), Java (n=9), Sulawesi (n=8), or Bali, (West-)Papua, Nusa Tenggara or everywhere around the world where there is forest (n=1 each). Of the 29 respondents who identified tigers successfully, three indicated that Sumatran tigers also occurred on Kalimantan (n=2), Sulawesi (n=2), and Java (n=1).

That habitat loss, killing by villagers, poaching, and prey depletion could be threats to the survival of tigers was acknowledged by 76%, 90%, 93%, and 86% of respondents, respectively, though some respondents indicated that one or several threats were not present in the area or did not affect tigers negatively as they were able to adapt or move to other forested areas that were considered still available in plenty. Two respondents were not sure if tigers eat meat, and 81% indicated that tigers eat the fruit durian (*Durio zibethinus*). Other food items including fruit, vegetables or other forest products like honey, bark, oil palm, soil and oxygen/wind ('angin') were specified by thirteen respondents (21%).

Different "tiger types" and spiritual beliefs

Eight respondents (13%; both areas combined) described a tiger type by name that transcends the biological tiger, namely: 1) an ancestral tiger or 'Inyiak' (n=5), 2) a guardian tiger ('penguasa'/'penunggu hutan') (n=2), and 3) a were-tiger 'harimau jadi-jadinya' (n=1), though similarities in characteristics can occur between them. These three tiger types may reflect the origin of spiritual tiger beliefs. The remaining 55 respondents (87%) did not distinguish or describe any particular tiger type, although spiritual characteristics were also mentioned here. A minority of respondents (19%) indicated that tigers never entered villages but a majority indicated that tigers may attack both humans and livestock (58%), whereas 23% of respondents said tigers attacked livestock only, or never attack at all (11%; among which spiritual explanations for tigers to do so were mentioned), or attack people only (3%; three unclear cases excluded). Three respondents indicated that only the wild tigers ('harimau liar') or 'the ones from further away/another place' would attack and not the ancestral and/or guardian type they had initially described.

Out of 62 respondents, 47 (76%) at least once indicated to hold a spiritual belief regarding tigers (one respondent excluded due to inconsistency in responding). Of these, all but one respondent included spiritual beliefs that caused and explained HTC (74%). Strong spiritual beliefs were held by 24 respondents (40%; excluding 4 cases of missing data) and this was significantly more in area two (tigers reported; Chi-square=7.900, df=1, p=<0.01).

Box 1. Committing adultery (‘berzina’)

Often initially described as ‘a person doing something wrong’ (‘orang salah’/‘kesalahan orang’), the act of committing adultery (i.e., premarital or extramarital sex) is a human behaviour often thought to cause a tiger to enter a village, to scare, follow and/or to attack a person or livestock. As explained by several respondents, it is something the tiger does not like and makes it angry. This behaviour will be punished or will be warned against after it has occurred. 16 Respondents from both areas indicated knowing about instances where a tiger had punished in response to this act. There is variation among respondents in where this customary law is (still) thought to apply and what the consequences are. One female respondent, age 80, from area one (no tigers reported) said: ‘Nowadays there are many young people committing adultery, and there are no tigers entering the village to attack. The rule now still applies in the forest, but not in the village anymore’. Twelve other respondents indicated that this belief was a myth or a lie, for example explained by describing that tigers were not able to know about such occurrences or by the fact that people in the area committed adultery but that there was no reaction by tigers.

The most frequently encountered spiritual belief was an effect of adultery (51%; Box 1). Again, significantly more respondents in area two (tigers reported) had strong adultery related beliefs compared to respondents in area one (no tigers reported; Chi-square=3.844, df=1, $p<0.05$). Moreover, when specifically asked, significantly more respondents indicated to believe in a causal relationship between adultery and HTC than was answered to open questions (33 versus 14 respectively, McNemar, $p<0.01$).

Other often mentioned spiritual causes for HTC were the breaking of behavioural prohibition (37%; Box 2) and the helix illness (21%, 5 missing cases excluded; Box 3). Incidentally mentioned spiritual causes for HTC were a tiger entering a village to survey, protect or warn villagers or his territory against bad people or tigers with bad intentions from entering, or warning against fires or earthquakes (n=2, 3%), an effect of Ramadan and the festival of sacrifice (‘bulan puasa dan haji’) during which the tiger surveys his territory once, similar to the guardian tiger (3%; excluding the respondent with inconsistent answers who also mentioned an effect of the birthday of Mohammad ‘Maulid Nabi’), problems between ethnicities or villagers (3%), having caused problems with a ‘were-tiger’ (2%), a triple divorce and fourth marriage with the same person without being married to someone else before the fourth marriage (2%), and entering the forest whilst pregnant (2%).

Box 2. Spiral marking (‘panyakit bulo’/‘bulo harimau’/‘pusa pusa harimau’/‘mantiko’)

The name ‘spiral marking’ was given to indicate what is most often described as a hair (‘rambut’) growth marking (‘tanda-tanda’) in the neck that grows like a spiral, similar to one’s hair crown on top of the head. The relation to tigers is described as being targeted, and a tiger will search, follow, attack and/or call or pick-up (‘jemput’) that person. Variation exists in how it is described: a spiral like hair growth, (black) skin, a small and dark collection of blood (the size of a gecko egg), one of the former with small animals like maggots (‘belatung’) or a small bone in it under the skin. Variation occurs in the number of spirals a person can have, i.e. one or two. It can be present in both humans and livestock or is restricted to either one of these. It can be present from birth, after touching a spiderweb in the forest or after obtaining a tick, then referred to as ‘Mantiko’ as described by only one respondent. Some say the marking can be seen, for example from age 12, or say it cannot be seen by normal people but only by a medicine man (‘dukun’). People who are marked can be differentiated by their behaviour: they are never scared, never look people in the eyes, and/or are alternately very scared or very brave. They might always struggle to survive or fulfil their livelihood. These people should visit a medicine man who will help them to get rid (‘buang’) of the marking, often described as letting blood, the maggots, or a small bone come out, or by opening (‘buka’) the marking before treatment. He does this with his esoteric spiritual knowledge (‘ilmu’) either by, or by combining the following: attacking and biting the marked area like a tiger would, cooling it (‘didinginkan’) by using a spell (‘mantra’), washing the marking with lime- or flower-enriched water (e.g., the species *Celosia cristata*), praying (‘doa’), reading out religious verses (‘bacabacaan ayatayat’), using cotton and betelpeper (‘sirih’), or bringing offers (‘ditawarkan’) including chickens. Though described in more detail here, this factor resembles descriptions of ‘Darah buruk’ partially, as referred to by Kerincinese peoples (Bakels, 2000).

Box 3. Prohibitions or taboos (‘Pantangan’)

Many variations in applicable prohibitions or taboos occur. The origin of these is likely found in attempts to prevent HTC by not disrespecting, disturbing, hurting or imitating a tiger (Bakels, 2000). When broken, varying degrees of warnings or punishments might be given by tigers. According to some, the causal link has been proven in the past by tiger appearances or attacks. The term ‘prohibition’ may include committing adultery or behaviour related to obtaining the spiral marking (see Box 2), but ‘forest prohibitions’ were often distinguished and described separately as ‘pantangan hutan’. Examples of prohibitions include:

1. You may not take water from a river using a cooking pan, but should use your hands or a scoop (or you may not take any water from a river at all and should bring it in from the village).
2. You may not talk arrogant or too much ('bicara sombong'/'ota'). This can relate to behaviour between villagers, and/or towards the tiger.
3. You may not wash yourself naked in the forest, but need to wear coverage.
4. You may not construct anything (permanently) on the tiger's path
5. You may not break wood on your leg, leave a chisel in a logged tree stump, turn a logged tree upside down for camp construction, or hammer another piece of wood into a logged tree stump.
6. You may not extinguish a cooking fire by blowing but need to use water, nor may you hit charcoal with a stick.
7. You may not marry with the same person for the 4th time, without being married to someone else after the 3rd divorce ('talak').
8. There may not be arguments/fights within families or between ethnic groups.
9. You may not take rice out of the pan with your hands, you have to use a spoon.
10. You may not drink straight from a forest river but need to use a glass.
11. You may not step on stones used for a cooking fire in the forest.
12. You may not steal durian from someone else.
13. You may not enter the forest when you are pregnant.
14. You may not cut your hair in the forest.
15. You may not defecate whilst standing in the forest.

Two respondents believed the prohibition related to not being allowed taking water from a river with a cooking pan and cutting hair in the forest only applied in the past but not anymore, either because tigers didn't occur in the area anymore or because the forest was already quite damaged.

Post-conflict behaviour

Fifty-one respondents (81%, both areas combined) expected villagers to call the government after a tiger had been sighted inside a village. 17 Respondents (29%) indicated that villagers might do nothing and 14 respondents (24%) indicated the potential for retaliatory killing by villagers themselves (4 unclear cases excluded). 12 Respondents (20%) indicated the potential for consultation of a hunter (3 unclear cases excluded) and ten respondents (17%) indicated that villager might consult a tiger shaman ('pawang harimau') for help. Five additional respondents chose consulting the shaman but were excluded due to a lack of spiritual beliefs and explanation of what the shaman would do, thus lacking any spiritual connection (2 unclear cases excluded).

The frequency that a respondent indicated a potential for a conflict tiger to be killed, including execution by non-villagers but the government for example, was higher in area one and the association was significant (Chi-square=6.894; df=1, $p<0.01$; seven unclear cases excluded). A second significant association was found between gender and post-conflict killing of a tiger, in which men less frequently indicated the opportunity for tiger killing as reaction to a conflict (Chi-square=4.791; df=1; $p<0.03$). When comparing the people who had or had not indicated holding any strong spiritual belief, no relationship regarding chance of tiger killing was found (Chi-square=0.561; df=1, $p<0.5$; ten unclear cases excluded). However, when comparing the inclusion of spiritual beliefs overall, a relationship was found where having spiritual beliefs was associated with a lower chance of killing (Chi-square= 4.891; df=1, $p<0.03$).

The perceived effect of environmental variables

Out of 13 environmental variables discussed (n=61, two respondents excluded due to age and difficulty of understanding), the highest agreement reached was on the variable 'Forest destruction' with the expectation that more forest destruction would result in more conflicts (57%; Table 1). Other variables with an agreement level >40% were 'Prey density', 'Tiger density', 'Rain season' and 'Fruit season', but these had different perceived effects onto HTC. There were four respondents who indicated no effect of any variable: three of these distinguished different tiger types and the fourth respondent mentioned invisibility of *tigers* after livestock attacks and hence also seemed to refer to spiritual characteristics. A fifth respondent only included effects of tiger density and prey availability, but related the positive effect of tiger density to increased activity of the guardian tiger in protection his area against tigers from outside.

Landcover types that were perceived to have the potential for a HTC to occur varied among respondents as well. The majority of respondent though conflicts could occur in forests (77%) and small-scale agriculture fields (70%). The potential of conflicts in villages was indicated by 57% of the respondents, and this was 33% for rice fields. Agreement on HTC potential in large scale plantations was lowest, with 48% indication a potential, 38% indication no potential and 15% indicating being unaware.

Table 1. Perceived effect of environmental variables with highest level of agreement among respondents in two areas enclosed by the Kerinci-Seblat tiger conservation landscape, Sumatra.

Environmental variable	Maximum agreement	Effect on HTC
Forest destruction	57%	More forest destruction results into more conflicts
Food availability in forest	49%	More (wild) food results into less conflicts
Tiger density	48%	A higher tiger density increases the chance on HTC
Rain season	48%	There is no effect of the rain season
Fruit season	43%	More fruit results into more conflicts
Distance to river	41%	There is no effect of distance to river
Livestock density	38%	There is no effect of livestock density
Distance to forest	38%	Closer to the forest the chance of HTC is higher
Elevation	38%	There is no effect of elevation
Slope	38%	There is no effect of slope
Population density in village	36%	There is no effect of population density on HTC
Distance to (main) road	34%	Further away from roads the chance of HTC is higher
Distance to village centre	30%	There is no effect of distance to village

4.4. Discussion

By assessing local perception on the causes of HTC we revealed that spiritual beliefs and folklore still play an important role in the explanation of conflict causes. Holding spiritual beliefs, though possibly associated with recent HTC experience, does not inherently provide tigers with increased protection. There is little agreement among respondents' perception on the effect environmental variables are thought to have on HTC. Our methodological decision to not distinguish different tiger types prior to our interviews has caused that our results should be interpreted with some caution. However, no predator other than the Sumatran tiger is capable of killing both humans and large livestock, hence it is this felid species that would assumingly be perceived as the greatest threat.

Overall communication regarding tigers was impeded by a lack of common agreement and/or knowledge on the species and its identification. Although some villagers still heavily depend on forests for their livelihood, changing livelihood practices and market integration have likely decreased individual and collective forest experience. The current accelerated rate of species extinction that threatens up to one million plant and animal species with extinction (United Nation, 2019), has furthermore reduced the overall level of local exposure to tigers and other wildlife, and hence it is not surprising that local species knowledge was lower than is often assumed (Nyhus et al., 2003; Tang and Gavin, 2016).

That Sumatran tigers actually occur in neighbouring forests was not always acknowledged. Inclusion of wildlife conservation themes in local primary and secondary education is furthermore usually minimal (ECK, personal observation) and as the risk to HTC has broadly decreased over the past 10 years (see Chapter 2), there generally seems to be little need or desire for villagers to obtain additional tiger knowledge.

The presence of folklore and a belief in spiritual causes of HTC was indicated by 74% of our respondents that almost exclusively represented the Minangkabau ethnic group from West-Sumatra. Comparison with other studies that included other Sumatran ethnic groups as well, confirms that a belief in an effect of adultery or other behavioural prohibitions can be very abundant and strong (Bakels, 2000; McKay et al., 2018). Moreover, we described a prevalent belief that has received little attention to date. The helix marking resembles ‘bad blood’ (‘darah buruk’ or ‘darah kotor’) as described by Kerincinese in the early 1990’s. Bakels (2000, p.249), who refers to it as a small gecko-shaped marking in the neck of a person, also describes how a person can unintentionally become affected with bad blood by walking on a tiger’s path or by touching a branch to which the blood of a tiger’s prey adheres. Based on our results, additional explanations or adaptations of this belief include, amongst others, a different appearance resembling a spiral hair growth, the presence of the marking since birth rather than obtained during lifetime, but also an effect of touching spiderwebs in the forest. Courageous behaviour was then also seen as an indicator of being affected and shamans were asked for treatment using similar methods as we described, to avoid becoming destined tiger prey. The practice of shamanism in our study area,

however, already seems to have all but disappeared, as no respondent was able to indicate where such person currently lived or how he/she could be consulted.

We interviewed both believers and non-believers of commonly held spiritual beliefs. Non-believers linked these to folklore or myths that were not based on reality, or had never heard about them. We also found that significantly more respondents indicated to believe in effect of adultery when asked directly, rather than indicating this effect themselves prior. This furthermore suggests that such beliefs remain well known but might not be as strongly held anymore at present. Bakels (2000) contributes observed erosion of TEK in the 1990's partly to the rise of the orthodox Islam which is not characterised by spiritual relationships between humans and animals. Different *tiger* types are however still distinguished and whether or not this is indicated, characteristics of biological tigers can be both biological and spiritual, indicating its lasting ambiguity. For example, one respondent mentioned how a mother *tiger* would enter villages to attack livestock after one of her offspring was captured or shot by villagers. He later explained that *tigers* are invisible after attacking livestock ('tidak kelihatan'*)*, and hence he did not believe the government could help in resolving HTC.

The dynamic loss of TEK and its implications for conservation management have received little attention to date but that is changing. For example, Turvey et al. (2018) found that folklore, compared to practical knowledge on hunting, was more quickly lost in communities where the Hainan gibbon (*Nomascus hainanus*) had recently gone extinct. They relate this due to the fact that older members of the community are usually the ones who hold and pass down such stories, while information about practical ways of interacting with biodiversity may be disseminated more broadly among younger members. Implications of folklore in HTC mitigation are especially important when it provides increased carnivore protection e.g., by decreasing retaliatory killing. We found that holding spiritual *tiger* beliefs does not inherently provide increased post-conflict protection. St. John et al. (2018) found that ethnicity and its associated beliefs might indeed be weak predictors of one's intention to hunt wildlife on Sumatra. However, hunting and retaliatory killing take place in very different contexts. McKay *et al.* (2018) found that although the Minangkabau more often indicated to hold customary laws regarding tigers than other ethnic groups, they also indicated higher tendencies to kill tiger in retaliation, thus supporting our findings

that holding spiritual beliefs does not clearly result in pro-conservation behaviour. Mitigation and explanation of HTC based on folklore therefore does not seem to be a viable conservation tool by itself, though its opportunistic and adaptive inclusion might be beneficial when spiritual beliefs are strongly held by effected community members (Fernández-Llamazares and Cabeza, 2018).

The lack of agreement on the effect that environmental variables may have on HTC occurrence that we found can partially be explained by a lack of HTC experience. The effect such variables have is furthermore based on a spatial scale that is larger than can often be comprehended by individuals, especially considering that the majority of villagers are mostly aware of their near surroundings only. Several respondents even indicated how they were unaware of the occurrence of any HTC or were unable to identify tiger successfully, despite the fact that livestock attacks or tiger sightings had occurred in the area within the last few years. Whereas Miller et al. (2016) found that communities in India accurately perceived differences between spatial difference in hunting patterns of tigers and leopards, their study included only people that personally experienced livestock attacks themselves. Besides the more obvious effect of habitat destruction, food availability and tiger density, a surprisingly high level of agreement was found indicating a positive effect of fruit season, specifically durian. This was also based on personal observations of tigers eating durians and an experiment (not published) showed how durian was indeed consumed by tigers, although it is not clear whether durian provides digestive or nutritional benefits. If and how durian consumption affects the probability of HTC is unknown.

By studying traditional and local ecological knowledge of Minangkabau surrounded by key tiger habitat, we found a strong presence as well as erosion of spiritual beliefs in relation to HTC. Although holding such beliefs does not seem to provide tigers with inherent protection, a decreased inclusion of tigers in local culture might weaken emotional connections between people and tigers, possibly resulting in reduced tolerance.

Supplementary S1. Questionnaire

Introduction

My name is Joey and I am a student from The Netherlands. I am visiting this area to learn about culture, nature and animals, and especially about the relationship between people and tigers (*harimau*). I would like to ask you questions about the causes of tiger-conflicts. The duration of the interview will be about 30-45 minutes. If you allow me, I would like to record your answers to enable me to improve my Indonesian speaking, and so that I can relisten to this conversation again to understand your answers better. If you don't want to be recorded, that is no problem. Once already started and you don't want to answer a question, or don't want to be recorded anymore, you can say so. The questions are for an assignment of me, and I will only share your answers with my University in a report. I will not write down your name or address so no one knows about your answers. I would only like to ask you alone, and after finishing, other people can respond as well.

Do you allow us to interview you?	YES NO
Do you agree to record the audio of this interview?	YES NO

Try to find a quiet place with little noise

Translator explains: sometimes conflicts with tigers occur. What we mean with the definition 'conflict' is when a tiger attacks livestock or a person in the forest or in the village, or only strays through the village. When a tiger eats a wild animal, this is not considered a conflict. [In some interviews the term 'problem ' (masalah) was used with the same definition rather than 'confict' (konflik) as this sometimes was understood better].

Do you understand what we mean with the definition 'conflict'?	YES NO

Part one

Q1. According to you, why do *tigers* enter villages?
Q2. According to you, why do *tigers* attack people or livestock in the forest or in the village?
According to you, if a *tiger* attacks livestock or people in the forest or in the village, or strays through a village, is this a problem or not? [excluded from analyses]
Y/N , why?

Environmental variables: Other than what you have answered above, we think there might be (other) environmental factors that could have an effect on the chance a conflict between people and tiger occurs. Because of this, I would like to know your opinion on environmental variables that might increase the chance of conflicts occurring. I will show several cards with variables and you can choose which ones, according to you, have an effect on the conflict chance (Supplementary S2)

	Choice	Affect **(Y/N)**	Order: n=…….
1.*Tiger* density / occupancy	**A – B** – C – D		
2.Food availability in the forest	**A – B** – C – D		
3.Livestock density	**A – B** – C – D		
4.Distance to a forest	**A – B** – C – D		
5.Distance to a (main) roads	**A – B** – C – D		
6.Distance to rivers	**A – B** – C – D		
7.Distance to village centre	**A – B** – C – D		
8.Population density in a village	**A – B** – C – D		
9.Elevation	**A – B – C** – D – E		
10.Slope	**A – B – C** – D – E		
11.Rain season or dry season	**A – B** – C – D		
12.Fruit season	**A – B** – C – D		
13.Forest destruction	**A – B** – C – D		
14.Habitat type: where can conflicts occur, and where do the most conflicts occur? **Conflicts can occur in:** 1. Forest; Y/N/TT 2. Small scale agriculture field; Y/N/TT 3. Company plantation (large scale); Y/N/TT 4. Rice field; Y/N/TT 5. Village; Y/N/TT	Order: 1. 2. 3. 4. 5.		
15.See Q3 below			
16.We would like to ask you to sort all the factors, that according to you have an effect, from the most influential to the least influential.			

Q3. Is there any other factor that might increase the chance of a conflict occurring?

Part two

Respondent information

Gender	Male / Female	Age:
Education	No school – SD (elementary) – SMP (secondary) – SMA (high school) – Universitas (Diploma - S1 – S2 – S3)	
Current occupation Former occupation if different	- -	
Is your religion Islam?	Y/N, other:	
Are you Minangkabau? From which etnic group are you?	Y/N, other: Suku: Melayu, Caniago, Jambak, Sikumbang,……..	
Since when do you live here? And before that?	Since: Near/Far:	
How many days within a week do you enter the forest nowadays? Did you enter the forest more often before, or less often?	Nowadays: Before:	
Do you have any livestock? How many?	Y/N. Cow: Buffalo: Goat: Chicken: Duck:	
Do you have dogs or cats? How many?	Y/N. Dogs: Cats:	
Is your livestock or are you dogs/cats kept in a cage?	Always/Never/Only at night	
How often have you encountered a *tiger?*		
What were the conditions like when you encountered the *tiger*?	In: village/forest: How far from here: Date/Month/year: Time/early morning/late morning/afternoon/evening: How did you encounter the *tiger*? What happened with the *tiger*: escaped, captures and released again, killed?	

Do you know other people who have encountered *tigers* (of which you can tell how it happened)?	Y/N, number:
What were the conditions like when he/she encountered the *tiger*?	In: village/forest: How far from here: Date/Month/year: Time/early morning/late morning/afternoon/evening: How did you encounter the tiger? What happened with the *tiger*: escaped, captures and released again, killed?

Part three

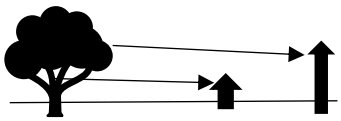
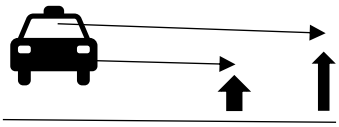
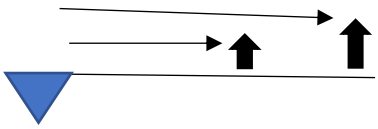
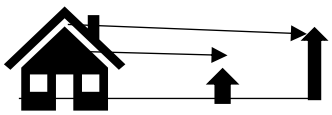
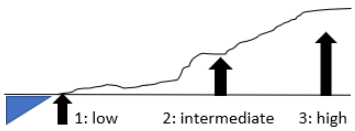
Q4. Do you know about any beliefs/myths regarding *tigers*? Can you describe? [Here we regularly but not systematically had to clarify what we meant with beliefs or myths. This was then described as things you may not do as the tiger will arrive, stories from the past told by others, and one assistant occasionally mentioned 'prohibitions' (pantangan) here as explanation] Do you believe this belief/myth? Why?	Y/N, Y/N,
Q5. When people do something wrong, like commit adultery, do you think (a) *tiger* will enter the village?	Y/N/Don't know,
Q6. Is there anything else that could make a *tiger* arrive in the village?	
Q7. Do you know anything about *puso puso harimau*? If so, what do you know? [Here we regularly but not consistently mentioned *penyakit bulo* in addition to *puso puso harimau* which is another name used to describe the helix marking. We also did not consistently asked if	Y/N,

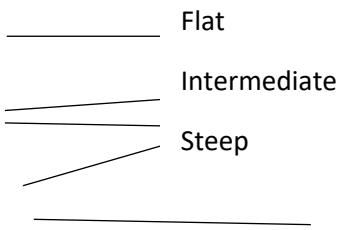
respondents, besides knowing about, also believed in the relationship between the helix marking and *tigers*]	
Q8. Do you know anything about marindu? [We did not consistently asked if respondents, besides knowing about, also believed if respondents also believed that shamans were able to call or lure tigers into cages but whenever this was indicated was it also recorded].	Y/N,
Q9. If a *tiger* would enter the village, what do you think the villagers would do to the *tiger*? Multiple options possible [Coding in ATLAS.tii was focused on categorising if there was a chance of *tiger* killing or not, and if a shaman would be called for help to make use of a spiritual connection between him and *tigers*].	Kill: yes/no Leave: yes/no Call the government to capture: yes/no Call hunter: yes/no Call a shaman: yes/no If shaman → what will he do? Ritual to return the *tiger* to the forest/capture/kill?
At this time, do you believe that the government can handle/help solve *tiger* conflicts?	Y/N/TT, why? Experience/knowledge: yes/no Special gear: yes/no

Part four

What is the name of this animal?	1: Leopard cat, 2: Clouded leopard, 3: Asian golden cat, 4: Sumatran tiger, 5: Marbled cat [Always shown in same order]
How are tiger population dynamics around the world?	Increasing – constant – decreasing – I don't know
On which islands in Indonesia do *tigers* occur?	Sumatra: yes/no Others:….
Approximately how many *tigers* are there on Sumatra?	
What factors threaten the survival of tigers?	1. Habitat loss = Y/N/I don't know 2. Killing by villagers: Y/N/I don't know 3. Poaching (to sell): Y/N/I don't know 4. Food depletion: Y/N/I don't know 5. Other =
What do *tigers* eat?	Meat: …., Fruit: …., Other: ….

Supplementary S2. Environmental variable interview cards

Tiger density	**Food availability in the forest**	**Livestock density**
Imagine: At a location with 10 tigers there are 5 HTC. What would it be like if there were 40 tigers there? --- A. Definitely more HTC B. Definitely less HTC C. There is no effect of tiger density D. I don't know	Imagine: At a location with 50 (prey) animals in the forest, there are 5 HTC. What would it be like if there were 200 (prey) animals? --- A. Definitely more HTC B. Definitely less HTC C. There is no effect of food availability D. I don't know	Imagine At a location with 50 livestock there are 5 HTC. What would it be like if there were 200 livestock there? --- A. Definitely more HTC B. Definitely less HTC C. There is no effect of livestock density D. I don't know
Distance to forest	**Distance to roads**	**Distance to roads**
Imagine  1: near (2km) 2: far (20 km) Where do most HTC occur? --- A. Definitely closer to forests B. Definitely further away from forests C. There is no effect of distance to forest D. I don't know	Imagine  1: near (2km) 2: four (20 km) Where do most HTC occur? --- A. Definitely closer to roads B. Definitely further away from roads C. There is no effect of distance to forest D. I don't know	Imagine  1: near (2km) 2: far (20 km) Where do most HTC occur? --- A. Definitely closer to rivers B. Definitely further away from rivers C. There is no effect of distance to rivers D. I don't know
Distance to village centre	**Village population density**	**Elevation**
Imagine  1: near (2km) 2: far (20 km) Where do most HTC occur? ---	Imagine 100 people live in one village and there are 5 HTC. What would it be like if there were 1000 people living there? --- A. Definitely more HTC B. Definitely less HTC	 A. Definitely more HTC at low elevation B. Definitely more HTC at intermediate elevation

A. Definitely closer to village centres B. Definitely further away from village centres C. There is no effect of distance to village centres D. I don't know	C. There is no effect of livestock density D. I don't know	C. Definitely more HTC at high elevation D. There is no effect of elevation E. I don't know
Slope	**Rain or dry season**	**Fruit season**
 --- Definitely more HTC in flat areas A. Definitely more HTC in intermediate areas B. Definitely more HTC in steep areas C. There is no effect of slope D. I don't know	When do HTC occur mostly? --- A. Rain season B. Dry season C. There is no effect of season D. I don't know	When do HTC occur mostly? --- A. During fruit seasons B. Outsiide of fruit seasons C. There is no effect of fruit seasons D. I don't know
Forest destruction	**Habitat type**	
When do HTC occurmostly? --- A. When forest is still intact B. When forest is destructed C. There is no effect of forest destruction D. I don't know	1. Forest 2. Small scale agri 3. Perkebunan perusahaan 4. Sawah 5. Kampung --- In which habit types can HTC occur? Where does this occur mostly?	

Felid identification colour photos

Leopard cat (Prionailurus bengalensis)

Clouded leopard (Neofelis nebulosa)

Asian golden cat (Catopuma temminckii)

Sumatran tiger (Panthere tigris sumatrae)

Marbled cat (Pardofelis marmorata)

A local tribe called Suku Anak Dalam, along with their dog, which they use for hunting (Fatris MF)

Chapter 5

Wild boar hunting and trapping as a threat for wildlife conservation

Erlinda C. Kartika , Ardi Ardono, Ignas M.A. Heitkönig

Abstract

Wild boar has the widest geographic distributions of all larger terrestrial mammals. Dog-assisted wild boar hunting may reduce disease transmission and crop raiding but also elevates the potential disease transmission from dogs to wildlife and *vice versa*. On Sumatra, game hunting tends to focus on wild boar, where hunters either actively use dogs or fire arms, or passively use snares. Dog-assisted wild boar hunting takes place in "parties" where many dogs track and kill wild boar and likely other game species too. In addition, dogs may carry diseases that can be transferred to wildlife, further threatening their dwindling populations. Our objectives are to understand: (1) the extent of active and passive wild boar hunting in Sumatra and West Sumatra in particular; (2) dog-assisted hunting practices, including target animal species, preferred hunting areas, and the motivation of the hunters for hunting; (3) potential disease transmission by hunting dogs to game. We conducted three types of data collection to cover the wide range of hunting techniques: (1) information from social media about dog-assisted wild boar hunting events in West Sumatra; (2) a questionnaire-guided survey among hunters around the Batanghari Protected Forest, West Sumatra; (3) expert interviews from provincial conservation offices about wild boar hunting practices in Sumatra. Active and passive wild boar hunting occurred in Sumatra. Firearm and snare hunting occurred in all eight provinces in Sumatra while dog-assisted hunting occurred only in 6 provinces. We found that at least 1331 dog-assisted wild boar hunting events occurred in 2019 across the province of West Sumatra, on a regular basis. The dog-assisted wild boar hunting events mostly occurred on Sunday but did not exclude any other day of the week. Events involve 10-300 people, where each hunter brings 1 to 9 dogs. Dog-assisted hunting in West Sumatra mainly hunts wild boar (69 respondents) and also other animals including Sambar deer (29 respondents) and muntjac (8 respondents). Their main self-reported motivation for hunting is hobby (71%), and their preferred hunting areas are oil-palm plantations (40%) and areas bordering the forest (29%). Many dogs used for hunting are reportedly not vaccinated (35%), risking transmission of diseases like Rabies and Canine Distemper Virus to game and wild predators. Wild boar are the main target species for all types of hunting methods but other wildlife is also unintentionally targeted. Hunting is inadequately regulated, rendering enforcement of these regulations impossible. The extent of wild boar hunting has as yet been unquantified but likely will have strong effects on the remaining wildlife populations. We call for proper quantification of hunting bags, and regulation, including

the use and health status of dogs, to prevent disease transmission from dogs to wild animals and to protect remaining wildlife populations.

8.4.Introduction

Wild boar (*Sus scrofa*) arguably has the widest geographic distributions of all larger terrestrial mammals; it occurs from Europe throughout the Greater Sunda Islands of South-east Asia (Keuling and Leus, 2019). The species is known to cause depredations on crops and it is considered as a pest in many countries (Khattak et al., 2021; Linkie et al., 2007). There is also growing concern that this species spreads diseases like African Swine Fever, dangerous to human and domestic animals (Denstedt et al., 2021; Meng et al., 2009; Pejsak et al., 2019; Penrith and Kivaria, 2022). Wild boar is also a preferred species of prey for carnivores like wolves (Sin et al., 2019) and tigers (Allen et al., 2021). Wild boar are generalists which live in many habitat types, and have potentially high reproductive rates (Bieber and Ruf, 2005; Podgórski et al., 2013). The crop raiding by wild boar motivates controlling wild boar populations through hunting, poisoning and trapping (Cruz et al., 2005; Rosa et al., 2018).

Wild boar hunting practices are part of ancient traditions (Dodd and Meijer, 2018) and are considered a cultural heritage in, for instance, Poland (Dajczak et al., 2021). Elsewhere they are hunted and killed for sport and recreational purposes (Quirós-Fernández et al., 2017), or commercially to fulfil the demand of pig meat (Luskin et al., 2014). For example,rock art in north-western Saudi Arabia depicts the earliest known dog-assisted hunting strategies from 9,000 – 10,000 years ago, even pre-dating pastoralism (Guagnin et al., 2018). In Japan, a strong association was noted between the first appearance of Jōmon dog burials and a shift to hunting terrestrial ungulates at about the same time, i.e., in the new Holocene deciduous forests of the region. This indicates that dogs were probably used as a dense-forest hunting adaptation after the Pleistocene–Holocene transition (Perri, 2016), in line with the findings of Clutton-Brock (1995).

While regulated wild boar hunting is considered beneficial either for the environment or for humans, unregulated hunting could lead to local over-exploitation and extinction of this species (Treves et al., 2019). Many hunters also target other species next to wild boar, which could be a serious threat for species with small populations (Luskin et al., 2014). Dog-assisted wild boar

hunting does not only increase the harassment and killing of wildlife (Orr et al. 2019) but also elevates the potential disease transmission from dogs to wildlife and *vice versa* (Doherty et al., 2017; Hassell et al., 2017; Sepúlveda et al., 2014).

Although it is known that wild boar hunting is conducted using firearms and snares (Massei et al., 2011; Sparkes et al., 2016), the organisation and the extent of dog-assisted hunting is unknown. In this paper we investigate, qualitatively, the organisation and extent of dog-assisted wild boar hunting in West Sumatra and how wild boar hunting practices affect other species populations in Sumatra. We also investigate potential disease transmission by hunting dogs to wildlife and *vice versa*.

8.4.Methods

We conducted three types of data collections for the study: (1) gathering information from social media to get information about dog-assisted wild boar hunting events in West Sumatra; (2) a questionnaire-guided survey among hunters around the Batanghari Protected Forest, West Sumatra; (3) expert interviews from provincial conservation offices and NGOs about wild boar hunting practices in Sumatera.

The extent of dog-assisted wild boar hunting in West Sumatra

Data on dog-assisted wild boar hunting events were collected from the platform Facebook. First, we searched and selected Facebook groups of dog-assisted hunting groups using keywords "PORBI'', "PORBBI", "Baburu Babi", and "Buru Babi", names by which these hunting groups are regionally known. We also used Facebook's "Related searches" button to obtain additional suggestions of hunting groups. We limited our study to hunting groups from Sumatra island and excluded others in Indonesia. Once we found an open access hunting group on Facebook we joined it; we joined private groups after having obtained their approval. After getting into the group we started to search for all hunting events in 2019 (January to December 2019) using keywords "tanggal" (EN: date), "alek" (EN: events), "alek gadang" (EN: big events), "buru" (EN: hunting) and "baburu" (EN: hunting). We recorded all events including date, locations of hunting and contact person for each hunting event. Some hunting events were posted in several groups, if this happened, we only recorded one hunting event by crosschecking date and location.

Questionnaire survey on dog-assisted hunting

We conducted a questionnaire survey among n = 69 dog owners which also identified themselves as wild boar hunters from eight villages in West Sumatra (see Figure 1) to understand their hunting practices. We had three sets of questions for each respondent concerning: (i) basic information about the dog's owner and demographic information of the dog(s) (age, sex, breed, etc.); (ii) hunting practices including area preferred for hunting, motivation for hunting and type of animal to be hunted; (iii) dog management, primarily focused on vaccination status against Canine Distemper Virus (CDV) and Rabies (RABV) if any; and the hunter's knowledge about these viruses.

We targeted the respondents specifically for experienced participants in dog-assisted wild boar hunting. Dog-assisted wild boar hunting is only carried out by male hunters, so all of our respondents were male. Respondents were chosen on the basis of the order in which they were met as we walked through the village, visiting each compound in turn. Only those people willing to participate were included in the survey.

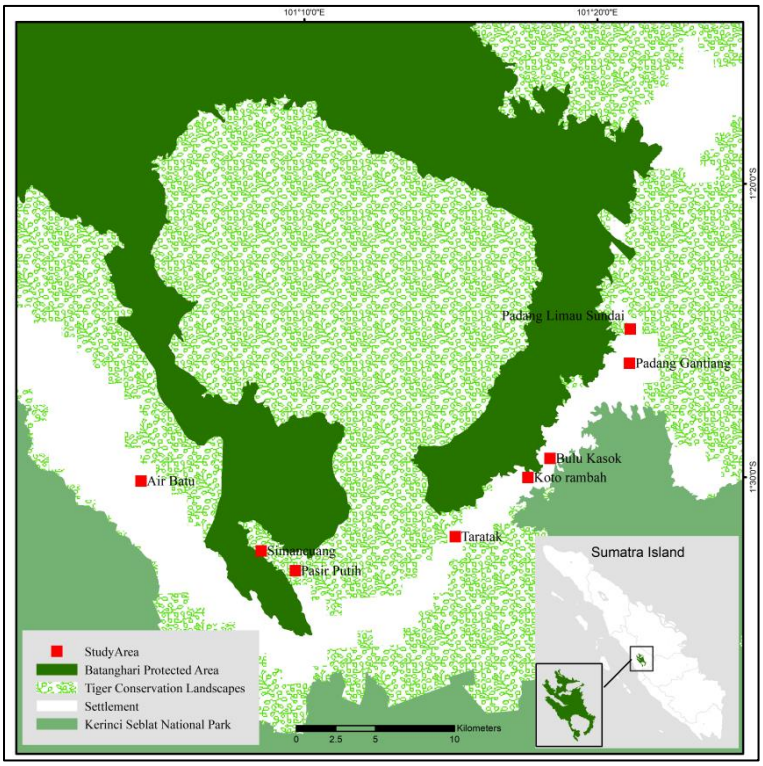


Figure 1. Eight selected villages (red squares) within 5 km of the boundary of the Batanghari Protected Forest where dog-assisted wild boar hunting was detected.

Expert Information

The expert information was obtained using an online questionnaire. The questionnaire was sent to the conservation offices of the Ministry of Environment and Forestry in each of the eight provinces on mainland Sumatra. The questions were mainly focusing on wild boar hunting practices in each province including type of wild boar hunting, equipment used for hunting, the area where people conducting wild boar hunting, hunting permits and animals killed other than wild boar. This also revealed information about arms and snare hunting.

5.3.Results

Dog-assisted wild boar hunting in West Sumatra

We found that there were several actors for wild boar hunting and trapping in Sumatra mainland: local wild boar hunters association (associated with PORBI), local farmers, a local tribe (*Suku anak dalam*), and the sport hunter association PERBAKIN. We identified at least twenty-six dog-assisted wild boar hunting Facebook groups in which three of them were not actively posting a hunting schedule.

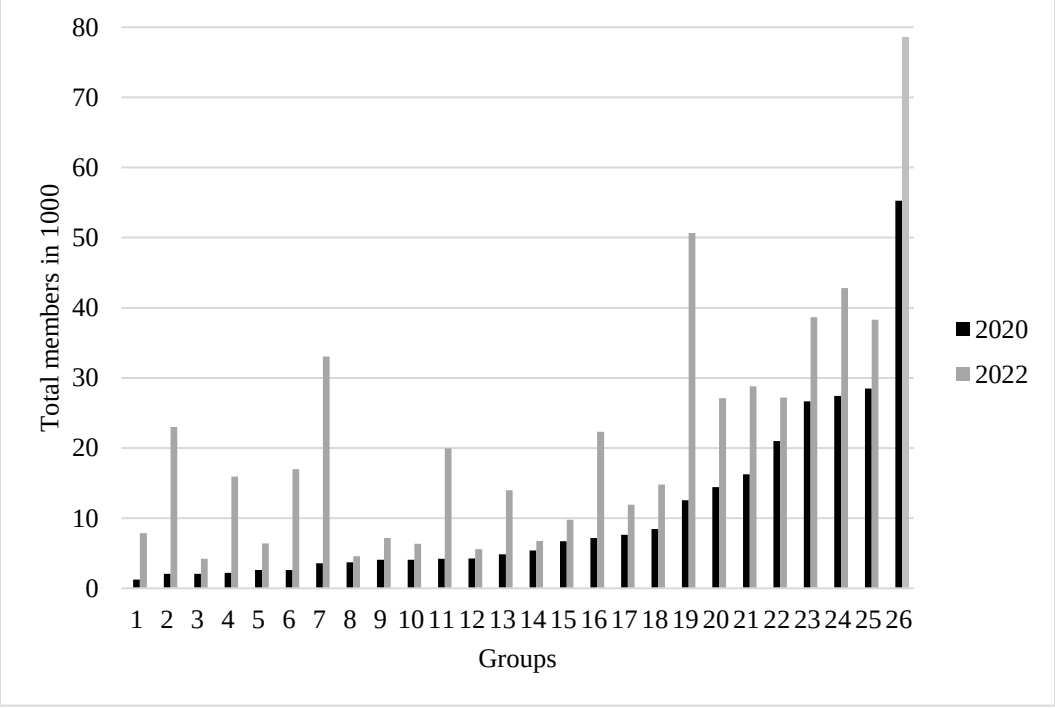


Figure 2. Increasing group members of wild boar hunter group in Facebook from 2020 to 2022. Group numbers refer to anonymized distinct Facebook groups. All hunter groups showed a distinct (22– 1025%) increase in membership from 2020 to 2022.

We recorded wild boar hunting events in each group from January to December 2019. Membership of the groups ranged from 1,252 to 55,273 individuals (accessed in May 2020). Membership increased in all groups from 4,213 to 78,537 between May 2020 and February 2022, i.e., from 22% to 1025% (Figure 2).

Dog-assisted wild boar hunting was detected in all regencies of West Sumatra. There were 1331 wild boar hunting events recorded in West Sumatra in 2019 (from January to December) (Table 1). The highest hunting events occurred in Padang Pariaman regency with 280 hunting events.

Table 1. Number of recorded wild boar hunting events in West Sumatra Province in 2019 per Regency; all regencies reported dog-assisted wild boar hunting

Regency	**Numbers of recorded events**
Padang pariaman	280
Agam	167
Pasaman	139
Tanah datar	126
Lima puluh kota	109
Pasaman barat	87
Dharmasraya	85
Sijunjung	72
Pesisir selatan	70
Solok	69
Padang	44
Sawahlunto	39
Payakumbuh	23
Solok Selatan	20
Bukittinggi	1
Total	**1331**

The documented hunting events showed that hunting was conducted in all days in the week (Monday to Sunday). Sunday was the day when most hunting took place (789 hunting events), followed by Wednesday (179 hunting events) and Tuesday (177 hunting events).

Dog assisted- wild boar hunting practices in West Sumatra: from the perspective of hunters

Most dog owners who hunt have 1- 2 dogs (61%, n=69) and maximally 9 dogs. Apart from hunting (57%, n=69), the hunters also use their dogs for other purposes: guarding their plantations from wild boar (17%), guarding their house from wild animals (12%), companion for going to the forest or plantation (9%) and for guarding their livestock (5%). Thirty-two respondents have dog(s) for hunting purpose only.

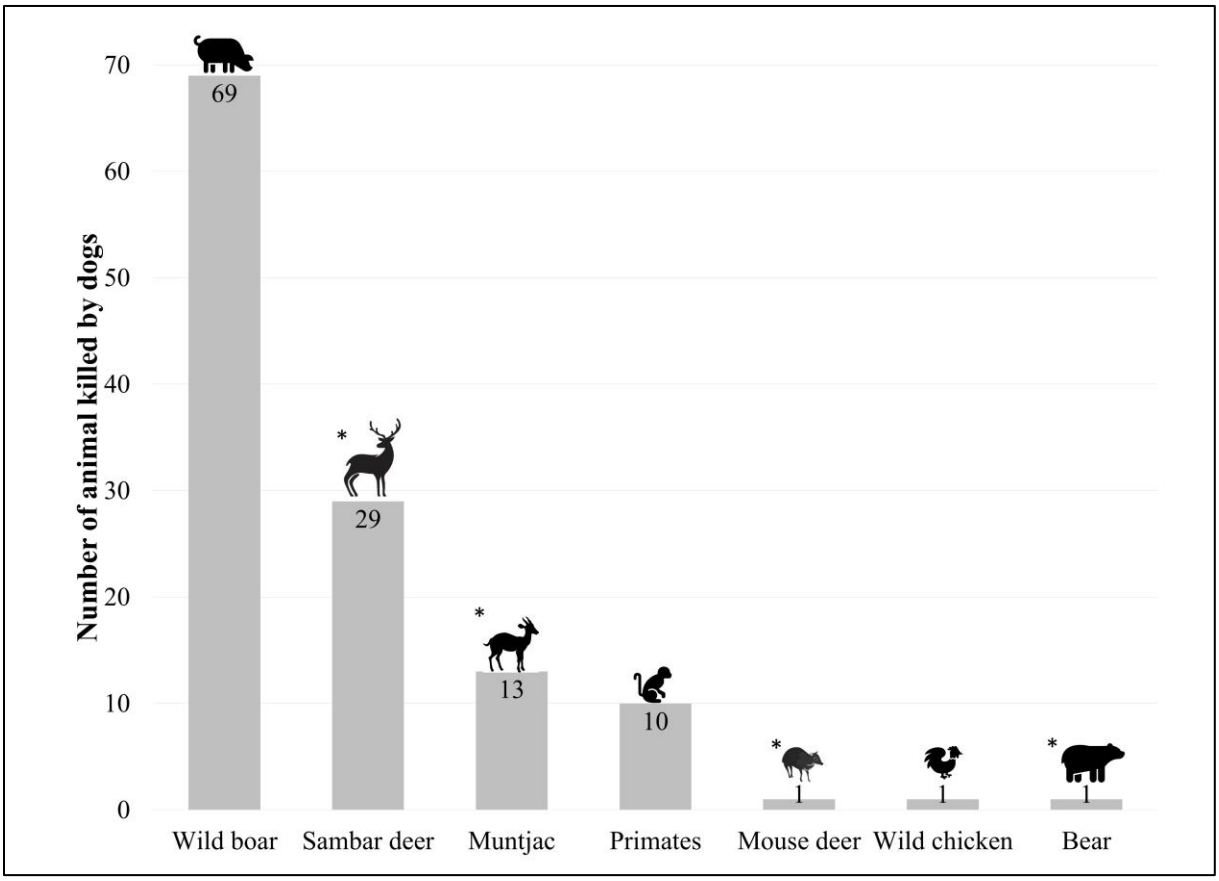


Figure 3. Number of interviewees reporting on species killed by their dog(s)during dog-assisted hunting events. Species with an asterisk (*) are protected by law.

The median number of hunters joining wild boar hunting in a month was eight times (min =1, max =16). Most hunters (71%) mentioned that their reason for wild boar hunting is hobby and only

seven respondents mentioned that they did wild boar hunting for pest control. Two areas preferred for wild boar hunting are palm-oil plantation (40%) and area bordering forest (29%).

All the interviewed hunters mentioned that their dog(s) had experience killing wild boar on at least one of the hunting events. The number of wild boars killed by the dogs in a week ranged from 1 to 30 wild boar. Most hunters (93%) mentioned that the killed wild boar was left in the hunting area and none of them reported that they sold the wild boar. The dogs not only killed wild boar during hunting event but also killed other wildlife such as sambar, primates, mouse deer, wild chicken and bears (Figure 3). In eight villages where the interviews were conducted, the hunting took place on Friday after the Friday prayer (around 13:00) and Saturday/Sunday, depending on the weather. If it was raining on Saturday morning then the hunter would go the next day. Friday hunting was mostly conducted in small groups of hunters (10-30 hunters) and only in one location close by the village. However, Saturday/Sunday's hunting parties were conducted with a large group of hunters (50-100 hunters) from several villages joining together, but also from hunters outside of the study area. Almost once a month, hunters conducted very extensive hunting party ("alek" or "alek gadang") where they invited hunters from other regency to join the hunting. In such cases the hunting was attended up to 300 hunters.

Wild boar hunting and disease exposure to wildlife

A total of thirty-five percent respondents mentioned that their dogs were not vaccinated against CDV and RABV. Most hunters know about RABV (88%) but far less so about CDV (7%). Fifty eight percent of the hunters reported that their dogs died in one of hunting events and 43% of the hunters lost their dogs in the forest.

Expert information about wild boar hunting in Sumatra: where and how

Wild boar hunting was found in all provinces of mainland Sumatra. There were three types of wild boar hunting in Sumatra: (1) using dogs; (2) using firearm and (3) using snare. Wild boar hunting using firearm and snare was found in all eight provinces in Sumatra mainland, however, hunting using dogs was only found in 6 provinces (Table 2).

Table 2. Type of wild boar hunting in each province of Sumatra mainland

Province	Wild boar hunting		
	with dog	with firearm	with snare
Aceh	Yes	Yes	Yes
North Sumatra	No	Yes	Yes
Riau	Yes	Yes	Yes
West Sumatra	Yes	Yes	Yes
Jambi	Yes	Yes	Yes
Bengkulu	Yes	Yes	Yes
South Sumatra	No	Yes	Yes
Lampung	Yes	Yes	Yes

Expert information: explanation on wild boar hunting with dogs

Wild boar hunting with dogs was done by local villagers and Persatuan Olah Raga Buru Babi Indonesia (PORBI translated as Pig Sport Hunting Association of Indonesia). The wild boar hunting using dogs was detected in six provinces in Sumatra mainland except for North Sumatra and South Sumatra (Table 2). Wild boar hunting using dogs was detected in four type of land-use including forest border, rice field, oil-palm plantation and area mixed agriculture. In West Sumatra, Jambi, Lampung and Bengkulu province hunting using dogs was conducted more than once in a week while other provinces just occasionally. There are four reasons people conducted wild boar hunting: hobby, tradition, pest control and for financial reason (sale of animal commodities). All of conservation offices reported that no one issued a permit when people conducted hunting using dogs.

Expert information: explanation on wild boar hunting with firearms

Different from hunting using dogs, hunting using firearms was mainly conducted by Persatuan Menembak dan Berburu Seluruh Indonesia (PERBAKIN, translated as Shooting and Hunting Association of Indonesia) and local people. Hunting using by PERBAKIN and local people was conducted 1-12 times in a year. It was also detected that hunting using firearms in Jambi area was conducted by local tribes *Suku anak dalam*. The tribes conducted hunting on regular basis where

some of the hunted animals were for consumption and others to be sold to North Sumatra especially for wild boar.

Wild boar hunting using firearms was mainly done in three areas including forest border, oil-palm plantation and mixed agriculture area. In West Sumatra and South Sumatra, the events were also reported to occur inside the forest area. The main reason of wild boar hunting using firearms was hobby, pest control and financial reasons. Different from wild boar hunting using dogs that was conducted regularly, this hunting using firearms was mostly conducted occasionally. Only one conservation office (West Sumatra conservation office) reported that they sometime received requests to issue permit from PERBAKIN.

Expert information: explanation on wild boar hunting with snare

The main reason for wild boar hunting using snare was for pest control and for economic purpose. This type of hunting was done by local people and mainly farmers. There were three types of snares used for this type of hunting: nylon, wire and wood. For pest control people usually place the snares around their agricultural or rice field. But for economic purpose, people will place the snares not only around their fields but also in the border of forests and sometime inside the forest area (South Sumatra and Jambi Province). The conservation office reported that this type of hunting sometimes also captured other wild animals, including Sumatran tiger (*Panthera tigris*), Malayan tapir (*Tapirus indicus*), Sun bear (*Helarctos malayanus*), Clouded leopard (*Neofelis nebulosa*), Sambar deer (*Rusa unicolor*), Muntjac (*Muntiacus 93ransmi*), and Sumatran elephant (*Elephas maximus*). The conservation offices reported that farmers never ask for permission if they wanted to put on snare for wild boar.

5.4.Discussion

We found that wild boar hunting occurred in all provinces in Sumatra. Three types of wild boar hunting were detected in Sumatra main island: (1) using dogs, (2) using firearms, and (3) using snares. Wild boar hunting using firearms and snares was detected in all province of Sumatra mainland and wild boar hunting using dogs was detected in six provinces. Hunters were also not only targeting wild boar for hunting but also other wildlife. Dogs were extensively used for wild boar hunting but many hunters were still not aware with vaccination and they have limited

knowledge about disease in dogs. Wild boar hunting using snares brings a risk for wildlife in general as it not only captures wild boar but also other wildlife species and the dogs may transmit or receive pathogens from wildlife.

Hunters in West Sumatra commonly use social media, like Facebook, for communication about dog-assisted hunting schedules and exchange information regarding wild boar hunting and dogs in general. The use of this and other digital platforms attracts many hunters to organised events. The number of hunting parties and the number of participants will likely increase in coming years as the communication between hunters gets easier using social media. All the data presented above is only documented data that was gathered from one social media platform (Facebook). It is possible that the hunters communicated through other social media platforms like Instagram and TikTok and/or through direct communications like WhatsApp, Telegram or Signal. Hence the actual number of hunting events could well be much larger than what we recorded over one year.

In the area where the interviews were conducted, the coffee shop is the place where hunters exchange information about hunting events. We also found that hunters use mosque loudspeakers to invite people to join hunting after Jum'at prayer (ECK personal observation). The mosque is a central point of information within a village. These meeting points and announcements suggest that wild boar hunting is completely embedded within society.

Respondents reported that their main motivation for wild boar hunting using dogs was for hobby. This type of hunting is followed by local people that usually joined as PORBI member. The hunting events were only attended by males of different age, from 12 years onwards (ECK Personal observation). In West Sumatra, the Minangkabau ethnic group considered as majority, has a matrilinear system in their society. This means that in the end, decisions are made by women in the family or society. A husband has marginal positions in his wife's extended family or even the leader of the society called *penghulu* which are usually men, cannot make decisions without the consent of old lady of this society called *bundo kanduag*. The wild boar hunting has been described as a political identity for men in the society to empower their status in women-dominated society (Arifin, 2012). Apart from hobby, the hunters also mentioned that they conducted hunting events

for pest eradication. Farmers in Sumatra considered wild boar as pest for their crops (Linkie et al., 2007).

The practices of wild boar hunting using dogs could increase the risk of disease 95ransmitssion from dogs to wildlife and *vice versa* (Rhyan and Spraker, 2010; Sparkes et al., 2016). Dogs particularly can transfer RABV and CDV to wildlife, especially wild carnivores, during hunting event (Knobel et al., 2014; Nouvellet et al., 2013). The interactions between dogs and wild boar in the study area are high. We found that more than 35% of dogs in the study area was not vaccinated against RABV and almost 100 % not vaccinated against CDV which means a high risk of disease transmission within the dog community during the hunting and also between dogs and other wildlife (Knobel et al., 2014). There is also a growing concern about the spread of African Swine Fever (ASF) from wild boar to domestic animals through the dogs. In Europe the concern of ASF transmission from wild boar to domestic pig has happened since 1957 (Cwynar et al., 2019; O'Neill et al., 2020). ASF has also emerged to wild boar in South East Asia since 2018 and there is a growing concern that this disease could spread to livestock and wildlife such as tigers (Denstedt et al., 2021; Luskin et al., 2021).

Farmers mainly use trapping methods such as snares for capturing wild boar mainly to prevent crop riding of their crops. Linkie (2007) found that 80% farmers around Kerinci Seblat National Park considered wild boar as pest for their agriculture. Crop raiding by wild boar is not considered to be a human-wildlife conflict and is therefore not addressed by the government of Indonesia. The governmental budget of mitigating human-wildlife conflict is mostly allocated to more charismatic animals such as Sumatran tiger, clouded leopard, sun bear, elephant, Malayan tapir, orangutan, and crocodile. Wild boar and macaque are almost ignored when it comes to budget allocation for conflict mitigation. That is why farmers are not seeking for help from the government to manage crop raiding by wild boar or macaque, but they set up traps for these species. However, these traps not only capture wild boar but other species too. Most carnivores can escape nylon traps by cutting the nylon using their tooth, but wood or metal wire tend to be fatal.

Wild boar hunting using firearms is usually conducted by the sport hunting association PERBAKIN and the local tribe Suku Anak Dalam. PERBAKIN usually attracts wealthy hunters,

as they can afford the cost of a firearm, the licence to use the gun (Luskin et al., 2014), and the hunting permit (Government of Indonesia, 1994). Different from snare/trapping – used mostly for pest control – the fire arm hunting purpose is for sport and hobby. PERBAKIN occasionally conducts hunting events and moves around across several islands in Indonesia.

All hunting activities discussed here need permission from the provincial conservation office (Ministry of Environment and Forestry, 2010a). However, almost all the hunting events in Sumatra were carried out without such permits: only the West Sumatra conservation office has ever received requests from PERBAKIN for hunting permits. There are three regulations for managing hunting in Indonesia, i.e. (i) hunting in general (Government of Indonesia, 1994), (ii) hunting permits (Ministry of Environment and Forestry, 2010a) and (iii) hunting management (Ministry of Environment and Forestry, 2010b). Indonesia has instruments to manage hunting, especially sport hunting, but the implementation and the enforcement of these regulations clearly need room for improvement. Another gap in the hunting regulation is that the provincial conservation office has not implemented the Ministerial regulation number P. 19/Menhut-II/2010 about hunting management. In this Ministerial regulation the local conservation office has to make a document consisting of the inventory for places where people could go for hunting and the types of animals including the number of animals that could be hunted. To date, no conservation office on mainland Sumatra has made this document.

In all wild boar hunting methods i.e., using dogs, firearm or trapping, wild boar are not the only targeted wildlife. Many other protected and endangered wildlife like Sumatran tiger, Malayan tapir, sun bear, clouded leopard, sambar deer, muntjac, and Sumatran elephant can also be killed intentionally or unintentionally during active hunting or trapping. All hunting methods are opportunistic, meaning that the hunters do not control if they kill young, juvenile or adult, male or female, wild boar or other wildlife. This likely negatively affects the population sizes of wildlife species, and continues to be major driver of population decline for these species (Mills, 2012; Milner-Gulland and Bennett, 2003).

We recommend that the use of social media such as Facebook groups for communications between hunters could be used for campaigning about the health status of the dogs or vaccination for dogs

(Schwedinger et al., 2021). Veterinarians from the local conservation office could take this opportunity to get connected to hunters. Moreover, the conservation offices could manage the hunting using this platform.

This paper described the organisation and the extent of dog-assisted wild boar hunting in West Sumatra and how wild boar hunting practices affect other species populations in Sumatra. We also investigate potential disease transmission by hunting dogs to wildlife and *vice versa*. The results from this study contribute to better understanding of the human – wild boar conflicts and the responses of local people in West Sumatra. Dog-assisted hunting occurs frequently and government should take action to regulate this type of hunting.

A group of wild boar hunters is preparing for wild boar hunting using dogs near a rubber plantation in West Sumatra

Chapter 6

Viral exposure in hunting dogs: risks of potential spill-over to Sumatran tiger

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Abstract

Domestic dogs can be a threat to wild carnivore populations through the transmission of infectious diseases. For example, Rabies Virus (RABV) and Canine Distemper Virus (CDV), commonly found in domestic dogs, have been recognized to cause population declines of large carnivores. The probability of virus transmission may increase through wildlife hunting practices using dogs, particularly within and near the borders of protected areas. Our objectives are to understand: (1) The exposure of dogs to RABV; (2) dog management practices, including dog owner's knowledge on RABV and CDV, and the RABV and CDV vaccine status of dogs; and (3) factors determining dog-wildlife interactions, particularly with regard to tigers. We carried out a cross-sectional viral-serological approach and conducted a questionnaire survey around the Batanghari Protected Forest, West Sumatra, Indonesia. We collected blood samples from 117 domestic dogs and interviewed 160 dog owners from eight villages within 5 km of the protected forest where tigers are known to be present and where dog-assisted wild boar hunting is carried out. Dogs were commonly used for hunting, including within the Batanghari Protected Forest. We found that 97% of sampled dogs had an antibody titer against RABV lower than the protective level of immunity (<0.5 EU/ml), both for vaccinated and unvaccinated dogs. Only <5% of respondents were familiar with CDV, versus 75% with RABV. Almost none of respondents vaccinated their dogs against CDV, while <50% gave RABV vaccine. The high number of unvaccinated dogs for RABV and CDV increase the potential of spillover to carnivores such as tiger. To prevent the spread of diseases to wild carnivores, effective vaccination in combination with strict hunting regulations, law enforcement and education about the diseases and vaccination is needed.

6.1. Introduction

There is a growing recognition of the impact of infectious diseases on wildlife populations (Cunningham et al., 2017; Loots et al., 2017; Tompkins et al., 2015). For example, infectious diseases have been the cause for extinction of the Polynesian tree snail *Partula turgida* from microsporidian infection (Cunningham and Daszak, 1998), drastic decline of many amphibian species from chytridiomycosis (Cunningham et al., 2017), and lion *Panthera leo* population declines from CDV (Roelke-Parker et al., 1996). There are several causes of disease emergence, but anthropogenic spread of the disease has been identified as a major driver of emerging infectious diseases in wildlife (Cunningham et al., 2017). Increasing human population and increasing need for living and agriculture space have led to increased contact among wildlife, humans, domestic pets and domestic livestock, which increases the probability of pathogen transmission among them (Hassell et al., 2017). People living within or close to wildlife habitat may have diseases that they can transfer to wildlife (Dunay et al., 2018). Livestock and domestic animals such as dogs (*Canis lupus*) that live in villages around or within wildlife habitat may similarly transfer diseases to wildlife (Knobel et al., 2014).

Domestic dogs play several roles in rural areas. Dogs protect people visiting the forest from wildlife attacks (Sepúlveda et al., 2015), they guard livestock from carnivore attacks, and they are being promoted as non-lethal strategies to prevent human-wildlife conflict in India and Africa (Khan, 2009; Marker et al., 2021). In many countries (e.g., Nicaragua, Bolivia, Australia, USA and Indonesia), people also use dogs for wildlife hunting, both for sport and subsistence (Koster and Noss, 2014; Luskin et al., 2014; Sparkes et al., 2016). However, dogs can be a source of disease that threatens wildlife (Acosta-Jamett et al. 2011; Orozco et al. 2014), posing a risk to 188 species on global scale (Doherty et al. 2017). Increasing access of domestic dogs to wildlife habitat not only elevates the potential of disease transmission from domestic dogs to wildlife and *vice versa* (Rhyan and Spraker, 2010), it also increases harassment and killing of wildlife, which can negatively affect those wildlife populations (Hassell et al., 2017). In particular, Rabies Virus (RABV) and Canine Distemper Virus (CDV) can be transmitted to wild carnivores (Knobel et al., 2014; Nouvellet et al., 2013).

RABV is an RNA virus in the family Rhabdoviridae, genus *Lyssavirus* (Rupprecht et al., 2017). RABV can infect ~190 mammalian species, of which 16 species are at high risk of extinction and two species, the Ethiopian wolf (*Canis simensis*) and the African wild dog (*Lycaon pictus*), are known to be directly threatened by this disease (Stuchin et al., 2018). The endangered Asiatic wild dog or Dhole (*Cuon alpinus*) has recently been hit by a Rabies outbreak in southern India (Mani et al., 2021). RABV is considered to cause a productive virulent infection in several large carnivore species, transmitted by domestic dogs (Butler et al., 2004), possibly contributing to bioaccumulation of pathogen exposure in top predators (Malmberg et al., 2021). Transmission of the virus occurs when an infected animal bites or scratches another animal, or when saliva from an infected animal makes contact with the eyes, mouth, or nose of a recipient. The first published record of Bengal tigers being rabies infected was in 1943 (Pandit, 1950).

CDV is an animal morbillivirus which is transmitted through aerosol droplets and through direct contact with infected body fluids (Loots et al., 2017), urine and feces (Ludlow et al., 2014). The importance of CDV as a threat to wild felids was first recognized during an outbreak affecting lions in the Serengeti in 1994, which caused 1,000 animals (approximately 30% of the population) to die (Cleaveland et al., 2000; Roelke-Parker et al., 1996). Outbreaks have also been recorded in solitary felines with less social contact than lions, such as jaguars (*Panthera onca*) (Avendaño et al., 2016) and pumas (*Puma concolor*) (Avendaño et al., 2016), and was recently found in Siberian tiger (*Panthera tigris altaica*) (Robinson et al., 2015). Kameo et al. (2012) also found the disease in wild boar (*Sus scrofa*) and sika deer (*Cervus nippon*), and Sakai et al. (2013) found CDV in nonhuman primates (Beineke et al., 2015).

Large carnivores may get the disease by eating infected animals, which can be either domesticated (e.g., dogs) or wild (e.g., raccoons and foxes) (Gilbert et al., 2015). Populations of tiger (*Panthera tigris*), the vulnerable leopard (*Panthera pardus*) and clouded leopard (*Neofelis nebulosa*) and many other large carnivores are declining and fragmented, and the stochastic effect of infectious diseases makes them more vulnerable to extinction (Haydon et al., 2002; Ripple et al., 2014). In Russia and India, CDV caused tiger deaths (Gilbert et al., 2015). Analysis of the DNA sequence of the CDV strain from tigers in Russia showed similarities to the DNA sequence of CDV in domestic dogs (Beineke et al., 2015), meaning that spillover from dog to tiger likely occurred.

Also, CDV in the Serengeti lion was closely related to the *Onderstepoort* CDV strain isolated from a domestic dog in South Africa. However, the CDV in an African wild dog population had no association with the CDV in domestic dogs in the region (Prager et al., 2012; Woodroffe et al., 2012). Only a handful of publications describe the rate of infection in rural dogs, and we found none about the rate of infection in wild animals. Hence, the actual transmission (spillover) of CDV from dogs to wild carnivores remains to be well documented.

Unvaccinated dogs are thought to be an important reservoir of RABV and CDV infection but possibilities for vaccination are limited (Pimburage et al., 2017; Prager et al., 2012). For example, the number of free RABV vaccines provided by the Indonesian government is limited, covering hardly 30% of the dog population in West Sumatra (Dinas Peternakan, 2016), well below the 70% recommended to be vaccinated by the World Health Organization (WHO, 2018). In Sumatra as another example, most dogs are not vaccinated for CDV and there is no obligation for dog owners to have their dogs vaccinated. Achieving high vaccination levels requires the commitment and collaboration of the stakeholders involved, including governmental vaccination programs and the willingness of dog owners to vaccinate their dog (Lapiz et al., 2012; Wera et al., 2016), whereas religious and cultural beliefs can undermine dog vaccination programs (Aréchiga Ceballos et al., 2014; Kaare et al., 2009).

This paper focusses on RABV and CDV in hunting dogs as potential pathogen spillover to the Sumatran tiger. In Sumatra, dog-wildlife interactions prominently take place during hunting where hunters in large groups use dogs to hunt for wild boar or other wild animals (Luskin et al. 2014) – see also Kartika et al. in chapter 6 of this thesis, near to and within the forest. Investigating diseases in domestic dogs in and around Sumatran rainforest habitats is vitally important to assess the risk of potential spillover of these diseases to wild carnivores. The goals of our study is to assess: (1) the immunostatus of RABV in domestic dogs; (2) dog management practices (Belsare et al., 2014); and (3) factors determining dog-wildlife interactions (Hassell et al., 2017).

6.2. Methods

We conducted our study in eight villages within 5 km of the boundary of Batanghari Protected Forest, West Sumatra, Indonesia, where tigers are present in the forest close to the village area.

We conducted a questionnaire survey of 160 dog owners, the number per village in proportion to village size, about their dog hunting and management practices, including vaccination against RABV and CDV and any dog– wildlife interactions. We also collected blood from 117 dogs in 6 villages, with permission, to assess the immunostatus for RABV (but not CDV as there is still no vaccination against CDV applied in the area) in individual dogs.

Study area

The Batanghari Protected Forest, an area of approximately 3000 km² in southern West Sumatra Province, Indonesia, is bisected by an inhabited valley which includes about eight larger villages (Fig. 1). The Batanghari Protected Forest also consists of a logging concession, a community forest, mixed agriculture and palm oil plantations. The forest is an important habitat for wildlife and provides a wildlife corridor between Kerinci Seblat National Park in West Sumatra Province to the South East and the Rimbang Baling Wildlife Reserve in neighboring Riau Province, further to the North East. Both Kerinci Seblat National Park and Rimbang Baling Wildlife Reserve are Tiger Conservation Landscapes (Sanderson et al., 2010), designated for saving the Sumatran tiger (*Panthera tigris sumatrae*), other wildlife and their habitats on the rapidly developing island of Sumatra. Local wildlife species of interest for this paper, apart from the Sumatran tiger, include the clouded leopard, wild boar (*Sus scrofa*), sambar deer (*Rusa unicolor*), muntjac *(Muntiacus muntjac*) and mouse deer (*Tragulus spp.*). In Sumatra and many other parts of the tiger's range, tigers coexist with other wild carnivores like the Sunda clouded leopard, the Asiatic golden cat, marbled cat and leopard cat (Sunarto et al., 2015). All these felids and carnivores communities in the forest near the study area are susceptible of RABV and CDV and are also reservoirs for CDV (Terio and Craft, 2013). For generalist pathogens like CDV especially, these carnivore community can maintain the survival of the pathogens which can lead to an outbreak if the disease not properly managed.

Some parts of Batanghari Protected Forest are managed as community forest (*Hutan Nagari*) since 2017, where the community is responsible for forest management, which includes the collection of non-timber forest products (KLHK, 2016). Our study focused on the southern part of Batanghari Protected Forest, where the protected forest has largely been classified as community

forest. We selected eight villages within 5 km of the southern boundary of Batanghari Protected Forest for our study (Figure 1).

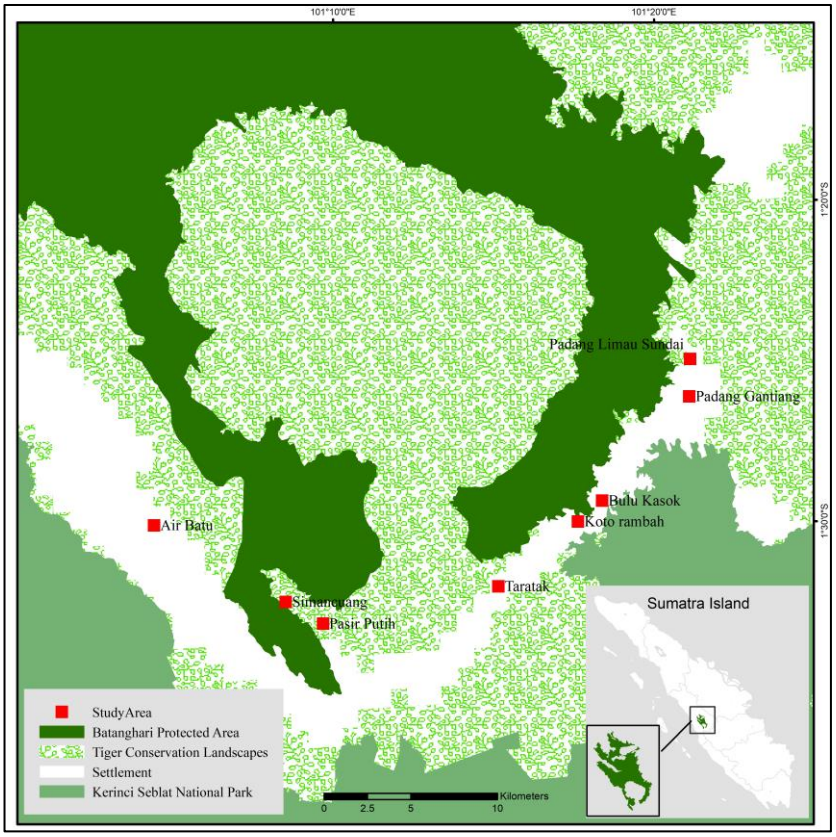

Figure 1. Eight selected villages (red squares) within 5 km of the boundary of the Batanghari Protected Forest. Light green = lands with no protected status (forest concessions, palm oil plantations, etc.); dark green = lands with protected status (including Batanghari Protected Forest north of the settlement area and Kerinci Seblat National Park to the south); white = settlement and agricultural area. All areas are part of the tiger conservation landscape (TCL) except settlement areas. (Source: Ministry of Environmental and Forestry -adapted)

Hunting practices in West Sumatra

In West Sumatra the primary motivation to hunt wild boars is social (Luskin et al., 2014), apart from executing pest eradication from their agricultural lands. Hunting usually occurs once or twice a week and often occurs as large daytime hunts which utilize dogs. In the study area, hunting occurred every Friday (usually after Friday prayer) and Saturday or Sunday. Friday hunting was

mostly village-based hunting, with villagers hunting in the lands surrounding village. Usually, 10-30 people participated in this hunting. Saturday or Sunday hunting involved 10–300 hunters from several villages joining together to hunt in areas containing a mix of forest, rubber and oil palm covering an area of approximately 15 km^2 (Luskin et al., 2014). The local hunting association organized a larger hunting event once a month, where many people from other municipalities joined the hunt, which may attract more than 500 people, and each person might have up to 9 dogs (*pers. Obs.* ECK). Hunters targeted wild boar and also sambar deer, muntjac and mouse deer, all of whose meat can be eaten. If the dogs captured wild boar, hunters mostly let them eat the carcass, and any carcass remaining after the dogs ate their fill was left on the ground (*pers. Obs.* ECK).

Large population of dogs in the study area will definitely increase the risk of CDV transmission to wildlife, numbering more than 10,000 individuals with a density ~13 dogs/km^2 (average ~209 dogs per village) in the human settlement area (Dinas Peternakan, 2016). The high population of dogs in the study area creates optimal conditions for having a large reservoir of RABV and CDV in dogs which can potentially transfer the disease to wild tigers and other carnivores (Acosta-Jamett et al., 2011). Hunting activities that occur twice per week (every Friday and Saturday or Sunday) and dog owners frequently bringing dogs into wildlife habitat for many purposes, increase the chance that dogs will interact with wildlife which can lead to spillover of CDV and other diseases from dogs to wild carnivores, especially tigers and other big cats that prey on dogs. The hunting mostly takes place in and around oil-palm plantations, rice fields, mixed agriculture and in the bordering protected area, but 32 % of hunters use the very edge and/or the fringe of the Batanghari Protected Forest when hunting bags are disappointing. Hunting inside the protected forest is illegal, but still continues unabated, due to ineffective law enforcement.

Blood Sample Collection

Prior to collecting blood samples from dogs, we asked each of the 160 dog owners for permission during the interview; 67 dog owners obliged. To assess the immunostatus of RABV, blood samples from 117 dogs were collected from six villages close to tiger habitat from December 2018 to January 2019. Two blood samples were excluded from further analysis because of insufficient volume.

Blood samples were collected in collaboration with veterinarians from the Livestock Department office in Solok Selatan regency. The protocol for blood collection followed the Indonesian regulation on animal welfare (Government regulation number: PP. 95/ 2012). After getting permission from the owner, we collected 2x ~5 ml blood samples from every dog and put the samples in 2 different tubes, one with coagulant and another with anticoagulant.

Laboratory analysis

We performed the enzyme-linked immunosorbent assay (ELISA) test from the blood serum to calculate titer antibody for RABV using a commercial rabies ELISA kit (indirect ELISA) as described by the manufacturer (PUSVETMA, n.d.). A dog is protected from RABV if it has ≥ 0.5 EU/ml (equivalent unit/ml) of RABV antibody titers (WHO, 2018). The RABV test was conducted by the Central Veterinary Research Office, the Ministry of Agriculture of Indonesia in Denpasar.

We examined antibody titers against RABV in sera samples of dogs. Using the Mann–Whitney U test, we compared the antibody titers between vaccinated and unvaccinated dogs to assess the effectiveness of the vaccination program in the study area.

Questionnaire on dog management practices and dog-wildlife interactions

We conducted a questionnaire survey among n = 160 dog owners in eight villages indicted in Fig. 1 to understand factors influencing dog-wildlife interactions and people's perception about vaccination. We had four sets of questions for each respondent concerning: (1) basic information about the dog's owner and demographic information of the dog(s) (age, sex, breed, etc.); (2) the dog's access to the forest and its involvement in hunting activities, including its wildlife related behaviour while hunting; (3) dog management, primarily focused on health care and the immune status of the dog, including vaccination against RABV and CDV if any; and (4) people's knowledge about RABV and CDV (Supplementary S1).

With regard to vaccination, we asked respondents what type of vaccine they gave their dog(s). The vaccine for CDV commonly used by local veterinarians is called Eurican 6, which protects dogs from six diseases including CDV. Therefore, apart from asking if a respondent gave a CDV vaccination to their dog(s), we also asked if they gave Eurican 6 or another vaccine for CDV to

their dog(s). To assess the respondent's knowledge about RABV and CDV we asked whether s/he knew about RABV and CDV, using the local names of both diseases. If the respondent answered conformingly, we would further ask to describe the symptoms of the diseases.

Households were visited and only one adult member of each household was interviewed. We recorded the coordinates of each household using GPS and measured the distance of the house to the boundary of Batanghari Protected Forest; both measures were included in dog-wildlife interaction analysis. Only dog owners were interviewed, and respondents were chosen on the basis of the order in which they were met as we walked through the village, visiting each compound in turn. Only those people willing to participate were included in the survey.

Analysis of dog-wildlife interactions

From the questionnaire survey we gathered information about dog-wildlife interactions. A dog-wildlife interaction was defined as the experience of dogs to kill or aggravate (e.g., bite, chase) wildlife based on information from the owners. We assumed that dog-wildlife interaction was mediated by factors that increase the contact rate between dogs and wildlife. We used a generalized linear model to determine factors influencing dog-wildlife interactions. A binary response variable was based on the dog owner reporting the presence/absence of a dog interaction with wildlife in the past one year. Variables included in the model are distance of households from the protected area; experience of dog in hunting (Y/N); history of dog going to the forest (Y/N); number of dogs per house; and type of food given by owner to dog (1 = more nutritious, 0 = less nutritious). The food was categorized as more nutritious if the respondent reported giving meat and/or dog food and/or fish and/or vegetables and was categorized as less nutritious if the respondent reported giving only rice for their dog(s). We then used an information-theoretic approach (corrected Akaike's information criterion, AICc) to select the best fitting model ($\Delta AICc < 2$) from all possible models (Burnham and Anderson, 2002) We used model averaging to generate parameter estimates.

Ethics Statement

Permission to collect blood samples in the study area was granted by the Livestock Department office of West Sumatra Province with number: *524.5/2015/Keswan&Kesmavet 2017*, and the protocol to collect samples was approved by the animal ethics committee of Wageningen

University. For the questionnaire survey, free prior informed consent was obtained verbally from all participants. Ethical approval was granted by the social science ethics committee of Wageningen University, with approval number *09131098.*

6.3. Results

The antibody titer RABV

More than 97% of the dogs had antibody titers less than the protective level for RABV (<0.5 EU/ml) (Table 1). The RABV antibody titer between vaccinated (median = 0.23, n = 74) and unvaccinated dogs (median = 0.19, n = 41) was similar (Mann-Whitney U = 1274.5, p = 0.16); only one titer value was above the WHO standard of 0.5 EU/ml, in the vaccinated group. From the interviews we found that 50.7% of respondents who gave RABV vaccination to their dog only did one vaccination while 45% of the respondents gave their dogs one vaccination and one booster.

Table 1. The antibody titers below protective level for RABV (<0.5 EU/ml) in six villages around Batanghari Protected Forest.

Village	Number of households in Village*	#Dogs sampled for CDV	% (n=67)	#Dogs sampled for RABV	RABV antibody titer <0.5 EU/ml ***	% (n=115)
Taratak	40	11	54.5	19	19	100.0
Pasir Putih	88	16	68.8	29	27	93.1
Koto Rambah	78	10	40.0	16	16	100.0
Bulu Kasok	45	11	90.9	22	22	100.0
Padang Gantiang	28	7	85.7	9	9	100.0
Air Batu	62	12	50.0	20	19	95.0
Total	341	67	64.2	115	112	97.4

* the number was obtained from the head village information, there is no official written documentation

***antibody titer <0.5 EU/ml means the dogs' antibodies are insufficient to protect it from RABV

Dog management

Most interviewed people had dogs for multiple purposes. Most of the people mentioned hunting (47%) and having a dog to protect their house from wildlife attack or from an intruder was mentioned relatively frequently (32%), as well as guarding plantations from wild boar attack (26%) and accompanying owners to the forest (23%). Only a few people mentioned having dog(s) for guarding their livestock (4%). Dog owners were not strict about keeping the dog in a cage or on a leash. Fifty-seven percent of the respondents allowed their dogs to be free ranging or partly free ranging.

In total, 71.9% of respondents knew about RABV but only 3.7% knew about CDV. Only 46.9% of the respondents had their dogs vaccinated and if so, it was against RABV. Only one person in our sample gave their dog Eurican 6 vaccination. The main reason given by respondents for not vaccinating their dogs (44.7%) was that the vaccinations are not free. Other reasons mentioned by respondents were: dogs were still too small (18.8%); had no time and/or vehicle to carry their dogs to the vaccination point (16.5%); not important (11.8%); worried if the dogs were less aggressive for hunting (5.9%); and no rabies symptoms (2.3%).

Dog-wildlife interactions

In the study area 80% of respondents mentioned that they bring their dogs to the forest on a weekly basis. In total 63% of the respondents had experience in bringing their dogs for hunting. Sixty-seven percent of respondents reported that their dogs experienced eating a wild animal in the past one year. Wildlife eaten by dogs in the study area included wild boar (72%), sambar deer (15%), macaques (*Macaca sp*) (7%), muntjac (3.5%), squirrel (*Callosciurus sp*) (3%), and wild chicken (*Gallus gallus*) (<1%).

The variables included In the best generalized linear model (ΔAICc < 2) to explain dog-wildlife interactions are group hunting experience and dog access to forest (both $p < 0.01$), number of dogs in households, distance of the dog owner's house to the forest, and type of dog food provided (Table 2).

Table 2. Best (ΔAICc < 2) generalized linear model explaining factors determining dog-wildlife interactions in West-Sumatra.

Variables	Regression coefficient (*b*)	Odds Ratio	SE of *b*	95% Confidence interval of *b*	p-value	Importance
Group hunting experience	3.53	34.22	0.63	2.29-4.77	<0.01	1.00
Dog access to forest	3.67	39.47	0.95	1.80-5.55	<0.01	1.00
Numbers of dogs at household	0.46	1.59	0.31	-0.15-1.08	0.14	0.55
Distance of dog owner's house to forest	0.52	1.69	0.47	-0.39-1.45	0.26	0.31
Type of food	0.91	2.47	0.84	-0.75-2.56	0.28	0.27

Forty-four percent of respondents using their dogs for hunting mentioned that they prefer to conduct hunting in palm oil plantations, followed by the border of forest (32%), rubber plantations (17%), rice fields (5%) and other areas (3%).

Twenty-one percent of respondents have experienced losing their dogs in the forest while hunting. In addition to hunting, dogs reportedly also entered the forest when the owner brought them for non-timber forest products collection, for company, and to protect them from wild animal attack.

6.4. Discussion

In this paper, we studied RABV in hunting dogs as potential pathogen spillover to the Sumatran tiger. Therefore, we assessed: (1) the immunostatus of RABV in domestic dogs; (2) dog management practices (Belsare et al. 2014); and (3) factors determining dog-wildlife interactions (Hassell et al. 2017). We found that RABV antibody titer (< 0.5 EU/ml) was detected in 97% of sampled rural dogs. Fifty-two % of the respondents vaccinated their dogs against rabies, but almost none against CDV. In total 75% of respondents were familiar with rabies, <5% of respondents were familiar with CDV. A great majority (80%) of the respondents mentioned that they brought their dogs to the forest on a weekly basis, and 63% of the respondents brought their dogs for

hunting. Dogs were commonly used for hunting, also within the Batanghari Protected Forest. Both dog hunting experience and dog access to the forest contributed strongly to the modelled dog-wildlife interactions.

Serological analysis in most tested dogs (97%) in our study area showing antibody titer below the protected level of RAVB which means the animal are susceptible of RABV. The antibody titer for vaccinated dogs and unvaccinated dogs were similarly low, which means that the vaccination program failed to create herd immunity of the dog's community in the study area. The government only provides ~2,000 free vaccines for the study area, not only for dogs (population approximately 10,000) but also for cats and macaques (Dinas Peternakan, 2016), falling far short of the required 70% vaccination rate with an antibody titer > 0.5 EU/ml. Moreover, each dog receiving just one vaccine in one or two years would not receive a booster after the first vaccination, whereas the World Small Animal Veterinary Association recommends two boosters within one year (in the week 26 and week 52) after the first vaccination to prevent the failure of the first vaccination and a booster every year (Day Mj et al., 2016). The practice in our study area results in antibody titers that are too low to protect vaccinated dogs from RABV. Wallace et al. (2017) also found similarly that ~90% of dogs failed to create minimum antibody titer when they only received a primary vaccination without any booster. This means that the majority of the dogs in our study area are susceptible to RABV creating a potential pathogen spillover to wildlife, among others the Sumatran tiger. Many studies on rabies focus on the coverage of mass vaccination program (Davlin and VonVille, 2012), but we found very few studies on the evaluation of the program if the dogs create sufficient antibody titer or not against RABV. Even though Hamson *et al.* (2009) mentioned that 45% vaccination is enough to eliminate the RABV in a stable population, a high dog population turnover and poor management practices require 70% coverage (Taylor et al., 2017). Apart from the cost of vaccination, another reason why people did not vaccinate their dogs is that they did not have a vehicle to carry their dogs to the vaccination location. Free vaccination usually took place at office of the main village head, which is located far from villages on the border of the protected area.

It is not surprising that almost all respondents to our survey were familiar with RABV. Several incidents of RABV in the region have made people more familiar about the disease. In West

Sumatra at least 15 human fatalities caused by rabies occurred from 2014-2016 (Ministry of Health, 2016). However, despite knowing about RABV and its impact to humans, many dog owners did not give their dogs RABV vaccination, mainly because they did not want to pay for vaccination and the distance to the vaccination place is too far. This is similar to what happened in Flores, Indonesia, where only 64% of the people were willing to participate in the free vaccination program but the number of people that people willing to vaccinate the dogs decreased to 24% when they were asked to pay for the vaccine (Wera et al., 2016). Most dog owners never heard about the CDV. Although veterinarians are aware about the disease, it is not included in the government's vaccination program, hence the focus of the veterinarians is on RAVB.

The fact that almost nobody had their dog vaccinated against CDV in the study area was likely because most people were not familiar with CDV. No vaccine of CDV means the chance of a dogs to get CDV is becoming higher. The prevalence of CDV reported from other populations around the globe considered as high in Santa Cruz Island, Galapagos for example the CDV prevalence in dogs was 73% (Diaz et al., 2016). In the Emas National Park in the Cerrado savanna of central Brazil the prevalence even higher which are 74% (Furtado et al., 2016), in the areas of the Araucania region in Chile the prevalence of CDV in dogs in rural areas was 72% (Acosta-Jamett et al., 2011), the same prevalence number with in the India's Great Indian Bustard Wildlife Sanctuary (Belsare et al., 2014).

Due to CDV, some tigers die from the infection itself, while others suffer neurological damage which reduces their fear of humans (Gilbert et al., 2015; Seimon et al., 2013). Reducing fear of humans can bring tigers into conflict with people and makes them much more vulnerable to poaching because they will not flee from poachers. In the past 10 years, it has been reported that some healthy-looking Sumatran tigers which stray into villages are behaving uncharacteristically: they are losing their fear of people for an as yet undetermined reason (*pers. Comm.*, Erni Musabine, 15 April 2018). As a result, the disease has the potential to negatively impact tiger populations (Gilbert et al., 2015, 2014), which are already under great threat from habitat destruction and poaching throughout their geographic range (Robinson et al., 2015).

Dog-wildlife interactions are increasing along with increasing movement of dogs into wildlife habitat. There are three possible route of disease spillover from dog to tiger: (1) dogs enter wildlife habitat, primarily facilitated by humans going hunting or taking dogs to the forest for protection; (2) stray dogs enter tiger habitat; and (3) tigers enter a village area and prey on dogs (Figure 2).

The first possible route of disease spillover is through dogs with poor immune status to enter wildlife habitat for hunting or for personal protection (Figure 2, route 1). Hunting using dogs has been carried out for generations in Sumatra, in part to reduce wild boar depredation of agricultural crops. Wild boar hunting attended by many hunters and dogs is commonly carried out on the border of protected area. This likely creates a landscape of risk, not only for prey species like wild boar, but likely also for wild carnivores (Lodberg-Holm et al., 2019; Mori, 2017). This landscape of risk may affect tiger and prey demography and abundance through non-consumptive effects which may have negative consequences on the population dynamic of species (Gaynor et al., 2019). This study shows that stopping the practice of hunting is not an easy task, but proper dog vaccination could help prevent the spillover of viruses to tigers. However, vaccination appeared to be limited and could be promoted and (financially) stimulated by government. At the same time, effective law enforcement could decrease hunting in the protected forest and reduce dog-wildlife interactions.

The second possible route of disease spillover is through stray dogs entering wildlife habitat (Figure 2, route 2). Grover et al (2018) reported a higher incidence of RABV in stray dogs further away from villages in wildlife-rich habitat in South Africa. Many stray dogs in our study area are from hunters who abandoned their dogs, often because the hunters believe that the dogs have become weak and can no longer hunt wild boar. Stray dogs in the study area may also be owned by local inhabitants who do not properly keep their dogs. Straying into wildlife habitat exposes dogs to getting bitten or eaten by a wild carnivore, and if disease infected, the carnivore may also get the disease. Registration of dogs with the authorities can be an effective solution for controlling stray dogs in the village; it can promote responsible dog ownership and enables dog population management. In combination with the livestock department capturing stray dogs on a regular basis, this can significantly reduce the number of strays that might enter the forest.

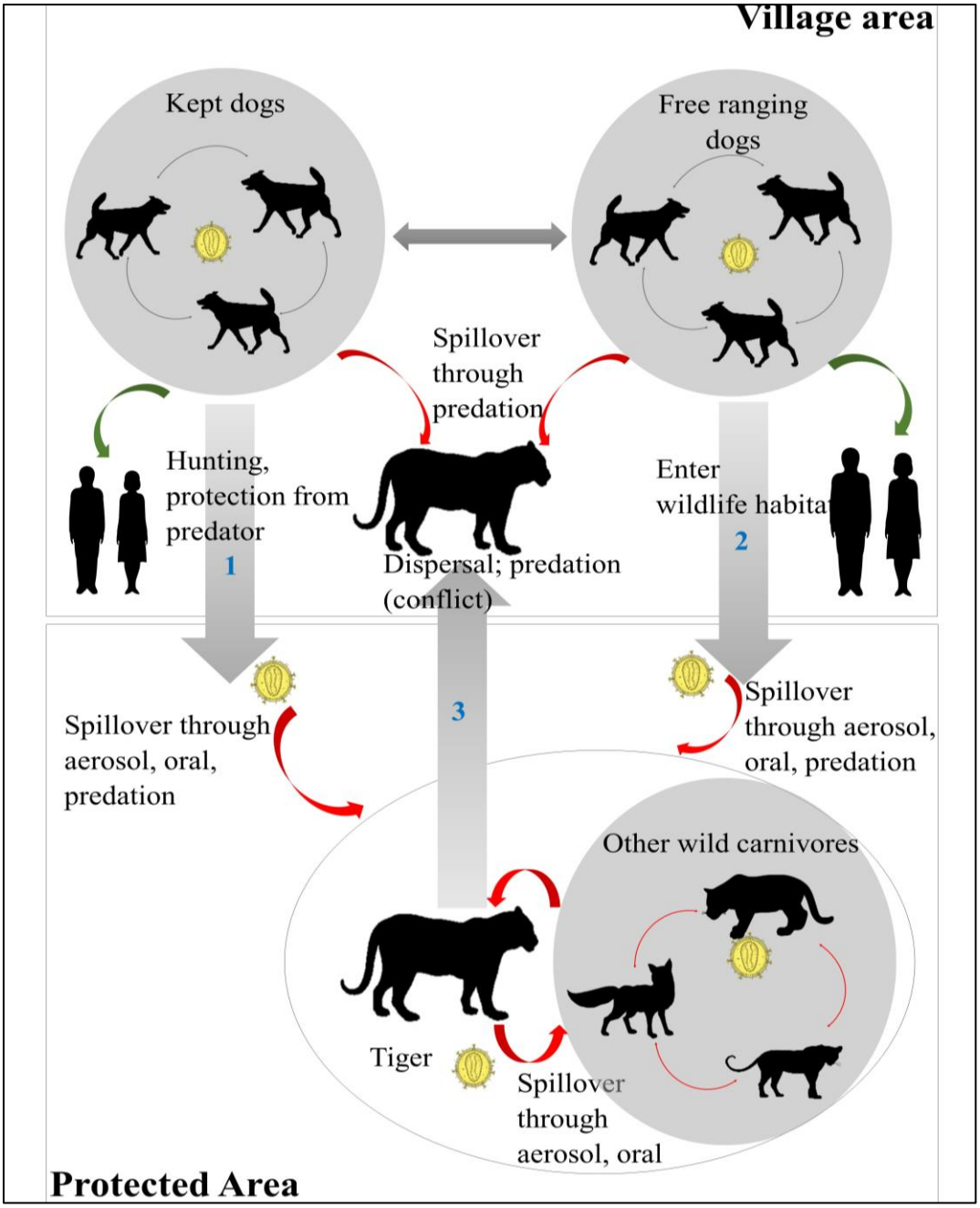

Figure 2. Framework showing possible routes of virus transmission (RABV and CDV) among dogs (grey arrows); spillover of RABV and CDV (red arrows) from dogs to tiger or to other carnivores; spillover of RABV (green arrows) from dogs to human. Yellow circles represent CDV or RABV virus. Three possible routes of disease transmission from dogs to wildlife: (1) Dogs access wildlife habitat with humans for hunting and for personal protection purposes; (2) stray dogs access wildlife habitat; (3) trough human-tiger conflict incidents where tigers enter the village and prey upon dogs

The third possible route of spillover is through predation of dogs by tigers in or near villages bordering the protected area (Figure 2, route 3). In Russia for example, 63% of 254 cases of documented tiger kills were dogs (Goodrich et al., 2011). Based on 15 years of human-tiger conflict data (2001-2016), approximately 14% of all 1,247 documented kills of domestic animals were dogs (Kartika, 2017), providing a high potential of CDV spillover (Fig 2). The high percentage of dogs with an antibody titer against RABV lower than the protective level of immunity suggests that there is a high potential risk of spillover when these dogs become infected to tiger that hunt close to villages.

Vaccination for both dogs and wildlife is one of the solutions to prevent RABV and CDV outbreak both in dogs and wildlife (Acharya et al., 2020; Gilbert et al., 2020). Although studies have shown that people who have good knowledge about a disease will voluntarily give vaccinations to their dogs to prevent diseases (Beyene et al., 2018), this study illustrates that incomplete vaccination yields no protection given the low antibody titer against RABV in vaccinated dogs, that were not different than the level in unvaccinated dogs. Therefore, local education programs to increase people's awareness of diseases in dogs and the importance of vaccination may increase the willingness of people to participate in a vaccination program. More-effective RABV vaccinations programs with 70% coverage of reservoir and a booster every year need to be instituted in villages around the Batanghari Protected Forest to minimize the occurrence of RABV and its possible transmission to tigers and other large carnivores.

No single management action will likely be maximally effective at reducing the potential of disease spillover from dogs to wildlife, particularly to Sumatra tigers. Instead, our results stress that a combination of strict hunting rules in combination with strict law enforcement to prevent dogs and hunting in the protected area, massive vaccination program of dogs in and around the protected area, better control of domestic livestock and agricultural crops, and an education program for the people, will likely minimize the potential for spillover of these two diseases from dogs to the Sumatran tiger and other carnivores in the Batanghari Protected Forest landscape.

Supplementary S1

ID NUMBER	

QUESTIONNAIRE DOG MANAGEMENT

DATE: _____

INTERVIEWER _____

VILLAGE: _____

Coordinate	
X	Y

READ: *Hello, I am a PhD student from Wageningen University, The Netherland. I am here to conduct my research and want to ask about how you manage your dogs and reasons you are having dogs. I would like to tape record our conversation, so that I can get your words accurately. If at any time during our talk you feel uncomfortable answering a question please let me know, and you don't have to answer it. Or, if you want to answer a question but do not want it tape recorded, please let me know and I will turn off the machine. If at any time you want to withdraw from this study please tell me and I will erase the tape of our conversation. All the answers that you give me will only be used for this research project. I will not record you name and/or address so all your answers are private and confidential. I will not reveal the content of our conversation beyond myself and people helping me whom I trust to maintain your confidentiality. I will do everything I can to protect your privacy, but there is always a slight chance that someone could find out about our conversation*

Are you happy to complete this survey? (tick (√) if YES; cross (X) if NO)	
Do you allow me to tape record our conversation? (tick (√) if YES; cross(X) if NO)	

	YES	**NO**
Questionnaire Complete		
Blood Sample Collected		

A. Dog's demography			
1	Do you have dog(s)?	Yes / No	Note: IF Yes, also ask possibility to collect blood sample from their dog
2	How many dogs you have now?		Note:
3	Describe how they are		

No	**Jenis**	**L/P**	**Umur (yrs.)**	**Berat (kg)**	**Catatan**

4	Since when you have dogs?		Note:
5	How many dogs do you have since you live in this village? (including current dogs)		Note:
Management			
6	What is your reason to have dog(s)?		Guarding livestock
			Guarding agricultural field
			Wild boar/wildlife hunting
			Protect yourself
			Others (mention)
7	How do you keep your dog(s) during the day?		
8	How do you keep your dog(s) during the night?		
9	How many times you feed your dogs in a day?		
10	What kind of food you give to your dog(s)?		
11	How many time you clean your dog(s) in a week?		
Health			
12	Did your dog(s) ever get sick?	Yes / No	If Yes go 12a if No go 13
12a	When?		
12b	How many time in a year your dog(s) get sick?		
12c	What did you do when your dog(s) get sick?		
12d	Did you allow your dogs to go outside house when it sick?		
13	Do you know about any disease on dog(s)?	Yes / No	If yes go 13 a; If No go to 14
13a	If yes, please mention any kind of disease on dog(s) that you know		
14	Do you know about vaccination on dogs?	Yes / No	

14 a	In your opinion why dogs get vaccination?		
15	Do you give vaccination to your dogs?	Yes / No	If **Yes** go 15a-b; if **No** go 15c
15a	If Yes; How many times in a year you give vaccination to your dog(s)?		
15b	What kind of vaccine you gave to your dogs		
15c	When is the latest time you give vaccination to your dog(s)		
15d	IF No; Why you don't give vaccine to your dog(s)?		
16	Do you know rabies vaccine?	Yes / No	
17	Do you know CDV vaccine?	Yes / No	
Dog's Behaviour and access to forest			
18	Is your dog(s) ever go to Forest?	Yes / No	
19	IF yes, how many time your dogs go to the forest in a week?		
20	Is your dog(s) ever eat animal in the forest?	Yes / No	If yes go 20a; If no go 21
20 a	What kind of animal they are eating		
21	Do you use your dogs for hunting?	Yes / No	If yes go 21 a-b; if No go 22
21 a	What kind of animal do you hunt?		
21 b	If Yes, haw many time in a month you do hunting with your dogs		
21c	Dimana		
22	Have you ever experience your dog killed by tiger?	Yes / No	If yes go 22 a-c; If no go 23
22 a	When		
22 b	Where		

22 c	How		
23	Have you ever experience your dog loss in the forest?		

Before continuing, explain about Rabies and CDV vaccine

	Please indicate how much you **agree or disagree** with the following statement: This year, if the government provides the vaccine free of charge, I will vaccinate my dog with					
	Vaccine	Strongly agree	Agree	Neutral (neither agree nor disagree)	Disagree	Strongly disagree
24	Rabies					
25	CVD					

	Please indicate how much you **agree or disagree** with the following statement: This year, if the government provides the vaccine at market price (Rp 25,000/dose), I will vaccinate my dog with					
	Vaccine	Strongly agree	Agree	Neutral (neither agree nor disagree)	Disagree	Strongly disagree
26	Rabies					
27	CVD					
	Please indicate how much you **agree or disagree** with the following statement: This year, even if the price is higher than market price (>25.000), I will vaccinate my dog with					
	Vaccine	Strongly agree	Agree	Neutral (neither agree nor disagree)	Disagree	Strongly disagree
28	Rabies					
29	CVD					

	Please indicate how much you **agree or disagree** with the following statement: I will cull my dog without compensation if there is a [disease] case in the dog population in my village					
	Disease	Strongly agree	Agree	Neutral (neither agree nor disagree)	Disagree	Strongly disagree
30	Rabies					
31	CVD					

	Please indicate how much you **agree or disagree** with the following statement: I will keep my dogs inside my house or leash the dogs for at least three months if there is a [disease] case in the dog population in my village *(repeat for each disease)*					
	Disease	Strongly agree	Agree	Neutral (neither agree nor disagree)	Disagree	Strongly disagree
32	Rabies					
33	CVD					

	Please indicate how much you **agree or disagree** with the following statement: I will not take my dogs to the [place] if they got disease/sick *(repeat for each place)*					
	Place	Strongly agree	Agree	Neutral (neither agree nor disagree)	Disagree	Strongly disagree
34	Forest					
35	Agricultural field					

	Even if you have never done vaccination to your dogs, we are interested in what you think about giving rabies vaccination to dogs.							**Don't know**
36	Good	1	2	3	4	5	Bad	
37	Harmless	1	2	3	4	5	Dangerous	
38	Beneficial	1	2	3	4	5	Harmful	
	Even if you have never done vaccination to your dogs, we are interested in what you think about giving CDV vaccination to dogs.							**Don't know**
39	Good	1	2	3	4	5	Bad	
40	Harmless	1	2	3	4	5	Dangerous	
41	Beneficial	1	2	3	4	5	Harmful	

	Please indicate how much you **agree or disagree** with the following statement:

	Culling of dogs during rabies outbreak reduces rabies cases in humans					
	Strongly agree	Agree	Neutral (neither agree nor disagree)	Disagree	Strongly disagree	Don't know
42						

	Please indicate how much you **agree or disagree** with the following statement: Culling of dogs during CDV outbreak reduces spreading disease to other animals					
	Strongly agree	Agree	Neutral (neither agree nor disagree)	Disagree	Strongly disagree	Don't know
43						

	Please indicate how much you **agree or disagree** with the following statement: I will support any measures that government will take to control [disease] *(repeat for each disease)*					
	Disease	Strongly agree	Agree	Neutral (neither agree nor disagree)	Disagree	Strongly disagree
44	Rabies					
45	CDV					

	Please indicate how much you **agree or disagree** with the following statement: Keeping dogs inside the home or leashing dogs during the rabies outbreak reduces rabies cases in humans					
	Strongly agree	Agree	Neutral (neither agree nor disagree)	Disagree	Strongly disagree	Don't know
46						

	Please indicate how much you **agree or disagree** with the following statement: Keeping dogs inside the home or leashing dogs during the CDV outbreak reduces disease transmission to other animals					
	Strongly agree	Agree	Neutral (neither agree nor disagree)	Disagree	Strongly disagree	Don't know
47						
	Please indicate how much you **agree or disagree** with the following statement: Not taking dogs to field/forest when it gets sick reduces disease transmission from dogs to other animals					
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Don't know

			(neither agree nor disagree)			
48						

	Please indicate how much you **agree or disagree** with the following statement: Rabies is a threat for human health, therefore it should be controlled					
	Strongly agree	Agree	Neutral (neither agree nor disagree)	Disagree	Strongly disagree	Don't know
49						

	Please indicate how much you **agree or disagree** with the following statement: Disease in dogs can transmit to other animals					
	Strongly agree	Agree	Neutral (neither agree nor disagree)	Disagree	Strongly disagree	Don't know
50						

	Please indicate how much you **agree or disagree** with the following statement: Dogs can transmit disease to people and animals; therefore, it should be controlled					
	Strongly agree	Agree	Neutral (neither agree nor disagree)	Disagree	Strongly disagree	Don't know
51						

	Please indicate how much you **agree or disagree** with the following statement: I will give my dog [vaccine type] vaccination IF my family/veterinarian/head of village/government/leader of religion/local human medical ask me to give my dog with vaccination					
	Vaccine type	Strongly agree	Agree	Neutral (neither agree nor disagree)	Disagree	Strongly disagree
52	Rabies					
53	CVD					

	Please indicate how much you **agree or disagree** with the following statement: I will give my dog [vaccine type] vaccination IF my neighbours/hunter group/people in my village also do it

	Vaccine type	Strongly agree	Agree	Neutral (neither agree nor disagree)	Disagree	Strongly disagree
54	Rabies					
55	CVD					

		Strongly agree	Agree	Neutral (neither agree nor disagree)	Disagree	Strongly disagree
56	I do have time to vaccinate my dog					
57	I do have the ability/skill to confine and tie up my dog					
58	I do have time to leash my dog					
59	I do have money to pay the vaccination fee					
60	I do have money to buy a new dog					
61	I do have money to buy a leash					
62	I do have money to build cage for dogs					

Please complete the following questions		
63	Gender of respondent: *(do not ask this question)*	Male Female *(circle one)*
64	What year were you born? *(write year in full e.g. 1974)*	
65	What is your current occupation?	
66	Do you have, or do you work farm land around here?	Yes No *(circle one)*
67	What is your level of education? *(Circle one)*	1. No school 2. Elementary 3. Junior high 4. Senior high 5. University
68	Are you Muslim?	Yes No *(circle one)* ***(If YES, skip to Q69)***
68a	What is your religion?	
69	How do you describe your ethnic origin e.g. are you Sundanese, Javanese, Kerincenese, Minangkabau or mixed?	***(If MIXED ask Q69a-b, otherwise skip to Q70)***
	How do you describe the ethnic origin of your parents e.g. Sundanese, Javanese, Kerincenese, Minangkabau or mixed?	**69a)** Father: **69b)** Mother: *(If either parent MIXED please specify)*
70	Were you born in this village? *(circle one option)*	Yes No ***(if YES, END)***
70a	Which village were you born in?	
70b	How long have you lived in this village?	

A camera trap picture of a Sumatran tiger in West Sumatra

Chapter 7

Conserving tigers beyond protected areas: Understanding the role of neighbouring habitats on the occupancy of tiger

Erlinda C. Kartika, Jasman, Morro Alan, Ignas M.A. Heitkönig

Abstract

Deforestation leads to shrinking habitat for forest-dwelling species, including large carnivores. Conversion of forests into plantations or agricultural cropland generally reduces suitability thereof for prey and predator species. In this paper we aim to understand the effect of forest conversion into plantation and agricultural cropland on the occupancy of the Sumatran tiger. Using camera traps, we conducted the tiger occupancy study in three different areas, namely (i) secondary forest in the core area of Batanghari Protected Forest versus (ii) secondary forest neighbouring oil palm plantations, and (iii) secondary forest neighbouring mixed agriculture. Using occupancy modelling, we found that tiger occupancy was highest in the secondary forest in the core forest area compared to areas neighbouring mixed agriculture and palm oil plantations. Preferred prey species were present in all habitats, but wild boar and bearded pig were particularly common near palm oil plantations, probably because of them being attracted to high-energy fruit and human food waste. Our data also revealed marked human and dog activity near palm oil plantations, and human (illegal hunting and gold mining) activities near the core area. We conclude that forest conversion into plantations and mixed agricultural landuse types, along with illegal activities harm Sumatran tiger populations.

7.1. Introduction

Worldwide, the steadily increasing human population leads to habitat destruction due to increasing needs for agricultural land and housing (Lewis and Maslin, 2015; Palumbi, 2001; Vitousek et al., 1997). Around 30-50% of the earth's surface is now affected and altered by a variety of human activities (Lewis and Maslin, 2015; Vitousek et al., 1997). Conversion of forests and natural areas causes the destruction of wildlife habitats (Hansen et al., 2013) and has become a primary driver of biodiversity loss (Brooks et al., 2002; Haddad et al., 2015).

Eastern and southern Asia not only hold large numbers of carnivore species, but also the highest proportion of threatened and declining species, while hunting, trapping and habitat loss caused by deforestation and agricultural expansion pose the main threats to the Carnivora order (Fernández-Sepúlveda and Martín, 2022). Forests are being converted on a large scale into agricultural areas and palm oil plantations with a rate of deforestation that is even more severe than in other tropical regions ((Wilcove et al., 2013). He et al. (2023) assessed that 78 Mha of montane forest was lost during 2001–2018 and that annual loss accelerated significantly in the last ten years. This habitat loss and fragmentation also takes place in Indonesia, where unsustainable logging practices, conversions of forest into oil palm and pulpwood plantations, and forest fires pose an immense threat to the remaining forest and wildlife species (Wilcove et al. 2013; FAO 2015).

Forest fragmentation encourages an increase of human activities like herding domestic animals, non-forest timber product collection, logging activities and poaching inside wildlife habitat (Farris et al., 2014; Liu, 2001) due to easier access, which can alter wildlife behaviour and decrease survival (Haddad et al., 2015; Smith et al., 2015).

There has been a growing realization of the importance of the landscape matrix quality in governing the dynamics of population and community-level processes in fragmented landscapes (Schooley and Branch, 2007; Thornton et al., 2013; Vandermeer and Carvajal, 2001). The matrix affects a.o. interpatch movement of animals (Bender and Fahrig, 2005) and also the type and magnitude of the edge effect, making it important in determining metapopulation dynamics (Kennedy et al., 2011; Schooley and Branch, 2007; Vandermeer and Carvajal, 2001). Species with a large home range, complex social behaviour and low population density, specialized niche

requirements and a high trophic level–- like large carnivores–- are less adaptable to habitat loss and fragmentation (Boitani and Powell, 2012). In a study in Brazil's Atlantic Forest, jaguars increased the dietary proportion of small-sized prey when deforestation increased, whereas ungulate predation increased with forest cover augmentation, (Magioli and Ferraz, 2021). Alternatively, carnivores may be attracted to nearby livestock as alternative prey (Morato et al., 2018), which can lead to increased human-carnivore conflicts. Plantations neighbouring uncut forests are known to harbour a wide variety of species – including mammals and larger birds – which may serve as prey for tigers.

The objective of this study is to understand how contrasting habitats neighbouring the core of a large protected area affect the occupancy of tigers and their prey. In particular, we expect that (i) tigers will have the highest occupancy in forest neighbouring its intact habitat, i.e., at the center of the protected area, that (ii) tigers will have the lowest occupancy in forests neighbouring oil palm plantations and mixed agriculture, where natural prey are harder to find.

7.2. Methods

Study area

We conducted a camera trap study in the Batanghari protected forest, which encompasses an area of approximately 3000 km², located in the province of West Sumatra, on the border of Jambi and Riau provinces. The Batanghari protected forest plays a vital role, providing important habitat for wildlife, in particular the Sumatran tiger. It acts as a corridor from Kerinci Seblat National Park to the wildlife reserve of Rimbang Baling in neighboring Riau.

Camera traps

We selected three areas in the border Batanghari protected forest which have contrasting neighbouring habitats, i.e., oil palm plantation, mixed agriculture and primary forest (Figure 1). Due to the fact that we were not granted permission by the palm oil plantation owners to place our camera traps in the plantation itself, we designed the system such that employed camera traps were not placed in any of the contrasting landuse types themselves, but in secondary forest directly neighbouring the contrasting landuse types. We employed around twenty camera traps inside each secondary forest–- from 0 to 10 km from the edge inward–- for a continuous period of 3.5–- 4

months in each of the three selected areas in the period of December 2017 to January 2019. The survey started in the secondary forest bordering the palm oil plantation from December 2017 to April 2018 (n = 22 camera traps). Next, the secondary forest bordering mixed agriculture was surveyed from April 2018 to September 2018 (n = 17 camera traps). Lastly, the area bordering the primary forest was surveyed from October 2018 to January 2019 (n = 20 camera traps) (Table 1). All cameras were installed facing an animal passage as defined by the local guards, without bait. Cameras were installed 40-50 cm from the ground, were set to work 24 hours/day and were checked every 21-28 days to collect the data from the memory cards, replace the batteries if necessary and maintain the equipment. If a camera was found to be non-functional, broken, or stolen, it was replaced by a new camera.

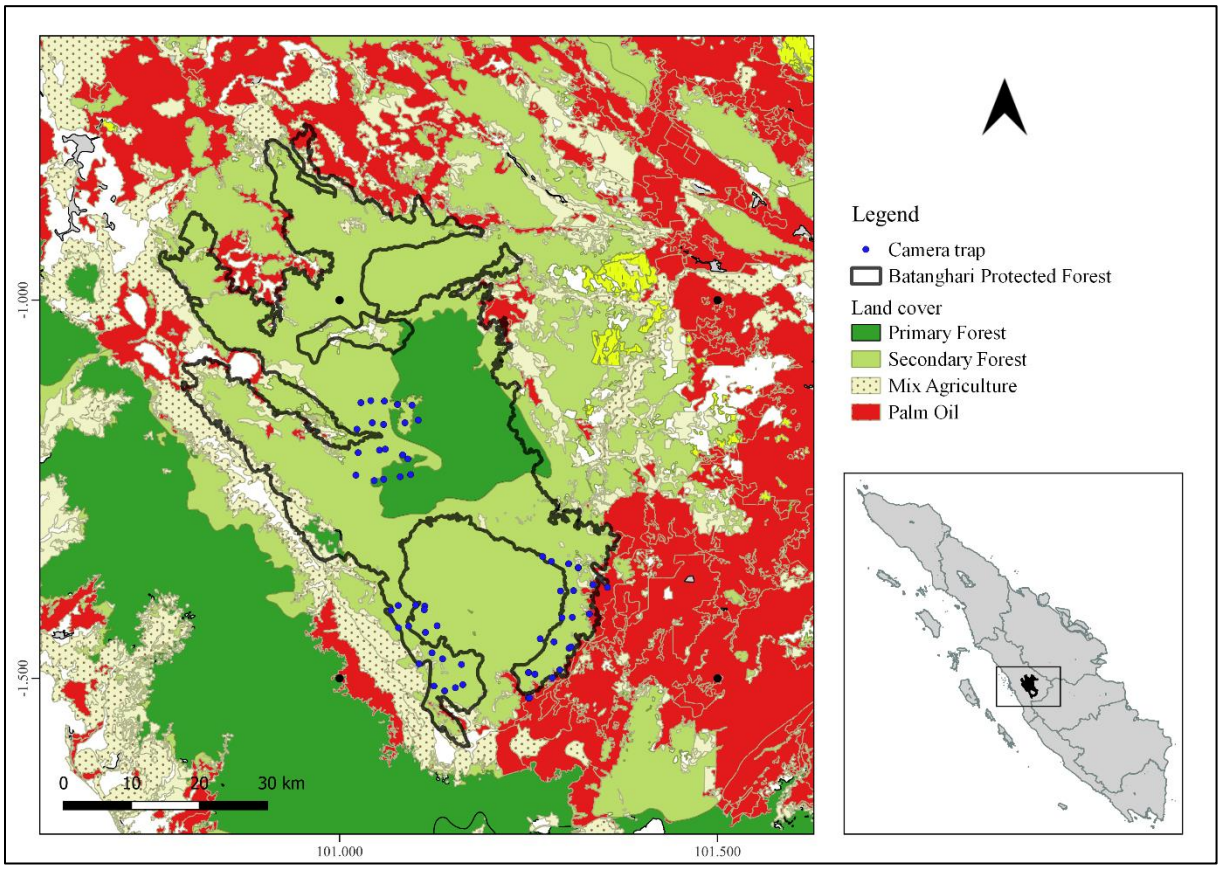

Figure 1. Camera trap locations (blue dots) in secondary forest neighbouring three different landuse types (matrix), i.e., in secondary forests neighbouring palm oil plantations (red), (2) in secondary forest neighbouring mixed agriculture (light red dotted), and (3) in secondary forests neighbouring primary forest (dark green).

Data analysis

Camera trap data was stored and processed using Agouti (https://agouti.eu/) and exported in csv files for further analysis. We used the vegan package (Oksanen et al., 2019) and "TEAM library 1.7.R" from Camera trapping for wildlife research (Rovero & Zimmermann, 2016) in R (R core team, 2019) to analyse the data. For tiger prey species, we used naïve occupancy of each prey species per study site. The occupancy of the tiger in the three different study sites was modelled using the occupancy model by Rovero & Zimmermann (2016).

7.3. Results

Camera trap activity and human records

Tabel 1. Description of camera trap stations in the three different neighbouring matrix types.

	Bordering Palm oil plantation	**Bordering Mixed agriculture**	**Bordering Primary Forest**
# Trap stations	22	17	20
Effective trap days	1903	1372	1653
Sampling period	29 December 2017 – 23 April 2018	28 April 2018 – 01 September 2018	15 October 2018 – 28 January 2019
Average inter-camera distance (m) (range)	1445 (275-2577)	1681 (1181-2898)	1779 (870-3160)
Average elevation (m a.s.l.) (range)	482 (325-690)	812 (489-1127)	852 (474-1171)
Cameras lost	7	4	1
Human pictures	199	14	119
Dog pictures	58	0	0

The total active cumulative time of all individual camera traps in secondary forest near primary forest was 1653 days (min. 8, max. 98 days), near mixed agriculture was 1372 days (min. 37, max. 104 days) and near palm oil plantations was 1903 days (min. 30, max. 121 days). This resulted in a total operational camera trap time of 4928 days, with a median of 96 days (min. 8, max. 121 days). The camera traps were active for a median of 96 and 97 days near primary forest and mixed agriculture, respectively, and near palm oil plantations for a median of 91 days (Table 1). A

Kruskal Wallis test showed no significant difference in active trapping days per camera between the three areas ($H(2) = 0.721$, $p = 0.70$). Human activity was highest in area near palm oil plantation (199 records) followed by the area bordering primary forest (119 records), and last in the area bordering mixed agriculture (14). Dog pictures only appeared in the area bordering palm oil plantations, where also the highest number of camera losses took place (7 cameras) followed by the area bordering mixed agriculture (4 cameras) and lastly in the area bordering primary forest (1camera).

Naïve occupancy of tiger and each prey species per study site

Tabel 2. The naïve occupancy values for the tiger and its prey species per sampling area and the total number of camera trap locations where they were documented.

Species	Bordering Palm oil plantation	Bordering Mixed agriculture	Bordering Primary Forest
Panthera tigris sumatrae Sumatran tiger	0.14	0.12	0.32
Acrocodia indica Malayan tapir	0.38	0.47	0.26
Macaca nemestrina Sunda pig-tailed macaque	0.81	0.76	0.74
Muntiacus muntjak Indian muntjac	0.62	1.00	0.63
Rusa unicolor Sambar deer	0.48	0.18	0.32
Sus barbatus Bearded pig	0.24	0.47	0.58
Sus scrofa Wild boar	0.81	0.18	0.16
Tragulus kanchill Lesser mouse-deer	0.48	0.18	0.00
Tragulus napu Greater mouse-deer	0.24	0.12	0.00

The occupancy of tiger in three different neighbouring habitat types

Tiger occupancy was highest in area neighbouring primary forest in the core area of Batanghari protected forest (Ψ=0.56±0.23) compared to the area neighbouring mixed agriculture (Ψ=0.22±0.15) and palm oil plantation (Ψ=0.24±0.14).

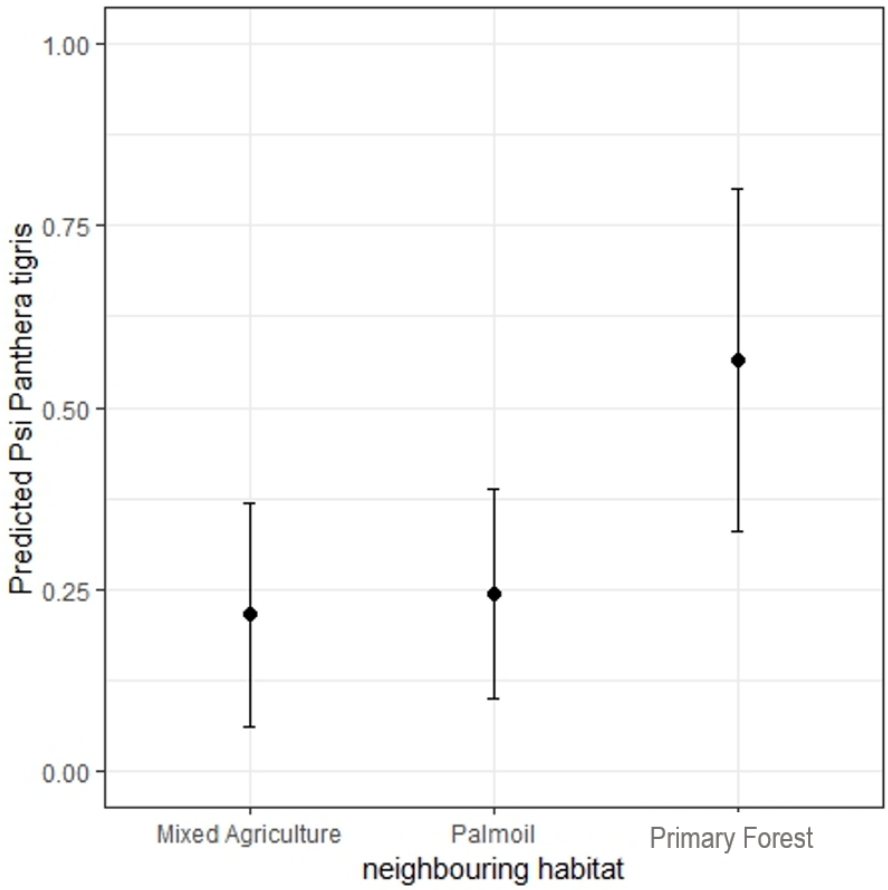

Figure 2. Tiger occupancy in secondary forests neighbouring three different landuse types

7.4. Discussion

Our results demonstrate that the highest occupancy of the tigers is in secondary forest neighbouring primary forest, i.e., in in the core area and that the other two areas both show much lower occupancy values. Many prey species occur in the secondary forests near mixed agriculture and palm oil plantations. However, there are still several prey that is available in the secondary forest in the core of Batanghari Protected Forest. Human activity was highest in the area bordering palm oil plantation showed by the highest number of human pictures and dogs.

Tiger occupancy was highest in the secondary forest neighbouring primary forest in the core area, similar to the findings by Sunarto *et.al.* (2012) that the occupancy of tigers is highest in the area close to centroid of the forest. Tiger occupancy did not strongly correspond with prey species occupancy (Table 1). Although this does not appear to be in line with the studies conducted by Penjor et al. (2019) and Karanth et al. (2004), who stated prey abundance as a key factor for tiger distribution, we do not have evidence that preferred prey densities of tapir, macaque, sambar deer and bearded pig are considerably lower in the core forest area.

We found that wild boar and bearded pig occupancies were considerably higher in the area bordering the palm oil plantations compared to secondary forest in the core area. This is in line with the study conducted by Fujinuma and Harison (2012). In palm oil plantation, there is an abundance of food and water for these pig species. Oil palm fruits are rich in energy, containing high levels of oil and fat, available year-round in these plantations. Additionally, the dense vegetation and undergrowth of the palm oil plantation offer shelter and cover for these prey species. Human activity in and around the plantation is high, aggravated by the availability of housing for workers on the plantation, which may contribute to an abundance of food and waste, i.e., more food for wild pigs. The reduced availability of predators in palm oil plantations also make them a relatively safe habitat for wild boar and bearded pig. In fact, the high naïve occupancy of wild boar near palm oil plantations leads to human-wild boar conflicts to the extent that people are motivate to reduce the wild boar populations by hunting them (see chapter 5 in this thesis).

The low number of people on pictures (21) in the area bordering mixed agriculture is likely due to the reduced accessibility of the area. The area consists of steep rocky hills. Both people and tigers tend to avoid these areas.

The number of people appearing in the secondary forest near the core area were mainly classified as hunters, non-timber forest product collectors and miners. Hunters mainly search for birds like White-rumped Shama (*Copsychus malabaricus*) that are nowadays only available deep inside the forest. While the non-timber forest product collectors mainly search for ‘Jernang’ drago’'s blood or resin came from *Daemonorops draco*, agarwood from *Aquilaria malaccensis* trees and honey

from wild bees. All of them have high economic value and are only found in the core area of the forest.

In addition, Batanghari protected forest has immense treat from illegal gold mining. Deep inside the forest there are many bulldozers digging and flipping the soil and the river beds, illegally search for gold. It is not only the river being destroyed by this mining, but the forest is even fragmented in many places inside Batanghari protected forest. The fragmentation mainly takes place when miners use bulldozers to create road in order to access the desired area for mining with draglines (ECK personal observation – see Figure 3)

Figure 3. Abandoned illegal gold mining area deep inside Batanghari protected forest. It took 3-4 days walking to get here from the forest border. (Own photograph)

Our study confirmed the expectations of higher tiger naïve occupancy in the core area, and lower but equal values neighbouring mixed agriculture and palm oil plantations. However, the pressure from illegal mining and other human activities are significant. The current protection status of the area does not seem enough to protect the area from human disturbance. Therefore, quick actions are necessary to protect the tiger in the area from local extinction due to the various anthropogenic

pressures mentioned above. Law enforcement to stop illegal mining is one of the key points to protect this important habitat. Providing alternative livelihoods for the miners can reduce the pressure from the illegal mining. Also supporting the development of community-based forest management systems can empower local communities to take ownership of forest conservation efforts and provide them with a stake in forest protection.

Despite the vast human activity and pressure in the secondary forest in the core area of Batanghari protected forest, tiger occupancy was twice as high in the secondary forest in the core forest area compared to forested areas neighbouring mixed agriculture and palm oil plantations. The neighbouring agricultural landscapes reduce levels of tiger naïve occupancy compared to the core habitat. Anthropogenic pressure in the study areas, including illegal gold mining and hunting, need to be limited to prevent the Sumatran tiger from local extinction.

A group of men and children poses with a recent killed tiger in May 1941 (H. Bartels/Tropenmuseum/Wikimedia Commons)

Chapter 8

Synthesis

8.1. Introduction

The threats and massive declines experienced by carnivore populations around the world are mainly attributed to anthropogenic pressures, including habitat loss and fragmentation, persecution, utilization, and disease transmission from domestic animals (Ripple et al. 2014), and this is disproportionally more the case in large carnivores (Hill et al., 2020). The highest proportion of threatened and declining carnivore species are found in East and South Asia (Fernández-Sepúlveda and Martín, 2022). Tigers (*Panthera tigris*) are case in point. Once likely widely distributed throughout eastern and southern Asia and numbering about 100,000 individuals just 100 years ago (Dinerstein et al., 2007; Morell, 2007), they have gone extinct in the wild on Bali (*Panthera tigris balica*), Java (*Panthera tigris sondaica*), and around the Caspian sea (*Panthera tigris virgata*), with the South China tiger on the brink of extinction (*Panthera tigris amoyensis*). The Sumatran tiger only occurs on the island of Sumatra and currently still under the same severe threat that also applies to tigers and many other large forest-dwelling carnivores elsewhere, i.e., human-caused mortality including hunting and retaliation killing, (Goodrich et al., 2022; Robinson et al., 2015), habitat loss and fragmentation (Joshi et al., 2016) and disease transmission (Gilbert et al., 2015). While the broad threats are known, it is not clear how they play out at the level of local communities, nor is it clear which approach is best to turn the tables on the decline of the population, which stands at only about 600 individuals (Luskin et al., 2017), and what approach to take at the community level (Holland et al., 2018).

In this thesis I embrace the definition of conservation science by Kareiva and Marvier (2012), which incorporates conservation biology into a broader interdisciplinary field that explicitly recognizes the tight coupling of social and natural systems. I aimed to gain a thorough understanding of multiple anthropogenic pressures affecting the Sumatran tiger in particular, to get quantitative and qualitative handles on the actual threats, in scales ranging from an island-wide analysis of human-tiger conflicts (Chapter 2) to cultural and spiritual values of people who have witnessed human-tiger conflict (Chapter 3-4) and veterinary issues (Chapter 5-6) and habitat fragmentation issue (Chapter 7). My approach involved a wide diversity of techniques, spanning from GIS with secondary data via intensive fieldwork involving camera trapping and modelling to in-depth local interviews. I hence focus on both the carnivores and as well as humans, spanning both ecological and social approaches to explore these problems. Several of my findings are new

to science, and my study will enable me to provide conservation authorities with up-to-date recommendations on how to best approach the conservation of the Sumatran tiger in and near protected areas in the complex spatial and cultural context of local communities and different landuse systems.

From a holistic perspective, I focused on human-tiger interactions, hunting on tiger prey, potential disease transmission from domestic animal to tigers and how different neighbouring habitats affect the occurrence of tigers. In this chapter, I will first summarize the findings of each of my research chapters in relation to these aspects (section 8.2). The findings of the first three chapters (section 8.2.1) relate to human-tiger interactions where ecological approaches (Chapter 2) and social approaches (Chapter 3 and Chapter 4) were used to understand the problem. Section 8.2.2 summarizes the exposure of tigers to wild boar hunting (Chapter 5) and the potential of disease transmission from domestic dogs to the carnivores (Chapter 6). The final chapter (Chapter 7), about the occupancy of the tiger in different neighbouring habitats, will be summarized in section 8.2.3. The discussion of the findings of each separate chapter is followed by the applicability of the results for carnivore conservation in the future (section 8.3). In section 8.4, I will present my view on how this thesis relates to the broader fields of wildlife conservation. I will discuss in a broader context how to manage the anthropogenic pressures and proposed management for conserving carnivores.

8.2. Findings

8.2.1. Human-wildlife interaction

The first set of studies presented in this thesis focus on understanding the anthropogenic pressures on tigers, particularly human-tiger conflict. To analyse this conflict, I examined the scale and impact of the conflict using official records spanning eighteen years from Sumatra Island, Indonesia. Using the species distribution model MaxEnt, I identified ecological factors that contribute to the conflict (Chapter 2). Through this modelling, I found that human disturbances are a major factor that explain the conflict. When people disturb natural habitats by converting them into human-centric developments, such as building roads, railways, and expanding crop lands (Venter et al., 2016b), it increases the probability of conflict between humans and tigers. Tigers are solitary, territorial, forest-dwelling animals, so habitat loss makes it more difficult for young

tigers to disperse, particularly when they are searching for new territories. Habitat loss also brings people and wildlife closer together, which is an important factor in our model for explaining conflict. Habitat loss through forest conversion continues to happen nowadays in Sumatra (Joshi et al., 2016; Poor et al., 2019). Where tiger habitat is fragmented or reduced, the surrounding matrix becomes important to maintaining a healthy tiger population and prevent it from local extinction (Chapter 7).

Livestock density is also an important factor explaining the conflict. Tigers may consider livestock to be easy prey because catching free-ranging domestic livestock requires less energy than catching wild prey (Woodroffe, 2000). When livestock density is high and coupled with poor livestock management, as is often the case in Sumatra and many areas bordering to forest in other countries, conflicts are unavoidable. Guarding and promoting stronger, proper enclosures for livestock in villages and dwelling close to tiger habitat can reduce the conflicts (Eeden et al., 2018; Holland et al., 2018) and can promote human-tiger coexistence.

Many studies on human-wildlife interactions emphasise the scale and impacts of the conflict from a human point of view and not from the wildlife's point of view (Bhattarai et al., 2019; Nyhus and Tilson, 2004; Perry et al., 2020; Thirgood et al., 2005). Given this situation, I investigated the impacts of the conflicts for both human and tiger (Chapter 2). From the human point of view, I presented the impact of the conflict by quantifying number of livestock and human casualties. While from tiger point of view, I calculated the mortality index and removal index, and assessed the fate of the tiger after the conflict, whether they escaped or were captured and put in captivity, translocated, or died. Through directly linking the fate of the tiger to the severity of the prior HTC events allows us to better understand the effectiveness of our conflict mitigation efforts. As many tigers are removed from their original areas, kept in zoos or translocated to other areas on an island-wide basis, there is a need to evaluate the effectiveness of these mitigation measures.

Human carnivore conflicts are complex (Dickman, 2010; Nyhus, 2016) and involve social and ecological systems (Lischka et al., 2018; Struebig et al., 2018) . The impact of carnivore conflicts on humans are not only about the direct cost that occurs at the time of the conflict but also many indirect costs involved in it. The costs of human-tiger conflicts seem to be low when only the direct

costs are calculated, but there are huge indirect costs that arise from these conflicts. The impacts of livestock depredations and human attack for example, it is not only affecting individuals associated with the conflict but also the entire community living in the area (Chapter 3). Huge opportunity cost also arises when human-carnivores conflicts occur which affect the entire community. These opportunity costs result from people's anxiety about tiger attacks, which makes them more likely to stay at home than go to the forest or their agricultural fields. Hence, the presence of a tiger in the vicinity of the village results in measurable economic impacts on the villagers, because fear of the tiger may prevent villagers from pursuing normal daily activities.

Ignoring the indirect impact of the conflict-affected community may lead to a negative attitude toward carnivores which leads to retaliation killing (Chapter 3). There were at least 129 tigers killed by the villagers in Sumatra over the period 2001-2019 due to HTC (Chapter 2). Understanding the human dimension factors including attitude and tolerance toward carnivores become crucial to prevent retaliation killing toward carnivores (Chapter 3). From the analysis that I did in Chapter 3, I found that the intention to kill a tiger was inversely correlated with conservation attitude and with tolerance towards tigers.

Key determinants explaining attitude and tolerance towards tigers were the impact of the conflict, frequency of conflict in the village, environmental education received, and location of agricultural fields relative to the forest boundary. Impact, but not the frequency of personal experience of conflict, determined the attitude and tolerance toward tiger. For example, people were less angry toward tigers in case of frequent attacks without human losses than in the case of one fatal attack. Naughton-Treves & Treves (2005) also found that tolerance toward wildlife was shaped more by actual impacts than by the frequency of conflicts perceived by individuals. Similar, Inskip et al. (2016) found that negative experiences with tigers did not directly affect the people's tolerance level in the Sundarbans, Bangladesh. To increase tolerance toward carnivores, minimizing impacts is key. Proper livestock management is important to prevent conflict, but if the conflict does occur, compensation to reduce people's anger appears necessary (Bauer et al., 2017). One solution to minimize the impact of livestock depredation could be promoting the registration of villagers living close to tiger habitat for a livestock insurance program currently offered by the Ministry of Agriculture of Indonesia.

Cultural norms and traditional beliefs were also found to reduce antagonism towards problem animals (Dickman, 2012). In Chapter 3, I found that there are many cultural beliefs which are considered as traditional ecological knowledge in relation to tiger, embedded in the Minangkabau community in the province of West Sumatra, which contribute towards explaining the attitude and tolerance toward tiger. How strong these beliefs currently remain in the community–- especially in the Minangkabau ethnic group in West Sumatra–- and whether holding this belief determines the chance of retaliatory tiger killing – is dealt with in Chapter 4.

The majority of respondents from the Minangkabau ethnic group held spiritual beliefs associated with the causes of human-tiger conflict (Chapter 4). The beliefs most commonly encountered were related to committing adultery, breaking of behavioural prohibition laws, and a condition known as the helix illness. When compared with other studies that included various Sumatran ethnic groups, it was found that a belief in the effects of adultery or other behavioural prohibitions was prevalent and strong (McKay et al., 2018). Both believers and non-believers of commonly held spiritual beliefs were interviewed, and the latter group often regarded these beliefs as folklore or myths that were not based in reality, or they had never heard of them. Interestingly, more respondents indicated a belief in the effects of adultery when asked directly, as opposed to indicating the effect themselves prior to being asked about it. This suggests that while these beliefs remain widely known, they may not be as strongly held in the present day.

The dynamic loss of traditional ecological knowledge over time and its implications for conservation management have received little attention to date, but that is changing. For example, Turvey *et al.* (2018) found that folklore, compared to the practical knowledge on hunting, was more quickly lost in communities where the Hainan gibbon (*Nomascus hainanus*) had recently gone extinct. They relate this to elderly people being ‘cultural repositories’ whereas younger generations practice, and hence have more knowledge about the use of their natural surroundings rather than its cultural meaning.

The significance of folklore in conflicts is particularly crucial when it may prevent them or when it offers added carnivore protection or raises the likelihood of retaliatory killing. My research indicates that possessing spiritual beliefs related to tigers does not necessarily offer greater

protection after a conflict. St. John *et al.* (2018) discovered that ethnicity and its associated beliefs may not be strong predictors of an individua''s intention to hunt wildlife in Sumatra. Nevertheless, it is important to recognize that hunting and retaliatory killing occur in distinct contexts.

In accordance with our findings, McKay *et al.* (2018) revealed that while the Minangkabau ethnic group demonstrated a greater inclination to uphold customary laws concerning tigers than other groups, they also displayed a higher inclination to retaliate and kill tigers, underscoring the idea that possessing spiritual beliefs does not necessarily equate to pro-conservation behaviour. Thus, using folklore to mitigate and explain human-tiger conflict does not appear to be a sufficient conservation strategy on its own. Nevertheless, its adaptive and strategic incorporation may prove advantageous when the affected community members strongly hold spiritual beliefs, as argued in the review by Fernández-Llamazares and Cabeza (2018). This is rooted in the idea that the beliefs are structurally free of power imbalance between conservation practitioners and local communities and the value thereof is demonstrated in several studies included in their review.

8.2.2. Hunting and the potential of disease transmission from dogs to the tiger

The second set of studies in this thesis focuses on hunting (Chapter 5) and the potential of disease transmission from domestic dogs to wildlife (partly Chapter 5 and Chapter 6). In these chapters, I presented my findings about wild boar hunting practices in Sumatra. Both active and passive wild boar hunting occur in Sumatra. Active hunting involves dogs and firearms, while passive hunting refers to the use of snares. Wild boar hunting using fire arms and snares occurs in all provinces in Sumatra while dog assisted hunting occurs in most provinces except North Sumatra and South Sumatra.

In all wild boar hunting methods i.e., using dogs, firearms or trapping, wild boar is not the only targeted wildlife. Many other protected and endangered species like the Sumatran tiger, Malayan tapir, sun bear, clouded leopard, sambar deer, muntjac, and Sumatran elephant can also be killed intentionally or unintentionally during active hunting or trapping. All hunting methods are opportunistic, meaning that the hunters do not control if they kill young, juvenile or adult, male or female, wild boar or other wildlife. This likely negatively affects the population sizes of wildlife

species (Conrad et al., 2021), and constitutes a major driver of population decline for these species (Mills, 2012; Milner-Gulland and Bennett, 2003)

Dog assisted hunting and snare hunting was mainly conducted by farmers and local people living close to forest, while wild boar hunting using firearms was mainly conducted by the sport hunting association called PERBAKIN and local tribes Suku Anak Dalam. In order to have firearms people need a permit and a licence to use the firearms. Local farmers usually install snares in or around their agriculture field to protect their plant from crop raiding by wild boar. Wild boar tend to live in the forest edge (Chapter 7) where normally agriculture fields are located next to it. Linkie (2007) found that 80% farmers around Kerinci Seblat National Park considered wild boar as pest for their agriculture. Crop raiding by wild boar is not considered to be a human-wildlife conflict and is therefore not addressed by the government of Indonesia. In this case farmers seeking for solution by installing snares to protect their crops. The material used for snares varied. It can be made of nylon, polyester rope, iron wire or steel cable. The last two are particularly dangerous for wildlife including the Sumatran tiger.

The practice of wild boar hunting using dogs may reduce crop raiding but also elevates the risk of disease transmission from dogs to wildlife and *vice versa* (Rhyan and Spraker, 2010; Sparkes et al., 2016). Dogs particularly can transfer Rabies virus (RABV) and Canine Distemper Virus (CDV) to wildlife, especially wild carnivores, during hunting events (Knobel et al., 2014; Nouvellet et al., 2013). The interactions between dogs and wild boar in West Sumatra are high and most dogs are not vaccinated. We found that more than 35% of dogs in the study area was not vaccinated against RABV and almost 100 % not vaccinated against CDV which means a high risk of disease transmission within the dog community during hunting and also between dogs and other wildlife (Knobel et al., 2014). Furthermore, we also found that even if the dogs were vaccinated, the levels of antibody titer are too low (<0.5 EU/ml) to protect the dogs from RABV infection (Chapter 6). Unvaccinated dogs are thought to be an important reservoir of RABV and CDV infection (Pimburage et al., 2017; Prager et al., 2012), therefore vaccination for dogs is a key to prevent disease transmission.

Dog owners in West Sumatra are familiar with RABV but not CDV. Despite knowing about RABV and its impact to humans, many owners do not vaccinate their dogs against it, either because of cost or the distance to vaccination centres. Even when the government offers free vaccinations, not all owners participate, as seen in Flores, Indonesia (Wera et al., 2016). Although Indonesia has a free Rabies vaccination program, it does not cover all dogs. Greater awareness of dog vaccination, especially for hunting dogs, is necessary. Dog ownership need to be documented and regulated properly including the minimum requirement list of vaccination for dogs.

Most likely, the reason why almost no one in the study area had their dogs vaccinated against CDV is that the majority of people were not acquainted with CDV. The prevalence of CDV reported from other populations around the globe is high. In Santa Cruz Island, Galapagos, for example, the CDV prevalence in dogs was 73% (Diaz et al., 2016). In the Emas National Park in the Cerrado savanna of central Brazil the prevalence was 74% (Furtado et al., 2016), in the areas of the Araucania region in Chile the prevalence of CDV in dogs in rural areas was 72% (Acosta-Jamett et al., 2011), similar to India's Great Indian Bustard Wildlife Sanctuary (Belsare et al., 2014). Although the prevalence of CDV among dogs in Sumatra has not yet been quantified, the daily practice of dog-assisted hunting in West Sumatra (as described in Chapter 5) is causing concern for wildlife conservation due to the large number of dogs involved and having access to the neighbouring forest area.

It has been proven that CDV caused death in tigers (Gilbert et al., 2015). Large carnivores may get the disease by eating infected animals, which can be either domesticated (e.g., dogs) or wild (e.g., raccoons and foxes) (Gilbert et al., 2015). From my study I hypothesized that there are three possible routes of disease spillover from dog to tiger: (1) dogs enter wildlife habitat, primarily facilitated by humans going hunting or taking dogs to the forest for protection; (2) stray dogs enter tiger habitat; and (3) tigers enter a village area and prey on dogs. Hunting certainly facilitates the dogs to get closer to or into the wildlife area, hence increase the exposure of disease spillover to wildlife. Hunting that was conducted mostly in the palm oil plantation area made the forest area bordering to palm oil plantation more exposed to spillover. From the camera trap study in Chapter 7, I found that the forest area neighbouring palm oil plantations is frequently visited by dogs.

Wild boar hunting in Sumatra, like in many other places, has potential risks and unintended consequences. I recommend implementing better management practices, law enforcement against illegal hunting, monitoring the use of dogs to prevent disease spillover, and increasing public awareness of the importance of sustainable hunting practices, in order to preserve wildlife populations and protect public health.

Furthermore, additional research is required to investigate the effects of wild boar hunting on the environment, animal populations, and the transmission of diseases. Gaining a deeper comprehension of the intricate ecological interactions associated with wild boar hunting could facilitate the development of more efficient management approaches that promote sustainable hunting methods and reduce inadvertent expenses.

8.2.3. Surrounding matrix quality to ensure healthy tiger population

The latest data chapter (Chapter 7) in this thesis is about the effect of habitat changes on the occupancy of the Sumatran tiger. I installed camera traps in 3 areas which have different neighbouring habitat, namely, secondary forest in the core area, secondary forest neighbouring palm oil plantation and secondary forest neighbouring mixed agriculture. From the analysis I found that tiger occupancy was highest in the secondary forest in the core area, compare to the agricultural and palm oil areas. This reflects the results of the study presented by Sunarto *et.al.* (2012) who also found that the occupancy of tigers is highest in the area close to the centroid of the forest.

Most of the tiger prey species, predominantly small and medium-bodied, have a higher occupancy in the area near palm oil plantation and mixed agriculture, whereas some prey species, mostly medium- and large-bodied, have a high naïve occupancy near the core area. Several of the herbivores, including wild boar and bearded pig and perhaps the mouse deer were likely attracted to the (palm) fruit availability in the palm oil plantations; for wild boar this aligns with the study conducted by Fujinuma and Harison (2012). The tiger naïve occupancy did not clearly correlate with prey naïve occupancies, perhaps because medium- and large bodied prey species were in satisfying supply in the core area. Fear of predators was perhaps another explanation why prey tended to have lower naïve occupancy values in prime tiger habitat (Laundré et al., 2010). The

interaction between carnivores and prey is complex, and my naïve occupancy data do not clearly single out simple predator-prey relationships.

Humans and dogs appeared on many of the camera trap pictures in the area near the palm oil plantation, which indicates high human activity in this area. Palm oil plantations was also the favourite place for the wild boar hunters for hunting using dogs (Chapter 5). If we look again (Chapter 6) at the potential disease spillover from domestic dogs to wildlife *vice versa*, the area bordering to palm oil plantation could be the gate for domestic animals to wildlife habitat and the gate for disease to enter wildlife habitat through domestic animals.

From the camera traps we found that there are still several tigers living in the Batanghari protected forest. However, habitat destruction caused by illegal mining activities is significant, and the current protection status of the area may not be sufficient to safeguard against human disturbance. Therefore, quick actions are necessary to protect the tigers in the area from local extinction.

The habitat of tiger and most carnivores in the world is fragmented (Ripple et al., 2014). Ecological corridors are essential for maintaining healthy carnivore population (Suttidate et al., 2021). To create a win-win solution for both tigers and humans, the corridor should be designed in a way that benefits both. Both mixed agriculture and palm oil plantation areas have potential as tiger corridors (Chapter 7). However, the fact that palm oil plantations could serve as a gateway for disease transmission to the primary wildlife habitat should be well-thought-out.

8.3. The future of tiger and other large carnivore conservation

8.3.1. Managing Human-Tiger Conflict

In a world where human domination increases and natural habitats for wildlife continue to decrease, conflicts between humans and wildlife are unavoidable. These conflicts exert pressure on both humans and wildlife. Managing the human-tiger conflict is not easy due to the complexity of the issue, which is not only about the ecology of the animal but also involves social, economic, cultural, and political factors (Dickman 2010; Nyhus 2016; Struebig et al. 2018; McKay et al. 2018). This study demonstrates that both humans and wildlife should have similar priority when resolving the conflict. It is important to note that resolving such conflicts requires a far more

comprehensive and multifaceted approach than merely addressing the immediate problems caused by wild animals to people and their resources. Conflict mitigation should also focus on preventing conflicts from happening, rather than resolving them after they have occurred. The following sections discuss some of the components necessary for achieving effective and long-term conflict mitigation and ensuring the coexistence between humans and wildlife.

8.3.1.1. Understanding conflict from multi perspectives

Before addressing the question of how to resolve the human-wildlife conflict, it is important to understand that the conflict has many dimensions and can be viewed from various perspectives. We need to understand how different entities formulate the causes of the conflict. From this study, I have learned that local people view the conflict from a cultural belief perspective, which is often neglected, while conservationists and scientists view it from an ecological, social, economic, or psychological perspective. It is not important how people define the cause of conflict; what is important is how we use the current knowledge we have, whether from cultural, ecological, social, economic, or other disciplines, to find the best way to mitigate the conflict and reduce or eliminate retaliatory killing towards carnivores. Conservationists, in particular, should be aware of these multidimensional perspectives because resolving conflicts between humans and wildlife requires much more than just mitigating the problems of wildlife damage.

8.3.1.2. Giving equal importance to both wildlife and humans

The human-wildlife conflict is a challenging issue that requires a balanced approach to ensure the safety and well-being of both humans and wildlife. Minimizing the impacts for both humans and carnivores is key to coexistence.

Minimizing the impact on individual tigers is achieved by reducing the removal of carnivores from their habitat and by reducing or possibly eliminating retaliation killing towards them. The focus of human-tiger conflict mitigation has mostly been on humans, and wildlife is often the party that has to be removed from the conflict area or sometimes translocated to other forest patches. However, translocation has been shown to not be the most effective way to reduce conflict and often creates new problems (Holland et al., 2018). For instance, translocating a carnivore could lead to a trophic cascade in the habitat it was removed from, which could lead to crop raiding. Moreover, the

translocated carnivore may cause conflicts in its new location, or attempts to returns to the area it came from (ECK, personal information).

Removal of carnivores is not only carried out by authorities. Local villagers sometimes make their own decision to kill carnivores. Many factors determine this negative attitude towards carnivores. Apart from those discussed in this thesis, including some communities not knowing where to report the conflict, slow responses from the government to the conflict could be the trigger for villagers to carry out retaliation killing towards carnivores (Viollaz et al., 2021).

Most of the governmental budget allocated to conflict mitigation is spent on handling problem animals, whether it is chasing them away or capturing and translocating them. Unfortunately, people are often neglected in this process. To minimize the impact of the conflict for humans, a sustainable compensation scheme is needed to reduce the negative attitude toward wildlife. Even when compensation schemes exist in some countries, they only apply to those who experience direct conflict, such as livestock being killed or family members being attacked by wildlife. However, when necessary, such as in cases of repeated conflicts or conflicts involving human casualties that cause local people to feel fearful and unable to engage in daily activities to earn money, support should be provided to affected communities. In one of the study areas where I conducted interviews, a tiger attack on humans made people too afraid to go to the forest and agriculture fields for more than two months. To survive, local people had to rely on help from family members outside the village to send basic necessities, or borrow money from others.

8.3.1.3. Increase tolerance by promoting traditional knowledge and environmental education

Knowledge about the ecosystem in which people live is important to increase tolerance toward carnivores (Carmi et al., 2015). In many communities around the world, folklore plays an important role in shaping beliefs and values. These stories are often passed down from generation to generation and can help create a sense of cultural identity and continuity. This is particularly true in communities where oral traditions have been the primary means of transmitting knowledge and history.

In the context of human-wildlife conflict, there may be value in preserving and promoting traditional beliefs and practices that help to mitigate conflict. By recognizing and valuing local knowledge and traditions, conservationists can work with communities to develop more effective and culturally appropriate solutions to environmental challenges, as suggested by Fernández-Llamazares and Cabeza (2018). One of their examples described how a 10-part radio series titled "Echoes of the Forest" interwove scientific and cultural aspects of lemur conservation around Ranomafana National Park (Madagascar), as part of a broad and diverse multi-year environmental education program "My Rainforest, My World" (Wright et al., 2019). Bhatia et al. (2021) have analysed the local Tibetan Buddhist folklore considering ibex, wolf and snow leopard, and suggested that a value-based approach be developed to enable conservation interventions to be more culturally sensitive. The positive narratives about carnivores then provide a starting point to enhance conservation messaging and outreach, while the negative ones can be used to initiate a dialogue with local communities. Another example is provided by Van der Ploeg et al. (2011) who describe how traditional knowledge about the Philippine crocodile has been incorporated in a holistic conservation programme broadly carried by local villagers, to the effect that ecologically damaging activities have stopped. Relying solely on traditional beliefs may however not be sufficient to conserve tigers or other carnivores. In my thesis, I found that younger generations in the Minangkabau community had lost faith in traditional beliefs about tiger. Given the quickly eroding traditional knowledge in Sumatra, I recommend that intergenerational transfer of traditional knowledge be put in place, as part of bottom-up, long-term environmental education programmes, adapted to regionally different cultural situations. In particular, educating high-risk communities on tiger biology, ecology, and conservation status may turn out to be critical for effective human-tiger conflict prevention and mitigation.

8.3.1.4. Multi-stakeholder involvement in conflict mitigation

The future of carnivore conservation is in the hands of people. The costs for handling human-tiger conflicts is very high and beyond the capacity of one organization i.e., government or NGO. Ideally, having the conflict management team at the local level that includes all stakeholders, i.e., NGOs, local government, and private sector, will likely be beneficial for the fast response needed when a HTC arises. To make the measures also less financially costly, involvement of the local community on conflict mitigations is indeed. I recommend that local villagers be trained to

handling the conflict, with skills to scare the tiger away from the village as part of a voluntary scheme.

Community and stakeholders engagement in conservation is the most sustainable strategy for managing conflict or other conservation issues (Sterling et al., 2017). People's participation in conservation and conflict management provides opportunities to strengthen emotional connections of communities with carnivores and hence support pro-conversation behaviours, also in times of conflict. This is evidenced by, e.g., the 20 years of experience in the Asian mountains on building partnerships with communities for biodiversity conservation (Mishra et al., 2017).

8.3.1.5. Livestock management is key to coexistence between humans and carnivores

Effective livestock management is an essential component of promoting coexistence between humans and carnivores (Chinchilla et al., 2022). Livestock is easy-to-catch prey for big carnivores especially when the former are free ranging. To reduce the risks of predation and minimize conflicts, it is necessary to implement sound livestock management practices such as providing secure fencing and adequate shelter for animals. However, building a strong livestock husbandry can clearly still entail significant costs, which may be unaffordable for the poorest families, which are also those which would be hit hardest by any depredation incident. The conflict mitigation costs are therefore best allocated to preventing conflicts by financially supporting the local people to make secure shelters for their livestock. Livestock farming in Sumatra is small-scale, each farmer may only have one or two animals, so it could be inefficient and more costly if each farmer has to make their own animal shelters. The solution for this is to create a communal livestock husbandry system with financial support by the government or the private sector, or other stakeholders working on wildlife conflict mitigation.

8.3.2. One-health approach for healthy wildlife population

The growth of human populations has contributed to the destruction and fragmentation of natural habitats, resulting in closer proximity between wildlife and humans or domesticated animals. Dog assisted wild boar hunting as studied in my thesis taking place in the proximity of the forest areas could be the gateway for disease transmission from domestic animals to wildlife *vice versa* (Rhyan and Spraker, 2010).

Not only do people enter wildlife habitat frequently, but wildlife also easily enters into the human-dominated landscape to feed on fruits and other crops (herbivores) or to prey on livestock (Terio and Craft, 2013). In the area I conducted my research, dogs are abundant in villages close to forested area as they provide benefits to humans, partly as guards to protect against carnivore attacks, but they can also be a source of disease that threatens wildlife (Sepúlveda et al., 2015).

To prevent disease transmission from the domestic dogs to the carnivores, a One Health approach that recognizes the interconnectedness of human, animal, and environmental health is crucial (Hassell et al., 2017). The application of One Health includes improving the health of domestic animals i.e., dogs, through vaccination campaigns or disease surveillance. To achieve this, initiatives that improve the health of domestic animals, particularly dogs, are necessary. This could involve vaccination campaigns to prevent the spread of infectious diseases, such as rabies or distemper, and disease surveillance programs to detect and respond to outbreaks in a timely manner. However, the success of such initiatives also depends on the engagement and participation of local communities. Therefore, community-based approaches that involve educating and raising awareness about the importance of animal health and disease prevention can also be effective in promoting the health of domestic animals and, in turn, reducing the risk of disease transmission to wildlife.

Wild boar hunting in any type (passive or active) needs to be managed properly in order to prevent the disease transmission from domestic dogs to wildlife and human. I recommend that this includes a mandatory health certificate for each dog, including vaccination registration; this could be one of the ways to reduce spill over. Preventing disease emergence can only be done by taking a coordinated and collaborative approach with local communities to develop effective disease control strategies.

8.3.3. Connectivity mater to ensure carnivore healthy population

The population of tigers and many other carnivores are fragmented due to fragmented habitat in Sumatra. To maintain healthy populations, connectivity is a critical aspect of carnivore conservation as it facilitates the movement of individuals between populations and allows for genetic exchange. The Bukit Barisan Forest area that span from the south to the north of Sumatra

Island is the main habitat that needs to be sustained and connected. There are fragments in several areas and ecological corridors could be a great advantage for maintaining the tiger population as well as reducing human tiger conflict.

From my study, apart from the secondary forest that could be an ideal type of habitat for ecological corridors, both palm oil plantation and mixed agriculture could be options for tiger corridors (Chapter 7). Palm oil plantations may provide a viable option for creating a tiger corridor due to their large size and potential to connect fragmented habitats. However, the risk of disease transmission to the primary wildlife habitat as I found in this study is a concern that must be addressed. The close proximity of humans and domestic animals to the plantations could increase the risk of diseases spreading to tigers and other wildlife (Hassell et al., 2017). Mixed agriculture, on the other hand, can provide a more diverse habitat for tigers and other wildlife while also benefiting local communities. To design the corridor, more research focusing on the use of the surrounding matrix by the tiger is needed.

Overall, the design of a tiger corridor should consider the needs of both carnivores and humans. Careful planning and implementation can help to create a win-win solution that benefits both parties and ensures the long-term survival of tigers in the wild.

8.4. Concluding remarks

Human-centered development poses a threat to the future of tigers and other wildlife in many ways. One of the effects of this development is the conflict between humans and tigers, which has negative impacts on both parties. The problems of human-wildlife conflict are complex and require interdisciplinary knowledge, including ecology, social sciences, economics, veterinary science, etc., to understand the processes behind the conflict and its impact.

A balanced perspective from both human and animal viewpoints is necessary for coexistence between humans and wildlife. Another effect of human-centred development is the spillover of diseases from domestic dogs to wildlife and *vice versa*. Potential disease transmission can occur through dog-assisted hunting on wild boars, making vaccination of dogs a key measure to prevent such spillover.

Habitat loss and fragmentation are additional issues with human-centred development. In fragmented landscapes, tiger occupancy is still higher in secondary forests within the core areas compared to those bordering mixed agriculture or palm oil plantations.

Effective management of natural resources by authorities, together with participation from the public, is key to preventing the extinction of tigers in Sumatra and likely other large carnivores elsewhere.

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About the author

Erlinda C. Kartika was born in Sugihwaras, Madiun (Indonesia) on November 19, 1981. She grew up in a village surrounded by forests, mountains, and year-round sunshine. Like the meaning of her birthplace, Erlinda is a 'rich' figure (Sugih means rich). She never stopped enriching herself with experiences.

In 2000, she received a scholarship to continue her undergraduate education and graduated from the Faculty of Forestry at IPB University in 2004. In 2008, she started her career in wildlife conservation and works at the Indonesian Ministry of Environment and Forestry. Since 2009, Erlinda has researched the Sumatran tiger, from ecology to social anthropology. The large mammal is one of the tiger sub-species that still survives today. She believes that animals deserve love. This prompted her to activate education and volunteering regarding the conservation of the big cat on earth. Erinda was a lecturer at a forestry campus in West Sumatra, a province in Indonesia. She also served as coordinator of communication and collaboration and the General Secretary both in the 'HarimauKita,' the Sumatran tiger conservation forum in 2014 and 2016 respectively.

Erlinda once conducted an internship at WildTeam Bangladesh, became a volunteer at WWF Netherlands, and wrote many articles about tiger-human conflicts to review the various cases, causes, and solutions needed. In 2019, she received a certificate of appreciation from the IUCN Commission on Education and Communication for her contribution to education and nature conservation. Her love for the Sumatran tiger made Erlinda continue her master's and doctoral studies in the Netherlands. She received scholarships, the StuNed Scholarship, and the Indonesia Endowment for Education, respectively, to study at Wageningen University & Research. Her interest in human-tiger interactions made her pursue her doctoral program, during which Erlinda returned to deepen her research on the Sumatran tiger. The study is quite ambitious, including monitoring the presence of Sumatran tigers in three different locations using camera traps, analysing conflict data between humans and tigers throughout Sumatra using a modelling approach, conducting community and pig hunter interviews to find out the potential for disease transmission from dogs to tigers, and analysing related policies on tiger conservation.

Erlinda is known as a person who easily socializes with anyone. She is good at cultivating meaningful friendships with others, alert, professional, and tends to be a perfectionist. Her friends compare her to a running deer. When a deer is truly motivated, it can run up to 35-40 miles per hour. Like a brave deer, Erlinda reaches her top speed when truly motivated. Erlinda kept running, searching for something that she never seemed to find. As a result of continuing to run, she did not realize she had travelled the world. She has traced Bangladesh, India, Australia, South Africa, the United States, the United Kingdom, Japan, Switzerland, Ireland, China, and many others.

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Written by: Muthia Ramadhani

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PE&RC Training and Education Statement

With the training and education activities listed below the PhD candidate has complied with the requirements set by the C.T. de Wit Graduate School for Production Ecology and Resource Conservation (PE&RC) which comprises of a minimum total of 32 ECTS (= 22 weeks of activities)

Review/project proposal (6.5 ECTS)

- Multiple anthropogenic pressures affect carnivore populations
- Carnivores in human dominated landscape

Post-graduate courses (13.7 ECTS)

- The science of conservation managing biodiversity in a changing world; PE&RC (2016)
- Introduction to R for statistical analysis; PE&RC (2016)
- Spatial ecology, geospatial analysis and remote sensing for conservation; Smithsonian Conservation Biology Institute (2016)
- Generalized linear model; PE&RC (2018)
- Bayesian integrated population modelling using JAGS; Melbourne University (2018)
- Dynamic models in R: programming, parameter estimation and model selection; Wageningen University (2019)
- Linier mixed model; PE&RC (2019)
- Citizen science: innovation in open science, society and policy; the German Centre for Integrative Biodiversity Research (2019)

Laboratory training and working visits (4.1 ECTS)

- PCR training; Livestock Health & Husbandry dept, Indonesia (2017)
- Introduction to canine distemper virus; Bukittinggi Veterinary Institute, Indonesia (2018)
- Canine distemper virus working visit; Udayana University, Indonesia (2019)

Competence strengthening/skills courses (3 ECTS)

- Information literacy including EndNote introduction; Wageningen UR Library (2016)
- Reviewing a scientific paper; Wageningen Graduate School (2016)
- Workshop carousel; Wageningen Graduate School (2018)
- Writing grant proposals; Wageningen Graduate School (2019)

Scientific integrity/ethics in science activities (1.2 ECTS)

- Research ethic seminar; Wageningen Graduate School (2017)

- Scientific integrity; Wageningen Graduate School (2019)
- Scientific integrity workshop Netherlands code of conduct for research integrity; Corporate Governance & Legal Services Wageningen University & Research (2020)

PE&RC Annual meetings, seminars and the PE&RC weekend (2.1 ECTS)

- PE&RC First years weekend (2016)
- PE&RC Last years weekend (2019)
- PE&RC day: exploring sustainability: now and for the future (2019)

Discussion groups/local seminars or scientific meetings (4.8 ECTS)

- R-user discussion group; Wageningen (2017)
- Animal monitoring in tropical forests; Utrecht (2018)
- Modelling and simulation discussion group; Wageningen (2019)
- ENCOSH An innovative platform to share knowledge and experiences of local initiatives worldwide on human wildlife conflict (2019)
- Conservation optimism summit; Oxford University (2019)

International symposia, workshops and conferences (4.1 ECTS)

- British ecological society annual meeting; oral presentation; Belfast, Northern Ireland (2019)
- World biodiversity forum; poster presentation; Davos, Switzerland (2020)

Societally relevant exposure (1.2 ECTS)

- Contributed to developing storytelling online course by IUCN commission on education and communication
- Interviewed by the Jakarta post about environmental education
- Keynote speaker in human-tiger conflict focus group discussion
- Keynote speaker in tiger disease workshop
- Guest lecture at Andalas University, West Sumatra, Indonesia
- Interview on classy FM Radio
- Interviewed by National Geographic Indonesia
- Interviewed by Kompas
- Write a book entitled Spatio-temporal patterns of human tiger conflicts in Sumatra, for the Ministry of Environment and Forestry of Indonesia
- Contribution to education and communication for nature conservation; IUCN

Lecturing/supervision of practicals/tutorials (3.3 ECTS)

- Animal ecology (2017, 2018, 2019)

BSc/MSc thesis supervision (3 ECTS)

- Traditional and local ecological knowledge, folklore and spatial risk mapping of human-tiger conflicts in Sumatra, Indonesia
- Surrounding matrix influence on the Sumatran tiger and its prey
- Fire management in savanna vegetation in Indonesia National Park
- Tiger mortality in Sumatran human-tiger conflicts
- Bottom-up and long-term environmental education as the key to human-tiger conflict mitigation
- Carnivore diversity in edge area in Batanghari protected area, West Sumatera in Bahasa Indonesia

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