Developing Applied Ecological and Socioeconomic Model to Avert the Extinction of Sulawesi's Rich and Endemic Biodiversity



Wulan Pusparini

Lady Margaret Hall
University of Oxford

A thesis submitted for the degree of
Doctor of Philosophy

Hilary 2024

This thesis was mainly written during the ongoing genocide of the people of Palestine. The horror of death is what haunts me every waking hour while I type the pages you are going to read. I dedicate this thesis to the scholars, academics, and students of Gaza, who have been killed and murdered by the occupying power, Israel.

And the children,
the children.

Declaration

I declare that this thesis is entirely my own work. Contributions by other authors are stated in the Contribution section. None of the work has been submitted, in whole or in part, for any previous degree application.

Wulan Pusparini
Hilary 2024

Abstract

Averting the trend of biodiversity loss is one of the main goals of the nature conservation movement. In this thesis, I attempt to rethink biodiversity conservation in Sulawesi using a system thinking framework and an interdisciplinary approach, focusing on wild meat consumption at the core of Wallacea's biodiversity hotspot, Sulawesi Island. From a systemic perspective, the interplay of wild meat consumers and biodiversity indicates a detrimental connection between humans and wildlife in a region. To elaborate on this, I define my study system's components as the conservation areas, the animal species that live in them, and the humans that live in their environs and the wider region. Before venturing into the heart of the issue, first I present the available wild meat knowledge and its gap in the context of Indonesia through a systematic mapping of published and grey literature. The result established Sulawesi as not only the hotspot of endemicity but also one of the islands with the most literature on wild meat use.

Conservation areas as the main stronghold of biodiversity protection are elaborated their representativeness through a Spatial Conservation Prioritization, and for Sulawesi, I demonstrated that the regions not yet designated for conservation protection include prime locations of great importance for animal and plant biodiversity, forest cover, and carbon stocks. These include the Mekongga Landscape in Southeast Sulawesi, the Bangkiriang Landspace in Central Sulawesi, and the Gorontalo corridor, all of which have been classified as high-priority areas for protection. While many protected areas (PAs), such as the Bogani Nani Wartabone National Park (BNWNP), remain high-priority sites for achieving biodiversity goals, others are simply relics of their past glory, with degraded habitat and poor biodiversity.

Then I turn my focus to the BNWNP to examine how the concept of a social-ecological system could be used there. BNWNP is a suitable study system since it is situated in an area where eating wild meat has long been regarded as socially acceptable. I provide empirical evidence on the negative impact of human encroachment within the park and wild meat markets in the vicinity of the park, on species richness. This discovery was expected; nonetheless, the use of causal inference to build a cause-effect link, rather than depending on 'association', as is customary for observational data, is novel and important.

To learn more, I did a thorough analysis of the wild meat supply chain. The analysis was reinforced by historical market trends spanning three decades. The results demon-

strated that even lawfully hunted animals, such as wild pigs and bats, are declining in abundance. With North Sulawesi as the 'sink', the previously indicated significant and priority areas of Southeast and Central Sulawesi, as well as Gorontalo, serve as the 'sink' area that provides animals for the wild meat trade. The interconnectedness of consuming wild meat with Minahasa identity, as well as significant profits from the wild meat trade, necessitate a more thorough evaluation of the solutions presently offered. To halt the supply, law enforcement on the currently illegal trade of threatened species is required, and the legality of trading animals with diminishing populations in the markets must be thoroughly examined. For those that can be harvested responsibly, it is critical to establish well-founded quotas to prevent over-exploitation. I suggest a novel technique for reducing demand that employs the concept of complex contagion to achieve the tipping point of societal change. This method has only just begun to be used in the conservation of biodiversity, and its application to the biodiversity hotspot of Wallacea, which includes a high biocultural area of Sulawesi, is vital.

Abstrak

Menghindari tren penurunan keanekaragaman hayati adalah salah satu tujuan utama dari gerakan konservasi alam. Dalam tesis ini, saya berupaya untuk memikirkan kembali konservasi keanekaragaman hayati di Sulawesi dengan menggunakan kerangka berpikir sistemik dan pendekatan interdisipliner, dengan fokus pada konsumsi daging satwa liar di pusat kawasan keanekaragaman hayati Wallacea, Pulau Sulawesi. Dari perspektif sistemik, interaksi antara konsumen daging satwa liar dan keanekaragaman hayati menunjukkan adanya hubungan yang merugikan antara manusia dan satwa liar di suatu wilayah. Untuk menjelaskan hal ini, saya mendefinisikan komponen sistem studi saya sebagai kawasan konservasi, spesies hewan yang hidup di dalamnya, serta manusia yang tinggal di sekitarnya dan di wilayah yang lebih luas. Sebelum memasuki inti permasalahan, saya terlebih dahulu menyajikan pengetahuan yang tersedia mengenai daging satwa liar dan kesenjangan informasi dalam konteks Indonesia melalui pemetaan sistematis literatur terbitan dan literatur kelabu. Hasilnya menunjukkan bahwa Sulawesi tidak hanya menjadi hotspot endemisitas, tetapi juga salah satu pulau dengan literatur terbanyak tentang penggunaan daging satwa liar.

Kawasan konservasi sebagai benteng utama perlindungan keanekaragaman hayati dijelaskan representativitasnya melalui Prioritas Konservasi Spasial, dan untuk Sulawesi, saya menunjukkan bahwa wilayah yang belum ditetapkan sebagai kawasan perlindungan konservasi mencakup lokasi-lokasi utama yang sangat penting bagi keanekaragaman hayati hewan dan tumbuhan, tutupan hutan, serta cadangan karbon. Wilayah-wilayah tersebut meliputi Lanskap Mekongga di Sulawesi Tenggara, Lanskap Bangkiriang di Sulawesi Tengah, dan koridor Gorontalo, yang semuanya telah diklasifikasikan sebagai wilayah prioritas tinggi untuk perlindungan. Sementara banyak kawasan lindung (PA), seperti Taman Nasional Bogani Nani Wartabone (BNWNP), tetap menjadi situs prioritas tinggi untuk mencapai tujuan keanekaragaman hayati, lainnya hanya menjadi peninggalan kejayaannya di masa lalu, dengan habitat yang terdegradasi dan keanekaragaman hayati yang buruk.

Selanjutnya, saya memfokuskan perhatian pada BNWNP untuk memeriksa bagaimana konsep sistem sosial-ekologis dapat digunakan di sana. BNWNP adalah sistem studi yang cocok karena terletak di wilayah di mana makan daging satwa liar telah lama dianggap dapat diterima secara sosial. Saya memberikan bukti empiris tentang dampak negatif perambahan manusia di dalam taman dan pasar daging satwa liar di sekitar taman ter-

hadap kekayaan spesies. Penemuan ini sudah diduga sebelumnya; namun, penggunaan inferensi kausal untuk membangun hubungan sebab-akibat, daripada bergantung pada 'asosiasi', seperti yang lazim dilakukan pada data observasional, adalah hal baru dan penting.

Untuk mempelajari lebih lanjut, saya melakukan analisis menyeluruh terhadap rantai pasokan daging satwa liar. Analisis ini diperkuat oleh tren pasar historis yang mencakup tiga dekade. Hasilnya menunjukkan bahwa bahkan hewan yang diburu secara sah, seperti babi hutan dan kelelawar, mengalami penurunan kelimpahan. Dengan Sulawesi Utara sebagai 'penyerap', wilayah prioritas penting yang telah disebutkan sebelumnya di Sulawesi Tenggara dan Sulawesi Tengah, serta Gorontalo, berfungsi sebagai wilayah 'penyedia' yang menyediakan hewan untuk perdagangan daging satwa liar. Keterkaitan antara konsumsi daging satwa liar dengan identitas Minahasa, serta keuntungan yang signifikan dari perdagangan daging satwa liar, memerlukan evaluasi yang lebih menyeluruh terhadap solusi yang saat ini ditawarkan. Untuk menghentikan pasokan, diperlukan penegakan hukum terhadap perdagangan ilegal spesies yang terancam punah, dan legalitas perdagangan hewan dengan populasi yang menurun di pasar harus diperiksa dengan cermat. Untuk hewan yang dapat dipanen secara bertanggung jawab, sangat penting untuk menetapkan kuota yang berdasar untuk mencegah eksploitasi berlebihan. Saya mengusulkan teknik baru untuk mengurangi permintaan yang menggunakan konsep penularan kompleks untuk mencapai titik kritis perubahan sosial. Metode ini baru saja mulai digunakan dalam konservasi keanekaragaman hayati, dan penerapannya pada hotspot keanekaragaman hayati Wallacea, yang mencakup wilayah biokultural tinggi di Sulawesi, sangat penting.

Contributions

The general introduction and epilogue are conceptualized and written by me, with review and input from Prof. David W. Macdonald, Dr Amy Hinsley, and Dr Lauren Coad.

Chapter 3 on systematic mapping of wild meat in Indonesia was conceptualized, designed, analysed, and written by me, with contributions from Prof. David W. Macdonald, Dr Amy Hinsley, and Dr Lauren Coad. The subsequent publication will include contributions and co-authors from Oliver Bridle (Bodleian Libraries, University of Oxford) on methodology, Dr Stephanie Brittain (Interdisciplinary Centre for Conservation Science - University of Oxford), and all authors will provide feedback on the manuscript before publication.

Chapter 4 on conservation priority was published as a journal article in Scientific Report in January 2023. The paper was conceptualized (original idea) and analysed by me, with input from Dr Matthew Linkie (Wildlife Conservation Society) and Prof. David W. Macdonald, with additional contribution from Andi Cahyana (Yayasan Konservasi Ekosistem Alam Nusantara, Indonesia) on data compilation and data analysis; Dr Hedley Grantham (Centre for Ecosystem Science, UNSW Australia) and Dr Sean Maxwell (University of Queensland, School of Earth and Environmental Sciences, Australia) providing validation for the method; and Dr Carolina Soto-Navarro (UNEP-WCMC) and all of the authors provided feedback on the paper.

Chapter 5 on predictive and causal inference was conceptualized (original idea), designed, analysed, and written by me, with inputs from Prof. David W. Macdonald, Dr Amy Hinsley, and Dr Lauren Coad. Subsequent publication has contributions and co-authors as well by Alfons Patandung (Wildlife Conservation Society – Indonesia Program), Heru Handika (Louisiana State University, LA, USA), Fahmi Idris Firdaus (School of Life Sciences and Technology, ITB, Indonesia) on species identification; Alfons Patandung, Herman H Lumenta (Bogani Nani Wartabone National Park - BNWNP, Sudarsono (BNWNP) contributed to fieldwork and data collection. All authors will give input on the manuscript for publication.

Chapter 6 on the vendor and market for wild meat was conceptualized (original idea), the study was designed, data was collected, analysed, and written by me, with input from Prof. David W. Macdonald, Dr Amy Hinsley, and Dr Lauren Coad. The subsequent publication will include contributions and co-authors from Jekson Wangka (Independent

Researcher) on data collection, Yunita Siwi and Dr Harry Hilser (Selamatkan Yaki) on data collaboration and manuscript input, and Dr. John Tasirin (Universitas Sam Ratulangi), as well as feedback from all authors on the manuscript for publication.

Chapter 7 on wild meat consumers was conceptualized (original idea), designed study, collected data, analysed, and written by me, with input from Prof. David W. Macdonald, Dr Amy Hinsley, and Dr Lauren Coad. Subsequent publishing will include contributions and co-authors from Jekson Wangka (Independent Researcher) on the collection of data, Yunita Siwi (Selamatkan Yaki), and Dr. John Tasirin (Universitas Sam Ratulangi), with all authors providing input on the manuscript for publication. This chapter has been formally invited to submit to the cross-journal Special Feature with People and Nature: 'Achieving Sustainable and Equitable Consumption of Wild Meat'.

Acknowledgements

I am eternally grateful to my supervisory team who accompanied me along the way and ensured the success of my study. To Prof. David Macdonald for his overwhelming support to me academically, but even more so, for always returning my stubbornness and candid opinion on any subject with kindness. To Dr Amy Hinsley and Dr Lauren Coad for introducing me to the world of social science, and all the complexity and interesting facets of it. This DPhil would not happened without the generous support of my funders: LPDP - Indonesia Endowment Fund for Education who gave me a full scholarship including funding for my fieldwork, and TradeHUB - WCMC who provided the majority of funding for my fieldwork.

I would also extend my gratitude to all collaborators in the past and future publication of my data chapters. WCS Indonesia Program and Bogani Nani Wartabone National Park, for permitting me to use the survey data. My main collaborators in Indonesia: Universitas Sam Ratulangi and Yayasan Selamatkan Yaki. For Dr John Tasirin at Universitas Sam Ratulangi for welcoming me to his university, providing office and support for me and my team to work and opening all the bureaucracy necessities a fieldwork demands. I also want to thank our friends and colleagues at Selamatkan Yaki, who served as our home base and support system throughout the fieldwork. For the countless hours we spent doing mock interviews, which sometimes makes the enumerators' training session feel like a casting studio for the next Netflix series, particularly I want to thank Yunita Siwi, Purnama Nainggolan, Ziva Justinek, Aprilia Balandatu, Tresia Reyni, and Harry Hilser. This research would not be feasible without my incredible enumerators' team: Jekson Wangka - my second in command, Andrew Donsu, Aprilia Balandatu, Astria Werung, Faldi Gonibala, Jeszy N Andakke, Mega Gusti, Mikael Maramis, Nindy Seroan, Rian Darwis, and Vino Umbas.

Oxford is indeed a beautiful place, but it won't be enjoyable without company. I am lucky to be joining two lab groups, the ICCS and WildCRU, which provide me with an endless supply of not only academic enrichment but also friendship. In WildCRU I am grateful for the friendship with Elisa, Ugyen, Singye, Sandra, Tanesha, Ming, Leo, Gui, Emily, Darragh, and many others. In ICCS I am grateful for the friendship with Trisha, Lessah, Shahzoda, Jack, Appy, Leah, Brittney, and many others. In the Biology department, room 10:14 and the wider first-floor BRAB crew, I am thankful for my Thesis solidarity sister, Aavika, and the lead cheers, Carla. It is done!

I could not have completed my final year with ease without the great support from Dr Annette Landjou, Dr Katy Schofiled, and the Arcus team. Thank you for believing in me, and giving me time until I am ready to fully join the Apes team.
And especially, this whole affair wouldn't have any meaning without the support of my family. My parents, Mama-Papa, and Ade, Riri, Aldi in Bogor. And the one I have closest in my heart, my Binar and my amazing partner, Ubun-Fakhrizal Setiawan.

Contents

I Prologue **1**

1 Overview **3**
1.1 Motivation . . . 3
1.2 Research Ethics and Positionality . . . 4
1.3 Research Aims and Objectives . . . 6
1.4 Thesis Structure . . . 6

2 Introduction **10**
2.1 From interdisciplinary to system thinking to solve the 'wicked problem' of biodiversity decline. . . . 10
2.2 The Study Systems . . . 11
2.2.1 Sulawesi as Part of the Wallacea Biodiversity Hotspot . . . 11
2.2.2 The Cultural and Political Identity of the Minahasan, and Notes on Other Northern Sulawesi Ethnic Groups . . . 13
2.2.3 Wild Meat Role as Food, Delicacy, and Biodiversity Conservation 16

II Data Chapters **18**

3 Increasing Visibility of The Wild Meat Issue In Indonesia Through An Inclusive Scientific Publication **19**
3.1 Abstract . . . 19
3.2 Introduction . . . 20
3.3 Methods . . . 21
3.3.1 Protocol . . . 21
3.4 Results . . . 25
3.4.1 The trend of themes and regions in published records over years . 26
3.4.2 Animals reported being consumed throughout the archipelago. . . 29
3.4.3 The identified information gap in the study of the wild meat supply chain in Indonesia . . . 29
3.4.4 The authors and inclusivity . . . 32
3.5 Discussion . . . 34
3.6 Limitation of the study . . . 38

4 A Bolder Conservation Future for Indonesia by Prioritising Biodiversity, Carbon and Unique Ecosystems in Sulawesi **39**
4.1 Abstract . . . 39

4.2 Introduction . . . 40
4.3 Methods . . . 41
4.3.1 Study Area . . . 42
4.3.2 Conservation Scenarios and Priority Setting Objectives . . . 42
4.3.3 Priority Area and Gap Analysis . . . 44
4.3.4 Representativeness of Sulawesi's Protected Area Network . . . 45
4.3.5 Identifying High-Priority Areas Outside the Current Protected Area Network . . . 47
4.4 Results . . . 47
4.4.1 North Sulawesi (Region 1) . . . 54
4.4.2 Gorontalo and Central Sulawesi (Region 2) . . . 54
4.4.3 Central Sulawesi (Region 3) . . . 54
4.4.4 Eastern Sulawesi (Region 4) . . . 55
4.4.5 Southeast Sulawesi (Region 5) . . . 55
4.4.6 South Sulawesi (Region 6) . . . 56
4.5 Discussion . . . 56
4.6 Data Source and Software Used . . . 60

5 Predictive and Causal Inferences for Investigating Species Richness Against Wild Meat Consumption in Sulawesi 61
5.1 Abstract . . . 61
5.2 Introduction . . . 62
5.3 Methods . . . 64
5.3.1 Study Area . . . 64
5.3.2 Data Collection . . . 65
5.3.3 Analysis and Modelling Framework . . . 67
5.3.4 Making the hypotheses explicit with a graph . . . 70
5.4 Results . . . 74
5.4.1 Environmental factors associated with species occupancy and richness 75
5.4.2 Effect of harvesting and consuming of wild animals to species richness. 79
5.5 Discussion . . . 83
5.5.1 Species distribution and its changes along environmental gradients. 83
5.5.2 Effect of anthropogenic pressure on species richness . . . 85
5.6 Conclusion and Recommendations . . . 87
5.7 Study limitations . . . 88
5.8 Data availability . . . 89

6 Untamed Harvest: Wild Meat Trade from Vendor Insights, Year-long Market Surveys and Three Decades of Trend Analysis 90
6.1 Abstract . . . 90
6.2 Introduction . . . 91
6.3 Method . . . 93
6.3.1 Study Area . . . 93
6.3.2 Characterizing the Minahasan wild meat vendors . . . 95
6.3.3 Quantifying the changes in price and trade volume . . . 95
6.4 Results . . . 98
6.4.1 Characterizing the wild meat vendors . . . 98
6.4.2 Quantifying the changes in markets' price and trade volume . . . 105

6.5 Discussion . . . 113
6.6 Conclusions and recommendations . . . 115

7 Urban and Rural Wild Meat Consumption, Food Culture, and Shared Identity in the Biodiversity-Rich Sulawesi within Wallacea Ecoregion 117
7.1 Abstract . . . 117
7.2 Introduction . . . 118
7.3 Method . . . 120
7.3.1 Study area characteristics. . . . 120
7.3.2 Respondents Interviews . . . 121
7.3.3 Data Coding and Analysis . . . 125
7.4 Results . . . 125
7.4.1 Respondent characteristics . . . 125
7.4.2 The frequency of consumption varies with the geography and demography of the respondents . . . 126
7.4.3 Preferences for wild and domestic species. . . . 128
7.4.4 Drivers of consumption . . . 131
7.4.5 Factors that may incentivise individuals to alter their patterns of consumption . . . 132
7.5 Discussion . . . 134
7.5.1 Reason and preferences in wild meat consumption . . . 135
7.5.2 How can we reach the tipping point of changing wild meat consumption habits/culture? . . . 137
7.6 Study Limitation . . . 138

III Epilogue 139

8 Some final brief reflections 141
8.1 Research questions revisited. . . . 141
8.1.1 Protected areas are social-ecological systems entrusted with maintaining biodiversity. . . . 142
8.1.2 Wild meat supply chains in North Sulawesi and their impact on biodiversity . . . 142
8.2 Strategy and policy recommendations . . . 144
8.3 Suggestions for future research . . . 144

IV Appendix 185

A Appendix for Part II 186
A.1 Appendix for Chapter 3 . . . 187
A.2 Appendix for Chapter 4 . . . 202
A.3 Appendix for Chapter 5 . . . 202
A.3.1 JAGS code terrestrial species Multi species Occupancy Model (MSOM).210
A.3.2 Code for Causal Inference with Structural Causal Modeling (SCM). 212
A.4 Appendix for Chapter 6 . . . 216
A.4.1 Wild meat vendors semi-structure interview . . . 216
A.4.2 Wild meat market monitoring . . . 218

A.5 Appendix for Chapter 7 222
A.5.1 Consumer Survey questionnaire. 222
A.5.2 Profile survey questionnaire. 225
A.5.3 Verbal Consent Guidance 226

List of Figures

1.1 The circle depicts the typical system for biodiversity conservation, with protected areas in the core/inner circle representing the ecology realm, and the gradually increasing human pressure in the outer circle representing the socio-economic realm, this begins in the rural area of the second ring and progresses to the urban area on the outside. Chapter 4, which discussed all land use types in Sulawesi, falls outside of this circle, as does Chapter 3, which discussed the wild meat issue that was reported nationally. . . . 8

3.1 Indonesia and its main islands 25
3.2 Flow diagram of records through the levels of identification, eligibility, and inclusion criteria of 184 records (1996-2023) which associated with wild animals or meat with any mention of consumption. 27
3.3 The records grouped by theme (a), region (b), the temporal frequency of the papers published (c-d), and the map of Indonesia's regions in this study (e). Plot (c) shows how people's focus has changed over time, especially regarding one health and sustainability. 28
3.4 Various wild species reported more than three times to be consumed/used. The animals (right) and region (left) are depicted as nodes, connected by lines whose width is proportional to the frequency of records. Because Maluku Is. and Lesser Sunda Is. have only a few records each, we present them together, and Java is not depicted on the map because none of the species recorded as being used there for wild meat was recorded more than three times. For full details see Table S2. 30
3.5 Conceptual flowchart of the wild meat commodity chain; orange rectangles represent the main commodity chain steps, green ellipses represent the issues surrounding these main supply chain steps, blue hexagons represent the benefits/drawbacks of eating wild meat, and grey ellipses represent issues not covered in this review. 31
3.6 A) The records included in the study are represented by green circles, while similar work that excluded are the blue circles. B) Connections among papers in this study database. The size of the circle indicates how many linkages each paper has with other circles/papers, with each link representing one citation. 33

4.1 Workflow for identifying priority conservation areas in Sulawesi under three protection scenarios. 46
4.2 Geographic regions we used to define and identify new priority areas in Sulawesi. 48

4.3 Sulawesi priority area size under six scenarios (two scenarios, 'a' and 'b', for protected area selection and three protection targets of 17%, 30%, and 50%). The dashed line denotes the total size of Sulawesi's current protected area network. 50
4.4 Sulawesi conservation features representativeness for all target scenarios (17%, 30%, and 50% protection target). The dashed line denotes the current protected area network on Sulawesi (18,602.4 km^2). 51
4.5 Priority areas in Sulawesi based on scenarios 'a' (in which the current PA network had to be included in the selection) and 'b' (in which any area could be selected), as well as the proposed order of selection for protecting these areas. 53

5.1 Camera trap stations in the Bogani Nani Wartabone Landscape, Sulawesi, Indonesia. 66
5.2 DAGs for the predictive and causal inferences. The blue box is the dependent variable, the orange box is the independent/covariate variable (or proxy independent variable for the causal inference DAG), the yellow box is the precision variable, the lime-green box is the unobserved independent variable, and the grey box is the unobserved confounding variable. 71
5.3 DAGs for the causal inferences. 'Intrusion' could be a collider variable which we will need adjustment. 74
5.4 Estimate of individual species occupancy (Psi0) and detection probability (p0). The community occupancy (0.15, SD 0.07) and community detection probability (0.05, SD 0.01) are represented by the red vertical line. The species with names starting with "B" are classified as having a large body size, while those beginning with "S" are classified as having a small body size. The large-bodied species have a higher occupancy (due to their larger home range) than the small-bodied species, but they are generally less common (lower detection probability) than the small-bodied species. . . . 76
5.5 The mean occupancy probability of 17 species in this study, as well as their responses to environmental conditions. Occupancy reflects the probability that a specific species is present or occupies the region of Bogani Nani Wartabone National Park, with one indicating presence and zero indicating absence. The blue lines show the mean posterior distribution, while the grey lines bound the uncertainty, expressed using the 95% Bayesian Credible Interval (CRI). 78
5.6 Association of the species occupancy with the environmental covariates. The closed circle points reflect the linear predictor's beta coefficient ($\beta 1$). Blue circle points represent a significant relationship. Error bars show 95% Bayesian credible ranges for coefficient estimations. Apart from elevation and vegetation index, none of the other covariates has a strong association with the species occupancy. 80
5.7 The backdoor paths for the direct effect of Access distance to Species Richness. 81
5.8 The backdoor paths for the direct effect of Intrusion to Species Richness. 81
5.9 The backdoor paths for the direct effect of Demography to Species Richness. 82
5.10 The backdoor paths for the direct effect of Market to Species Richness. . 83

5.11 The estimated species richness level in the study area and the effect of anthropogenic pressures. 86

6.1 A map of the nine traditional wild meat markets where intensive year-long data collection and vendor interviews were conducted. The modern supermarket, not shown on the map, is Freshmart in Manado. The inset map shows the North Sulawesi province, which is shaded red. 94
6.2 A map of the Sulawesi Provinces where the wild meat (wild pigs, bats, and snakes) is sourced. The red dots are the areas within provinces which are specifically mentioned by the vendors. 100
6.3 A map of the region surrounding Bogani Nani Wartabone National Park (black circle in Figure 6.2), that vendors claim is the source of their wild meat (small bats, rats, and snakes). It covers all of Bolaang Mongondow District, with red dots indicating areas mentioned by the vendors within each district. Green polygons are conservation areas. 101
6.4 Local-level hunting and trade networks in the Dumoga Regency. 102
6.5 Average monthly net profit per vendor from selling wild meat. 104
6.6 Species richness and body mass of different animals in wild meat markets. 106
6.7 The graph shows a 12-year trend in wild animal sales with each tick in the x-axis representing the year. We excluded dogs, cats, frogs, and quail, as they were not included in the 2011-2020 data. The "Threatened" category includes bear cuscus, macaques, civets, and dwarf cuscus. The banded rail (weris), monitor lizard and squirrel all fall under the "Anything Else" group. 108
6.8 Seasonal effect on the volume of meat traded and its price. The main markets are: Tomohon, Langowan, Kawangkoan. The rural: Amurang, Motoling, Imandi, and Dumoga. The urban: Bersehati, Karombasan, and Freshmart. For the price unit, both bats and rats are for whole animals, while wild pigs are per kg. 110
6.9 A thirty-year trend of two endemic pigs, the babirusa and Sulawesi wild pigs, sold in Langowan market, Minahasa regency, North Sulawesi. Each tick on the x-axis represents the year. 112

7.1 Village survey locations surrounding the Bogani Nani Wartabone Landscape and urban-suburban region in Manado-Minahasa, Sulawesi, Indonesia. The wild meat market icon on the Village 9-11 polygon is not a market, but rather an important middleman that supplies wild meat to urban markets. 121
7.2 The graphic shows the odds ratio of the predictor and responder variables; the black square represents the mean estimate, and the whiskers indicate the 95% confidence interval. The odds of consuming wild meat rarely ($\geq$ once a month) increase as the estimate moves to the right, and vice versa. 127
7.3 The frequency with which respondents consumed meat in the consumption survey. The results from both rural and urban areas appear similar, with chicken, pork, wild pig, and fish being the most often stated. However, most respondents reported eating fish every day. 129
7.4 The most popular animals to eat, as reported by survey respondents. Graphs a, c, and d are taken from the consumer survey (n = 373 respondents), and b is from the profile survey (n = 155 respondents) . . . 130

8.1 Taken from (Clements et al., 2024) on the evolution of the protected area concept. 143

A.1 Species photographed at least once and the habitat type in which they were detected. Species in bold are endemic to Sulawesi, whereas those in red are domesticated or feral. 202
A.2 The association between predictors and frequency of consumption 229

List of Tables

4.1 Size of the priority area (for planning units with a selection frequency ≥75) in scenarios 'a' and 'b'. 49
4.2 Recommended order for assigning protection to priority areas outside of Sulawesi's current protected area network. 51

5.1 The list of covariates used, their extraction method, and their source. . . 68
5.2 Summary of the terrestrial species found and used in the analysis of this study through camera trap surveys in the Bogani Nani Wartabone Landscape, Indonesia, with their IUCN Red List status, endemicity, and body mass. 75

6.1 Wild meat survey days count per year. The survey can be done in ≥ 1 market (see Table S1).
* We don't know the exact number of survey days, so '1' simply indicates that there are surveys in that month. 97

7.1 The questions from both surveys, including the one used in this study. . . 123
7.2 Model selection table for candidate models in predicting which factors are associated with wild meat-eating frequency. 127
7.3 The count of how many times a given topic was referred to in the consumer survey (with the percentage from total). 131
7.4 The consumption survey respondents' opinions on wild vs. domestic meat (with the percentage from total). 132
7.5 The condition that will urge consumers to change their consumption habits (with the percentage from total). 133
7.6 Average Price Increase of Meat per Unit Sold 134

A.1 Wild meat issue mentioned in the selected papers. *IPLC = Indigenous People and Local Community 187
A.1 Wild meat issue mentioned in the selected papers. *IPLC = Indigenous People and Local Community 188
A.1 Wild meat issue mentioned in the selected papers. *IPLC = Indigenous People and Local Community 189
A.1 Wild meat issue mentioned in the selected papers. *IPLC = Indigenous People and Local Community 190
A.1 Wild meat issue mentioned in the selected papers. *IPLC = Indigenous People and Local Community 191
A.1 Wild meat issue mentioned in the selected papers. *IPLC = Indigenous People and Local Community 192

A.1 Wild meat issue mentioned in the selected papers. *IPLC = Indigenous People and Local Community 193
A.1 Wild meat issue mentioned in the selected papers. *IPLC = Indigenous People and Local Community 194
A.1 Wild meat issue mentioned in the selected papers. *IPLC = Indigenous People and Local Community 195
A.2 The list of animals or species described in the records, together with their corresponding regions. 196
A.3 The list of uncited records based on their type of publications and disciplines. 101 records did not get cited in the list. 200
A.4 Summary statistics for all three blocks surveyed using camera traps in Bogani Nani Wartabone National Park, Indonesia (2016–2019). 203
A.5 List of animals that can be identified to species level and photographed at least once in the Bogani Nani Wartabone Landscape, Indonesia, with their IUCN Red List status and endemicity. *NE = Not Evaluated; LC = Least Concern; NT = Near Threatened; VU = Vulnerable; EN = Endangered; CR = Critically Endangered 204
A.6 Coefficient estimates and uncertainties of the community response of the terrestrial species in the Bogani Nani Wartabone Landscape, to environmental and anthropogenic variables. 207
A.7 Posterior summary results of the occupancy and detection probability of each species during camera trap surveys in the Bogani Nani Wartabone Landscape. The uncertainties of the mean are shown as standard deviations (SD) and 95% Bayesian credible intervals (2.50% – 97.50%). 208
A.8 Markets that were surveyed, as well as the number of survey days. Langowan is the only market that has been consistently surveyed over the years.
*The market was surveyed for at least that number of days. 219
A.9 Types of wild meat sold in Freshmart (a modern market in Manado city), Karombasan and Bersehati (traditional markets in Manado city), and the three big wild meat markets of Tomohon, Kawangkoan, and Langowan. 220
A.10 Types of wild meat sold in four rural wild meat markets. 221
A.11 Demography of the Consumption and Profile Survey's Respondents . . . 230
A.12 The odds ratio of the predictor's variable on the frequency of wild meat consumption. The odds ratio value less than 1 means the odds are higher for consuming wild meat more frequently, and the odds more than 1 means otherwise. 231
A.13 Situation that the respondents in consumption surveys reported will make them change their wild meat consumption habit. 232

Part I

Prologue

"Let's face it, the universe is messy. It is non-linear, turbulent, and chaotic. It is dynamic. It spends its time in transient behavior on its way to somewhere else, not in mathematically neat equilibria. It self-organizes and evolves. It creates diversity, not uniformity. That's what makes the world interesting, that's what makes it beautiful, and that's what makes it work."

— Donella H. Meadows

1

Overview

Biodiversity conservation has always involved at least three aspects: the space in which the event takes place, the object under our consideration, and the actor or subject of the action. In this thesis, I investigate all aspects of the protection of terrestrial species (objects - biodiversity richness) on the island of Sulawesi (space) that are influenced by human habits and actions (subject - part of cultural richness), with a particular emphasis on the practice of eating wild meat. To be truly interdisciplinary, I address each component with a range of methodologies, including ecology modelling, spatial analysis, social science, and qualitative research.

1.1 Motivation

This DPhil thesis is motivated by my professional background in endangered species conservation. Over 12 years of my professional life, as I was preoccupied with population modelling of the Sumatran rhinos, elephants, and tigers, I felt this work, while worthwhile, was missing something. Although the precise estimation of population parameters is technically challenging, it has nonetheless been my comfort zone. However, whatever the elegance of the equations, they depicted a closed system, ignoring the human communities living in and around the species' habitats. Too often, it seems to me, core ecological research was distanced from a more informal consideration of the impact on communities living in and around the species' habitat. Even the inclusion of generally negative anthropogenic factors in statistical models was, in my experience, too often a very rudimentary consideration of sociological factors. Treating protected/conservation areas as a closed system while treating people living nearby as separate topics risks partial, artificially simplified interpretations, and inadequate science. I argue for a more formal integration

between ecology and socio-economic facets of conservation and treating the entire system as an active, interacting entity that should be understood and studied as a whole.
The call for this type of integration, however, is nothing new. In one famous Rede Lecture at the University of Cambridge more than six decades ago, C. P. Snow 'christened' what he called The Two Cultures, a call to action for greater integration and mutual understanding between the sciences and the humanities (Snow [1959]). A quick keyword search using phrases "interdisciplinary, transdisciplinary, or multidisciplinary" and "conservation biology" returned 164 publications in Web of Science and 309 in Scopus, with the earlier articles written from the end of the 80s - early 90s (searched on March 2nd 2024). Both roughly demonstrated that the lexicon had entered the conservation biology discourse more than 30 years ago, with arguably the most famous example being Michael Soule's "What is Conservation Biology?" (Soulé [1985]). Despite all this, the trickle of application from theory to practice, at least in the part of the world where I worked, is not enough. Yes, different sections of conservation organisations (or any entity for that matter) may have a science (usually natural) division, a social science division and even policy specialists. However, in my experience, a truly interdisciplinary strategy just wasn't there yet. Having been presented with a rare opportunity to do a thesis project of my choice, this thesis is the embodiment of what I think is possible in my ideal world where both the object (species) and subject (human) are considered with the same weight of importance. That ideal made the wider framework and motivation of this thesis.
Another reason for this thesis being as it is, is purely selfish. Being trained and brought up as a natural scientist, I have timid suspicions, and perhaps fear, about anything that cannot be measured. Having concluded that understanding the subject, of humans, is important in interdisciplinary conservation biology, my earlier squeamish attitude toward social science had to change. This thesis is my first venture into social science, from designing the survey and questionnaire, conducting the interview, and learning new concepts I had never engaged with before, such as declaring my positionality as a researcher in my work. Through this thesis, I learned simply how what we consider 'data' and 'knowledge' in both disciplines, natural and social, are different. Sometimes you lose the nuanced, the variants if you will, by only focusing on the aggregate information, those regressions towards the means. And while knowing the general pattern is important, understanding the nuances and variants can lead you to more just conservation. And I hope I do myself justice too by correctly mastering this social science discipline and developing the art of understanding things that cannot quantifiably be measured.

1.2 Research Ethics and Positionality

The social science part of the thesis (Chapters 6 and 7) was approved by the Central University Research Ethics Committee (CUREC) 1, with Ethics Approval Reference number

R76942/RE001 on 7th January 2022. The Ethics Approval was then amended to include audio recordings of the interview into R76942/RE002 on July 12th 2022. The surveys were then conducted in collaboration with the Universitas Sam Ratulangi, the largest public university in North Sulawesi, under a Memorandum of Agreement (MoA) OU/LSO/0241/v5. The MoA was signed by The Chancellor Master and Scholars of the University of Oxford, Ana Serra Barros, the Research Contracts Lead on 6th October 2021, and the Dean of the Faculty of Agriculture, Universitas Sam Ratulangi, Prof. Ir. Robert Molenaar, on 18th October 2021. The survey is also in close collaboration with the main partner in the ground, the NGO Selamatkan Yaki, in which some of their data is also included in Chapter 6.

All social survey fieldwork and interviews were conducted by me, assisted by my Research Assistant, Jekson Wangka, and nine enumerators, all of whom are Indonesian nationals. Except for me, the team members reside in the province of North Sulawesi and are proficient in the local Minahasan and Bolaang Mongondow languages. I am a Western-educated natural scientist with practical conservation experience, and I conceptualized the questionnaires. Adjustments to the local context were made in collaboration with Dr John Tasirin from Universitas Sam Ratulangi and Yunita Siwi from Selamatkan Yaki before conducting the study, including practising and piloting interviews in an urban market and rural village. The study's findings are presented through a lens that blends my Western-educated perspective with input from Dr. John Tasirin, Yunita Siwi, Jekson Wangka, and local enumerators. The team composition ensures a balance in terms of gender, race, and religious affiliations, which is particularly relevant given the predominant association of wild meat consumption with specific races and religions.

To mitigate the team's outsider status, rapport was built by spending a minimum of a week familiarizing us with the markets or villages before initiating data collection. Emphasizing our identity as neutral students and scientists, we assured participants of the confidentiality of their information and the anonymity of their credentials. This approach facilitated access to villages with significant hunting activities and the main markets of Langowan and Tomohon, enabling interviews with hunters, consumers, and vendors who shared sensitive information about hunting practices and intermediary involvement. Despite our efforts to present authentic knowledge, we acknowledge potential biases in the transcription and interpretation of data. The interview results underwent two translations—from Minahasan or Bolaang Mongondow to Indonesian and finally to English, introducing the possibility of bias. Furthermore, the study focuses solely on the consumption aspect of the supply chain, offering a partial understanding of the overall situation concerning wild meat use in the region.

1.3 Research Aims and Objectives

The main goal of this thesis is to present a practical framework for interdisciplinary conservation, specifically on the issue of wild meat consumption, in addition to academic exercises and discourses. For each of the three previously indicated aspects, the place, the species as the object, and the human as the subject, the thesis offers a methodical process. By doing this, as can be seen from the combination of both paradigms used in the unfolding data chapters, one can also provide a practical example in which the flexibility of choosing the most appropriate approach is required, liberating oneself from the dichotomy of quantitative-qualitative, or natural-social sciences.
The specific objectives of the thesis are to answer three major research questions which are the core of this thesis:

1. How does the whole system of actors and events that comprise the wild meat issue affect the conservation of threatened species, human and animal wellbeing, and what can be done to facilitate more just conservation?

2. How well does the current protected area network (representing government conservation investment) protect forest cover, important ecological ecosystems, and high-carbon storage areas?

3. How does species richness vary along a geographic and environmental gradient, and what effects do levels of wild meat consumption and trade have on species richness?

1.4 Thesis Structure

I present the answer to the research objectives in five empirical papers as follows:

- **Chapter 3:***A systematic mapping of the wild meat supply chain in Indonesia.* The topic of wild meat consumption and its relevance to conservation is not a well-established topic in Indonesia; we discovered that most of the literature on the subject comes from research focused on hunting wildlife rather than consumption. The analysis revealed that, while Sulawesi has been the subject of the most published studies on wild meat, all of Indonesia's main islands are involved in wild meat issues. One-third of the publications we reviewed had been authored by mostly national scientists in local journals, siloing them from international scientists. This Chapter serves as a transition into a more in-depth investigation of the wild meat supply chain in the following two sections.

- **Chapter 4:** *A spatial conservation prioritisation for the island of Sulawesi, visualising how the 30 by 30 approach may be implemented here and addressing the present gap in the protected area network.* This paper (published as Pusparini et al.

[2023]) evaluates the background of conservation in Sulawesi by assessing how effective and representative the current Protected Area (PA) network is for protecting Sulawesi's critical species and habitat features. In line with the new targets and goals of CBD post-2020 GBF, particularly the thirty-by-thirty target, we imagined how this can be applied in Sulawesi. We use spatial conservation planning with an annealing algorithm and reveal gaps in the current PA network. We identified important areas outside of the current PA network and simultaneously showed that the current National Parks, such as Bogani Nani Wartabone, are critical for the conservation of Sulawesi's biodiversity.

- **Chapter 5:** *Using two inference techniques, predictive and causal, to understand how the pressure from wild meat trade and consumption affects the species richness.* This Chapter evaluates how species distribution changes along environmental gradients and land use types in and around Bogani Nani Wartabone National Park (BNWNP). Further, we made a formal mathematical assessment of the species richness and the effect of wild meat consumption and trade surrounding the BNWNP system. In this Chapter, we apply a novel ecology modelling approach designed for observational data to make a predictive inference of the species population parameters (richness and distribution) inside the system (national park), and then a causal inference of the impact coming from outside the system on those species populations.

- **Chapter 6:** *Understanding the trend in wild meat markets and the vendors in North Sulawesi.* This Chapter examines the trend in wild meat trade over the last thirty years, revealing a significant decrease in wild pig stock and a price increase, suggesting the collapse of local wild populations. The yearlong intensive market monitoring allows for an assessment of current challenges (COVID-19 and ASF), seasonal impacts, and the type of threatened species that remain on the market. This Chapter also demonstrated that monetary profit in the wild meat market, as well as the lack of clear regulations on 'legal' wild meat trade, provide strong incentives to participate in the supply chain.

- **Chapter 7:** *Characterizing the urban and rural wild meat consumers and comparing it with people's perceptions in North Sulawesi.* This Chapter discovered a significant difference in wild meat consumer characteristics, with younger males in rural areas consuming more frequently than those in cities. We also look at the price inelasticity of wild meat, the reason-believe-social norm associated with it, and how the perception of supply and demand for wild meat changes over time. The findings help to fill an important knowledge gap in understanding wild meat consumers as the end of the supply chain.

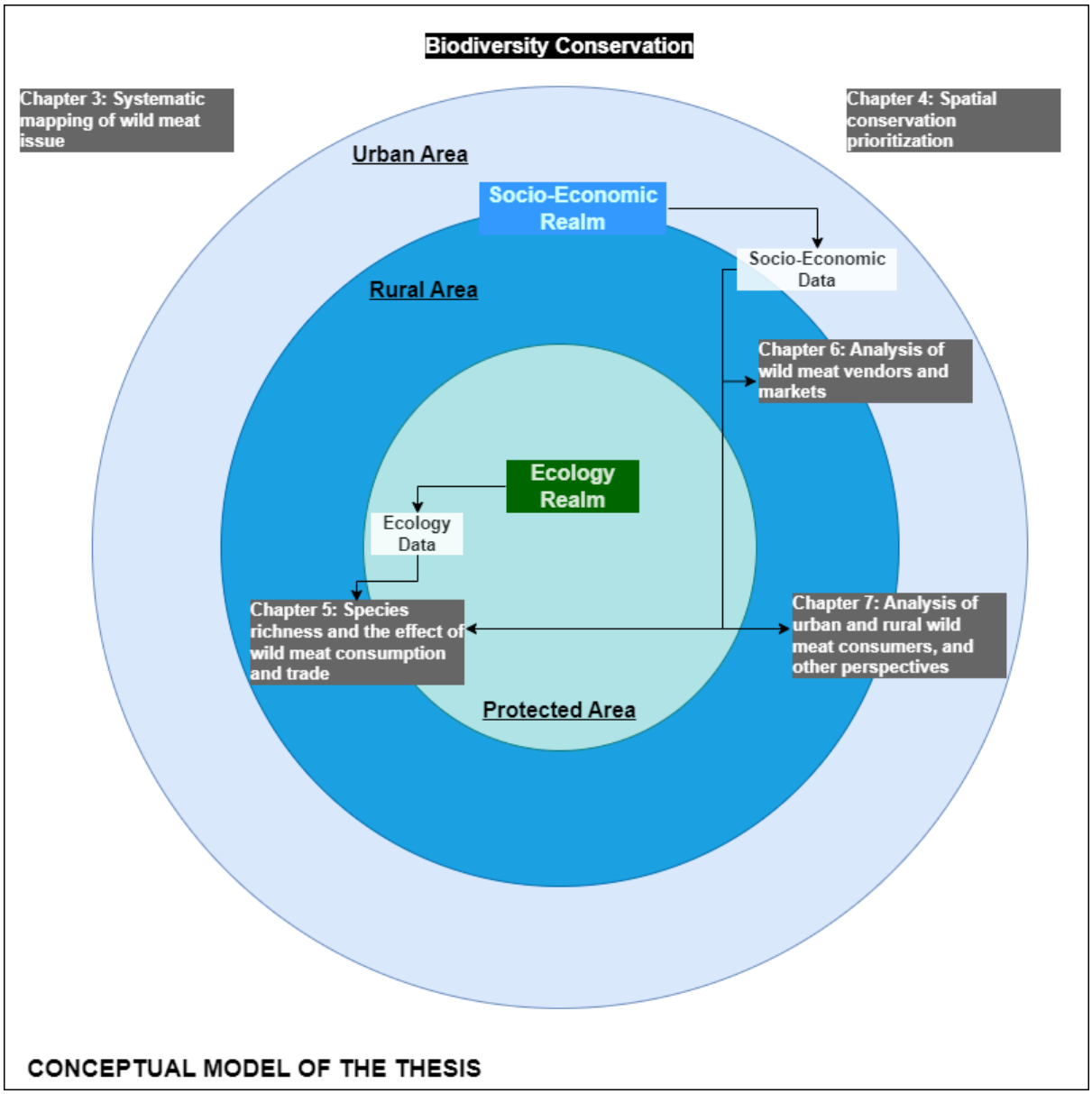


Figure 1.1: The circle depicts the typical system for biodiversity conservation, with protected areas in the core/inner circle representing the ecology realm, and the gradually increasing human pressure in the outer circle representing the socio-economic realm, this begins in the rural area of the second ring and progresses to the urban area on the outside. Chapter 4, which discussed all land use types in Sulawesi, falls outside of this circle, as does Chapter 3, which discussed the wild meat issue that was reported nationally.

The conceptual model of the thesis is presented below in Figure 1.1. It provides a graphical depiction of how each Chapter fits into the thesis as a whole, in terms of realms (ecology or socioeconomics) or systems (outside and inside protected areas). A synthesis of the component chapters provides a corpus of knowledge to benefit both biodiversity and people through a more effective conservation strategy.

2

Introduction

2.1 From interdisciplinary to system thinking to solve the 'wicked problem' of biodiversity decline.

In *"Whose conservation?"* (Mace [2014]) asked a pertinent question at the very heart of biodiversity conservation. For whose benefit are we saving the endangered tiger, lion, shark, orchid, or any other nonhuman living creature? The answer to this has shifted the biodiversity conservation thinking landscape in recent decades, with greater emphasis on the connection between people and nature (Mace [2014]). One example is the inclusion of Indigenous people and their knowledge of the most recent IPBES report (IPBES [2021]). This shift resulted from the realisation that conservation efforts that undermine human welfare are usually ineffective or only successful in the short term.

At the start of the conservation movement, with roots in the USA, John Muir and his contemporaries proposed the total protection of a large landscape, which led to the framing of 'Nature for itself.' This conservation framework, particularly the concept of the protected area, then spread to much of the *'colonialised'* world, including Indonesia (Jepson and Whittaker [2002]). As much of the world decolonises and society and social mores evolve, so does the perception of things that matter; the result is a redirection of goals. Conservation biology was a new discipline when Michael Soule defined it in 1985, however, even then, the idea of interdisciplinary (or multidisciplinary, as he put it) was there: *"A new synthetic discipline addresses the dynamics and problems of perturbed species, communities, and ecosystems."*. Soule also called it, as conservation biologists frequently emphasise in diverse situations, a *crisis discipline*, in which one must act before knowing all the facts. This means that the interdisciplinary synthesis is less of a recommendation and more of a necessity. Soule drew a parallel with cancer biology, in which conservation

biology, as a multi-disciplinary science, includes natural resource fields, social sciences, Eco-philosophy, environmental monitoring, veterinary medicine, hazard evaluation, historical biogeography, island biogeography, physiology, population biology, and genetics. The area becomes increasingly intriguing with the introduction of various multi-disciplinary syntheses (Blair et al. [2017], Pooley et al. [2017], Macdonald et al. [2019]). Transdisciplinary, multidisciplinary, and interdisciplinary are frequently used to characterise it (Schroeder [2022]). Although it is difficult to define those three categories precisely, transdisciplinary may refer to the process of integrating multiple disciplines to form a new field of study (Macdonald et al. [2019]). The approach is especially crucial in solving challenging and complex issues such as climate change, biodiversity loss, and social-policy problems such as chronic poverty, and pandemics, which are also commonly referred to as "wicked problems" (Walls [2018], Steinhall et al. [2023]). By 'wicked', there is no inference of evil, but rather a problem that is difficult to solve because the problem is only understood after the formulation of a solution, it has no stopping rule, and the solutions are not right or wrong, where every wicked problem is essentially novel and unique, every solution is a 'one shot operation', and the problem has no given alternative solutions (Rittel and Webber [1973], Conklin [2005]).

Using the case study of biodiversity decrease in Sulawesi, I try to approach the solution of our wicked problem by employing system thinking (Grewatsch et al. [2023]). In her seminal book 'Thinking in System', Donella Meadow defines a system as an interconnected set of elements that is coherently organised to achieve something. Particularly, to be called a system, something must have three kinds of components, elements, interconnections, and a function of purpose (Meadows [2008]). This is relevant to the problem in my research case since biodiversity conservation is plagued with intricate interactions between science, society, and many interacting systems across temporal and geographical scales (Davila et al. [2021]). In my thesis, I approach a problem as an interconnected system, taking advantage of a framework constructed from many disciplines to find a solution. Since there may be multiple approaches needed to tackle each cog and wheel in the system, we maintain the methodological separation and apply it appropriately, based on the situation. In this thesis, I viewed the closed protected areas' environmental realm and the outside socio-economic realm as one cohesive system. As the fundamental element included in any conservation effort, I have decided to concentrate on the environment, the animals that live there, and the people that live nearby within those systems.

2.2 The Study Systems

2.2.1 Sulawesi as Part of the Wallacea Biodiversity Hotspot

The research in this thesis took place in Sulawesi, one of Indonesia's 17,000 islands and the largest island in the Wallacea region of biodiversity hotspots. The uniqueness of

Sulawesi biodiversity, evolution, and conservation has been highlighted since Alfred Russel Wallace's expedition to Sulawesi (then the Celebes) in the 18th century (Wallace [1869a]). In the modern conservation movement, the Wallacea ecoregion, with Sulawesi at its centre, is one of the twenty-five global hotspots for biological conservation (Myers et al. [2000]). However, after two decades, Sulawesi has lacked sufficient conservation attention (Cannon et al. [2007], Broto and Mortelliti [2019]). Sulawesi has one of the world's highest levels of species endemism (Struebig et al. [2022]), which adds to the urgency of addressing the several key threats that drive the decline in the island's species and habitats. These threats include wild meat consumption (Rejeki [2018]), hunting for illegal wildlife trade (IWT) (Milner-Gulland and Clayton [2002], Lee et al. [2005]), and conversion of forest to farmland (Kelley et al. [2017], Kelley and Prabowo [2019], Voigt et al. [2021]). The overall decline in Sulawesi's biodiversity frames the particular and urgent concern for four iconic Sulawesi mammal species: anoa (*Bubalus depressicornis* and B. *quarlesi*), babirusa (*Babyrousa celebensis*), black macaque (Macaca nigra and M. nigrescens), and the Sulawesi civet (*Macrogalidia musschenbroekii*). After the first data chapter, the rest of the focus will be on the Bogani Nani Wartabone National Park (BNWNP) in North Sulawesi province. As this thesis was written in an integrative format, which means each Chapter or data chapter can stand as its own published literature, I will not dabble too much in the study area. A more detailed and appropriate description of the study system concerning the context of questions it is trying to answer is provided in either the Method part of Chapter 4 or the Introduction section of Chapter 5 of the Data Chapters that readers will find in Part II.

The Space They Share - Prioritising Conservation at the Landscape Level

Like a medical emergency department, conservation biodiversity faces the challenge of allocating scarce resources to the most urgent cases, ideally those that are realistically salvageable. As a result, biodiversity protection is frequently an expensive endeavour. This means setting aside a significant area of land for landscape purposes that is not included in the local development plan. This is always a difficult task, for the obvious, if regrettable, reason that ecological considerations rarely win when in competition with the economy, particularly in a nation where the extraction of natural resources is the backbone of economic growth.

To prioritize the most vulnerable and significant area relative to the rest of the world, conservationists designated areas as biodiversity hotspots (Myers et al. [2000], CEPF [2014]), key biodiversity areas (Smith et al. [2018]), endemic bird areas (Stattersfield et al. [1998]), Ramsar (Ramsar Convention Secretariat [2010]), or ecoregions (Olson and Dinerstein [2002]), to prioritize the most vulnerable and important area compared to the rest of the globe. Once these areas have been identified, the next concern is how to address the conservation resource distribution issue among regions of similar importance

(Wilson et al. [2006]). One way to approach this is by applying a simulated annealing algorithm to the select area (planning unit) that represents the greatest number of required conservation targets (i.e., species distribution, forest cover, critical area, etc) at the least cost, through a QGis plugin called Marxan (Loos [2001], Game and Grantham [2008], Ball et al. [2009], Watts et al. [2009]).

The Biodiversity - Species richness and endemism in an island

The intricate dance of coevolution between organisms and their island habitats results in a heightened dependence on a diverse species assemblage. As such, species richness becomes not only a measure of ecological health but also a crucial factor determining the ability of ecosystems, especially islands, to withstand the impacts of climate change and maintain their ecological integrity. In the context of Sulawesi's unique biodiversity, the idea of species richness is a poetic turn. It was here, on this island, that Wallace, independently from his contemporary Charles Darwin England, first attempted to quantify and compare the diversity of species. However, it wasn't until the mid-20^{th} century that ecologists began developing more systematic and quantitative approaches. One of the pioneering indices is the Margalef index, proposed by Spanish ecologist Ramon Margalef (Margalef [1958]), which accounts for both the total number of species and the total number of individuals in a community. The Shannon-Wiener Diversity Index, developed by Claude Shannon in information theory in 1949 (Shannon and Weaver [1949], Spellerberg and Fedor [2003]), was later adapted for ecological purposes by Robert H. MacArthur and Edward O. Wilson (MacArthur and Wilson [1967]). This index considers both the number of species and their evenness in a community, providing a more comprehensive measure of diversity. Over the years, other indices like the Simpson index and the Fisher alpha index have been introduced (Beck and Schwanghart [2010]), each offering a unique perspective on species richness and diversity. Modern advancements in computing and statistical methods have further refined the measurement of species richness, with the development of rarefaction curves, non-parametric estimators like Chao's estimator (Chao [1984]), Jackknife, or Bootstrap, and the latest one is the use of occupancy models such as the one used in this study (Kery [2008], Kéry and Royle [2016]).

2.2.2 The Cultural and Political Identity of the Minahasan, and Notes on Other Northern Sulawesi Ethnic Groups

North Sulawesi administrative area

North Sulawesi is a province of Indonesia located on the island of Sulawesi with a population of 2.575.933 people and a size of 15069,00 km^2 (BPK RI [a]). It is now divided administratively into eleven Regencies and four Municipalities. The administrative division stems mostly from the expansion of three ethnically diverse regions: Minahasa Raya, Bolaang Mongondow Raya, and Nusa Utara. The Minahasa Raya region, located in the

eastern half of the North Sulawesi peninsula, includes the cities of Manado, Tomohon, Bitung, Minahasa Regency, Minahasa Utara Regency, Minahasa Tenggara Regency, and Minahasa Selatan Regency. The Bolaang Mongondow Raya is located in the western portion of the North Sulawesi peninsula and shares a border with Gorontalo. It includes the city of Kotamobagu, Bolaang Mongondow Regency, Bolaang Mongondow Utara Regency, Bolaang Mongondow Selatan Regency, and Bolaang Mongondow Timur Regency. The Nusa Utara region includes the Kepulauan Sangihe Regency, Kepulauan Siau Tagulandang Biaro Regency, and Kepulauan Talaud Regency, which are islands in the north of the mainland of Sulawesi Utara (information from here).

North Sulawesi ethnics and languages

The three regions, Minahasa Raya, Bolaang Mongondow Raya, and Nusa Utara, are home to twelve (or more) ethnic and sub-ethnic groups, each with their own language or dialect, culture, and religion (Melalatoa [1995], Munkar Sejarah dan Budaya). Here they differentiate themselves based on the similarity of dialects used, however, I agree with Hitchcock and King in Jacobsen [2002] that "*ethnicity is a highly relative and contingent concept and that people are primarily interested in defining themselves in relation to others whom they perceive as different*". We will see more of this in the discussion of what makes someone a 'Minahasan' concerning eating a wild animal in Chapter 7.

According to BPK RI [b], the Protestant Minahasan make up around 30% of the total population. Aside from the big group of Minahasan ethnicity, also known as the Manado or Kawanua people, the sub-ethnic groups are distinguished by the language dialects they speak: Bantik, Ponosokan, Ratahan (Toulumalak), Tonsawang, Tontemboan, Tombulu, Toulour (Tondano), and Tonsea. The last three dialects share lexical similarities up to 90%. The Ponosokan are the only Minahasan sub-ethnics who are predominantly Muslim, and they speak Ponosokan, which is more similar to the Mongondow-Gorontalo dialect. Another sub-ethnic group is the Borgo, who are descendants of Minahasan sub-ethnics (Tombulu) who mixed with European colonials from Spain, Portugal, and the Netherlands.

Sangir (Sangihe) is the province's second-largest ethnicity, making up 19.8% of the total population. They are part of the Nusa Utara region, which also contains the Talaud ethnic groups. The Sangir have their dialect, while the Talaud have six distinct dialects that are not shared with the Sangir or other regions.

The Bolaang Mongondow Raya region is home to the 11.3% mostly Muslim Mongondow people who speak Mongondow and Melayu-Manado. Other sub-ethnic groups in this area include the Bintauna, Bolaang Itang, Kaidipang, and Bolaang Uki. Other ethnicities include the Muslim Gorontalo (7.4%), who were once part of North Sulawesi in the west but now have become a separate province. This separation has a consequence on the social and political makeup of contemporary Minahasan and North Sulawesi province. As

explained by Verdery 1994 and Barth 1994 in Jacobsen [2002], "*The point of departure for analyzing ethnicity, according to Verdery and others, is thus not culture per se, but rather the potential social or political manipulation of such constructed identities, thereby underscoring their situational character*".

North Sulawesi economy and politics

Before delving into Minahasan, which is of particular relevance in terms of wild meat consumption, we must first grasp the province's economic and political situation. The North Sulawesi province is the most economically advanced and prosperous of the Sulawesi islands, with the lowest proportion of its population living in poverty. In comparison to the national average, their human development index is slightly higher (BPS - Statistics of Sulawesi Utara Province [2024]). The province's main sources of income are divided into three categories: 1) Agriculture, forestry, and fishing; 2) Mining and smelting, construction, procurement of energy, fuel, water, and waste management; and 3) commerce and services (food and beverage, education, health, etc.). The third category dominates Nusa Utara and Minahasa Raya, while the first category dominates Bolaang Mongondow Raya (BPS - Statistics of Sulawesi Utara Province [2024]). Compared to Bolaang Mongondow Raya, the Minahasa Raya region has a higher average net wage/salary per month for both formal and informal workers, as well as a far greater percentage of power consumers.
When Gorontalo separated in early 2001, Christian Minahasan dominated the North Sulawesi province in terms of population and politics, with Minahasans serving as governor, vice governor, and representatives. The establishment of Minahasa as a political community aims to "Minahasanize" political authority in North Sulawesi Province, giving them control over economic assets (Jacobsen 2002).

The elusive Minahasan contemporary social identity

Minahasan's identity is a complex topic. Their identity is elusive since the relationship to pre-colonial identity is obscure. The word Minahasa means 'unified' and refers to the eight or more sub-ethnic groups of the Minahasa described in the previous section. Minahasa was 'formed' in the nineteenth century under heightened Dutch colonial control, forced coffee plantations, Christian missionary activities, and Western education (Henley [1996]). The *unity* of the Minahasan sub-ethnics is implied in their common experience with Dutch colonial experience when Christian missionaries preached unity as an explicit social ideal related to both Christian brotherhood and the idealisation of Minahasan pre-colonial history. Cultural westernisation and intermarriage with Europeans have also resulted in a society that is more akin to the Philippines than to the rest of Indonesia. Minahasan's relationship with the Dutch colonial was characterised by negotiation rather than confrontation. The Minahasaraad, a democratic council established in 1919, demonstrated that gradual emancipation under Dutch authority was feasible. Minahasans, who worked as office workers and soldiers, had a stake in the colonial system, but they did

not believe colonial control was permanent. By 1942, most educated Minahasans identified as Indonesians but maintained strong Minahasan nationalism. They envisioned an independent Indonesia where each ethnic group, including Bangsa Minahasa, would have political autonomy in a federal structure (Henley [1996]).

The post-colonial period of Soeharto's New Order rendered the concept of 'true' Minahasan ethnicity even more obscure, where the teaching of pre-colonial cultures and local languages has not been included in the school curriculum. Jacobsen [2002] referred to this as the two blindfolds: Christianity and the New Order. To exemplify this, Jacobsen [2002] questions the Minahasan about identity markers and what it means to be Minahasan. The answer is a set of general features that include distinctive traits: land, genealogy, Christianity, education, Westernisation, food, (local) languages, and cultural history. It was noticed that language and cultural history, two factors that typically influenced the classification of people into one ethnicity, were less important for the adult generation in early 2000, just after General Soeharto's 30+ year reign ended. The linkage between land ownership, kinship bonds, and Christian practice has a greater impact on how individuals view themselves as Minahasans. This insight from 20 years ago contrasts with what I discovered in my fieldwork in 2022. Finding the 'true' meaning of who Minahasan was before colonisation is critical for today's youth. The resurrection of the ethnic signifier is evident in the local government's and community's efforts to establish culturally associated tourism, the most visible example being gastronomy. Minahasan cuisine or food is one of the traits that people typically use to define a Minahasan, as it involves the intake of spicy foods and 'extreme' meat. Even 20 years ago, Jacobsen [2002] found indications that the then younger generations are increasingly interested in pre-colonial cultures while discussing identity, whereas those over 40 hold the *contemporary elusive Minahasa identity*.

2.2.3 Wild Meat Role as Food, Delicacy, and Biodiversity Conservation

Meat eating as our evolutionary heritage rose much earlier, about 1.5 million years ago (Smil [2002]) than the time when the first 'behavioural modernity' human started evolving around 50,000-65,000 years ago (Schlebusch et al. [2017]). The desire to eat flesh predates the invention of tools, artefacts, cave art, and even our capacity to hunt, as we were primarily scavenged from much larger predators at the time (Larsen [2003]). The shift from hunting and gathering to domesticated, both plant and animal, happened much later around 10,000 years ago (Larsen [2003]) where most humanity are not so dependent on wild animals anymore. The practice of eating wild meat, however, stays. Not only for the dependence on it as the main source of protein such as communities in Africa, South America, or Asia (Kaswamila et al. [2007], Pattiselanno and Lubis [2014], Pattiselanno and Nasi [2015], Cawthorn and Hoffman [2015], Chausson et al. [2019], Ingram [2020]), as

a luxurious delicacy (Drury [2011], Sandalj et al. [2016], Shairp et al. [2016], McNamara et al. [2019]), but also serve as recreational and cultural reason (Payne et al. [1987], Supit et al. [2021], Arobaya et al. [2022], Hendra et al. [2023]). The practice can be both sustainable and good for the environment if the animal has a high growth rate and/or the hunting rate is lower (Alvard [2000], Goguen and Riley [2020]), or in most scenarios, lead to over-exploitation and biodiversity loss (Tollefson [2019], Rija et al. [2020]).
Our focus is North Sulawesi, where in the early 2000s the wild animals for sale in North Sulawesi markets were mainly rats, fruit bats, and wild pigs (Clayton et al. [2000], Lee et al. [2005], Milner-Gulland and Clayton [2002]), together with legally protected species such as macaques, babirusas, anoas, deer, cuscuses, and tarsiers which were also sold in smaller numbers (Clayton et al. [2000], Lee [2000], Milner-Gulland and Clayton [2002]).

Human Influence - A risk of over-exploitation of wild meat

In conservation practice, overuse of natural resources is typically the only relationship between humans and biodiversity that is thoroughly investigated. The topic I investigated for my thesis was the overuse of non-domesticated, primarily wild, animals for food. Sulawesi's situation is revealed to be less problematic than that of at least some regions like tropical Africa, where most studies on wild meat, or bushmeat, are undertaken because there is no reliance on meat as the primary source of protein. As I shall demonstrate, the primary driving forces behind eating it in Sulawesi are habit, tradition, and flavour. A detailed investigation into every aspect of each agency is required to comprehend the complex relationships between them in the supply chain. For this thesis, I examined the entire supply chain, including interviews with hunters, surveys of rural and urban households' consumption, interviews with restaurateurs, vendors, and middlemen, and meticulous year-long market observation. I provide a thorough introduction to the relevant background in each data Chapter. The issue of wild meat consumption across Indonesia is summarized in Chapter 3, vendors and market trends are covered in Chapter 6, and consumption patterns in urban and rural areas are covered in Chapter 7.

Part II

Data Chapters

3

Increasing Visibility of The Wild Meat Issue In Indonesia Through An Inclusive Scientific Publication

3.1 Abstract

The consumption of wild meat is under-studied in Tropical Asia. In this review, we explore the extent and drivers of wild meat use in Indonesia, referring to both peer-reviewed articles and grey literature. We used the PRISMA guidelines for a systematic review to identify and screen 334 articles, finally including 184 of them in our mapping and analysis. We found that most of the literature on wild meat in Indonesia considers the hunting or harvesting of wild animals, while information on the role of wild meat for consumption and food security is generally understudied. Outside Sulawesi Island, which has been the region of Indonesia where wild meat consumption has been most thoroughly studied, we found evidence of widespread use across Indonesia, with high levels of use in Kalimantan. The range of wild animals eaten is wide, from threatened babirusa (*Babyrousa celebensis*) and orangutan (*Pongo pygmaeus*) to dusky pademelons (*Thylogale brunii*). We also found that one-third of journals or studies identified in this review were conducted by national scientists whose findings were rarely cited by international researchers, likely because they had been published as grey literature or in national rather than international journals or did not publish with a primary focus on biodiversity conservation. By showing how the drivers and uses of wild meat in Indonesia differ from those revealed in more commonly studied regions such as Tropical Africa, this study provides a novel perspective on wild meat issues in Indonesia with wider implications for the study of these issues across Tropical Asia. A nuanced regional

understanding is critical for guiding interventions and conservation strategies associated with wild meat in Tropical Asia.

3.2 Introduction

Before the advent of agriculture, humans fulfilled most of their needs for dietary protein by hunting. All animal protein was wild meat before the domestication of livestock. Of the world's estimated two million animal species, only 14 have been domesticated (Diamond [2005]), of which the 'big four' are the most valuable: goats, sheep, cows, and pigs (Teletchea [2019]). Even now, not all people depend on domesticated livestock. Many communities in Africa, South America, and Asia still depend on wild meat as their main source of protein. This is because either they live a traditional lifestyle, live in remote places away from livestock distribution lines, or simply prefer wild meat over farmed meat because of the taste, perceived health benefit, ease of access or tradition (Chausson et al. [2019], Brittain et al. [2022]).

There are broadly two types of consumers engaged in wild meat consumption, those in local rural communities and urbanites who are at the end of supply chains (Milner-Gulland et al. [2003]). When the communities that live around wildlife are low in numbers and hunt for subsistence, the impact of the consumption on wildlife populations can be negligible (Alvard [2000]). However, in an urban setting, where consumers still eat wild meat due to cultural ties/upbringing and will pay a premium for it, consumption of wild meat generally becomes unsustainable (Drury [2011], Coad et al. [2019a]). The high aggregate demand from increasingly populous urban communities drives the hunting of wild meat in rural areas, even when per capita consumption in urban areas is low. Most wild meat comes from species that largely cannot be easily domesticated or farmed (Drury [2009a]), and they and their ecosystems will be severely impacted if they are harvested beyond their carrying capacity (Brashares et al. [2004]). Despite numerous studies on the use of wild meat, an assessment of at least two decades of progress revealed that this information has seldom been turned into action, partly due to a lack of proper monitoring and evaluation (Ingram et al. [2021]).

Increasing human populations, rural-urban migration, and the rise of the middle class in the Global South make the sustainability of wild meat consumption an ever-more pressing topic (Ingram [2020]). In this context, characterising Indonesia as a member of the 'global south', a term that is not broadly embraced, is problematic. In comparison to its Southeast Asian neighbours, or even in contrast to the more distant but much more studied bushmeat consumption and trade in African and South American countries, this archipelago country has received minimal attention and study on wild meat consumption. Within Southeast Asia, the focus has been primarily on Cambodia (Coad et al. [2019b]); Vietnam (Drury [2009a,b, 2011], Sandalj et al. [2016], Shairp et al. [2016]) and Laos (Pruvot et al. [2019]). Those articles in peer-reviewed journals that focus on Indonesia tend to

report on hunting and trade Milner-Gulland and Clayton [2002], Sheherazade and Tsang [2015], Rejeki [2018], Latinne et al. [2020]).

Indonesia is the largest country in Southeast Asia, and rich in biodiversity; hence this gap in knowledge on wild meat is problematic, making it harder for Indonesia to protect its wildlife from over-exploitation. With the devastating, but foreseeable (Macdonald and Laurenson [2006]), emergence of zoonotic viral disease in Southeast Asia (e.g. the COVID-19 pandemic, following SARS-CoV-2, arbovirus, H5N1, SARS-CoV, MERS-CoV (Saba Villarroel et al. [2023]), the inclusion of Indonesia on the map of wild meat research is important not only for biodiversity conservation but also for wider issues of geopolitical stability (Montgomery and Macdonald [2020]). A recent systematic literature study showed that emerging zoonotic disease is prevalent in the region, and judges Cambodia and Vietnam as high priority (Nguyen et al. [2024]); these are the two countries that received the most attention from research on wild meat in Southeast Asia. While correlation is not causation, it is surely noteworthy that more study of wild meat is associated with more evidence of emerging zoonotic disease. Regarding food sustainability, there has been no assessment of the reliance on wild meat as a protein source in Indonesia, the fourth most populous country in the world, therefore there is no evidence of the consequences for food security of a hypothetical (but not implausible) future restriction on wild meat consumption.

As a step toward addressing this knowledge gap in Indonesia, we conducted a comprehensive mapping of publications concerning the wild meat issue in the region. We were mindful that published records did not necessarily reflect the size or nature of the problem in that place, but rather an observer bias stemming from the attention focused there. We selected systematic mapping because, unlike a systematic review, it does not seek to answer a specific question but rather gathers, synthesizes, and explains all that can be learnt from current data on wild meat concerns in Indonesia (Grant and Booth [2009], James et al. [2016]). After carrying on the mapping, the resulting information allows us to explain four topics: i) The number of published records over the years and the themes that are most frequently researched; ii) the type of animals recorded as being consumed in different regions; iii); the nature of the information gap on the wild meat supply chain in the published records, and iv) who is writing about the issue, and the relevance of their background in terms of inclusivity.

3.3 Methods

3.3.1 Protocol

A systematic mapping of the wild meat issue in Indonesia was carried out following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (Moher et al. [2009], O'Dea et al. [2021]). For this analysis, I adopted a broader

category of wild meat than what has been specified by the IUCN General Assembly Resolution 2.64 (Coad et al. [2019b], Nasi et al. [2021b]) as "terrestrial animal wildlife used for food in any part of the world". I considered all non-domesticated animals, such as birds and fish. To maximise the search, we triangulate the method of finding literature by incorporating: 1) The traditional database, grey literature and library catalogue, 2) Google web search, which includes Google Scholar and domain searching in Google, and 3) AI-based applications using the Research Rabbit App (https://www.researchrabbit.ai/). The first approach yielded most of the records collected in this study and was undertaken by exhaustively searching within the list in Table S1 using the search phrases described in the following section, except for the CIFOR (Centre for International Forestry Research) Indonesia library. The latter is in the form of an Excel worksheet, so the search was done manually. The second method was designed explicitly to search for grey literature from Indonesia by entering '*site:.id*' before the search phrases in Google.

The third approach uses Research Rabbits, an AI-based app to search related papers and/or authors. The app has the property of building a network between the papers/records (the vertices) connected by lines (the edges). All of this is accomplished by analysing how those publications cited one another, with green vertices (circles) representing papers that are already in our database and blue vertices representing those that are not. The papers inputted are those identified and selected from the first two stages of triangulation: the traditional path and a Google-based search (green vertices/circles). The width of the vertices represents how frequently the papers are cited. This is the simplest network in graph theory, with symmetric edges that are undirected, which means they have no stated orientation, and it is widely used in ecology in Social Network Analysis (SNA) (Dale [2017]). The graphs are from the 'Explore articles' section, which displayed other articles not on our input list based on similarities, earlier and later works by those authors by displaying similar, earlier, and later works (from the date the submitted paper was input) outside of the list of papers we entered into the app. We then filtered the entries in blue vertices, which were not previously in our records, using the inclusion/exclusion criteria described in the next section.

Search strategies

The searches were conducted in both Indonesian and English. We evaluated four search phrases, but in the end kept the results from only the second and fourth search phrases, because the first and third were encompassed within the results from the second search phrase.

1. (bushmeat* OR "bush meat*" OR wildmeat* OR "wild meat*" OR wildgame OR "Wild game") AND (indonesia* OR sumatra OR sumatera OR java OR jawa OR sulawesi OR celebes OR borneo OR kalimantan OR papua OR "west papua" OR "irian jaya" OR "Sunda Islands" OR bali OR lombok OR flores OR sumba OR

"Maluku Islands") NOT (Africa OR America OR Australia OR China)

2. (bushmeat* OR "bush meat*" OR wildmeat* OR "wild meat*" OR wildgame OR "Wild game") AND (indonesia* OR sumatra OR sumatera OR java OR jawa OR sulawesi OR celebes OR borneo OR kalimantan OR papua OR "west papua" OR "irian jaya" OR "Sunda Islands" OR bali OR lombok OR flores OR sumba OR "Maluku Islands")

3. (bushmeat* OR "bush meat*" OR wildmeat* OR "wild meat*" OR wildgame OR "Wild game" OR "daging satwa liar*" OR "daging satwaliar*" OR "daging hutan*" OR "daging utan*") AND (indonesia* OR sumatra OR sumatera OR java OR jawa OR sulawesi OR celebes OR borneo OR kalimantan OR papua OR "west papua" OR "irian jaya" OR "Sunda Islands" OR bali OR lombok OR flores OR sumba OR "Maluku Islands") NOT (Africa OR America OR Australia OR China)

4. ("daging satwa liar*" OR "daging satwaliar*" OR "daging hutan*" OR "daging utan*")

Inclusion and exclusion criteria

The mapping protocol is conducted at three levels: 1) screening the title and abstract, 2) screening the full content, and 3) extracting the data from the records. We included any records that documented, addressed or mentioned wild meat use in Indonesia (including areas that are now part of Indonesia but were not before its independence in 1945, such as West Papua). We exclude records that do not meet our inclusion criteria or for which we are unable to access the complete content. We cover all digitally available sources, including peer-reviewed and non-peer-reviewed literature, thesis, dissertation, report, video, photos, and book chapters. We considered both review papers and those that presented primary data. We did not limit the year in which the record was published, the discipline/major field of the records, or the language of publication. Except for insects and freshwater fish, interest in wild meat is limited to terrestrial wild or non-domesticated animals. We also include domestic cats and dogs in our research because they are consumed and traded locally.

Synthesis of extracted data

We considered peer-reviewed journal articles, books, book chapters, bulletins, magazines, and grey literature, such as doctorate and master's theses, class projects, reports, and conference proceedings, in any language and from any year. The first synthesis was done by classifying the selected records based on the theme of the contents, regions in Indonesia mentioned within the record, and the discipline where the records were published. The themes were coded following deductive reasoning from hypotheses derived from prior

studies (Staal et al. [1996], Van Vliet et al. [2019], Pattiselanno et al. [2020]) and inductive reasoning to incorporate categories not previously identified (Patton [2015]), which gave us six themes: hunting, consumption, trade, sustainability (in term of biodiversity), one health (for those publications on zoonosis with or without direct effect to human), and food security. For region specification, those records that do not specify a specific site are referred to as Indonesia as a whole, and the rest are classified as the main island or collection of smaller islands: Sumatra, Java, Kalimantan, Sulawesi, the Maluku islands, which include all islands from North Maluku in the north to Banda Neira in the south, the Lesser Sunda Islands, which include Lombok in the west and Timor in the east, and West Papua (Figure 3.1). Every record can, and usually does, have more than one theme and/or region. This synthesis allows us to understand the trend in published records on the theme per year, the general trend on the theme, and which regions recorded the most. The second synthesis used a Sankey diagram to show the relationship between the animals and where they are reported to be used, with the regions and animals as nodes and the frequency of reports as links/connections. Animals are recorded by species name, vernacular name, group (e.g., fish, monkey), or even class (e.g., mammals). We grouped them into the closest category, only graphed the ones mentioned more than three times and removed 'wild animals' from the graph to make it clearer (Table A.2). The third synthesis is intended to summarize the information from the records we selected. We conducted content analysis and 'coded' the result as the type of topic discussed (Table A.1).

The fourth and last synthesis examines our hypotheses on why wild meat, as a conservation concern, does not receive adequate attention in Indonesia; we look at how inclusive and, ultimately, how widespread the exposure of this issue is among Indonesian conservation scientists and practitioners. As a visual assessment, we used the network graphs of who-cited-who, and we assessed them concerning whether the first author and affiliation are international or national, their rank of publication based on SCImago (Butler [2008]) and their discipline. The network graph is generated using the Research Rabbits as a quick and effective way to visually examine this by showing the graph of who-cited-who among our identified records, and a second network graph shows the relationships between the first authors in our database. This last graph has all the vertices are green, with the widths proportional to the most cited among those inputted articles. In our effort to understand why some articles are cited more than others, we also used the Journal Rank, here we used SCImago which ranks journals using the Hirsch Index (Butler [2008]), and includes a new metric the SCImago Journal Rank (SJR) – (https://www.scimagojr.com/journalrank.php). SCImago Journal Rank factors in the subject field, quality, and reputation of a journal on citations by assessing the average number (frequency) with which content published in a journal was referenced in other

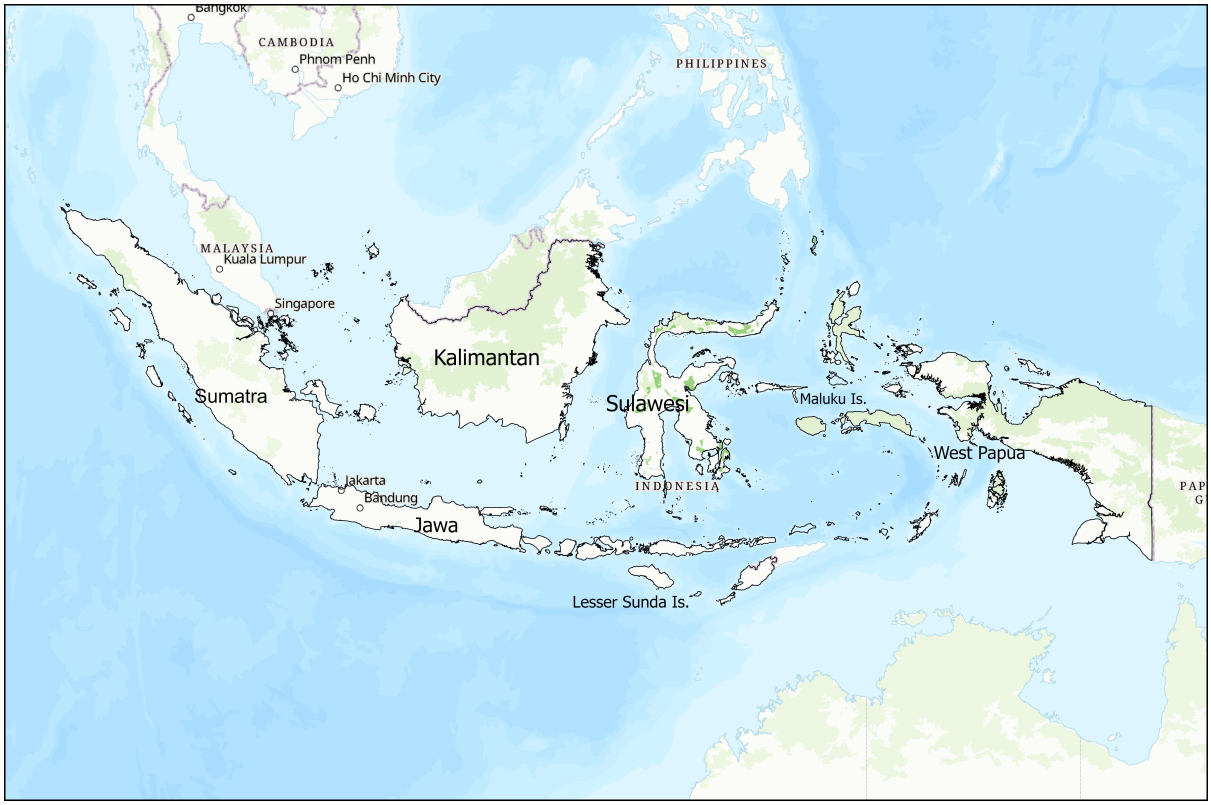


Figure 3.1: Indonesia and its main islands

journals during the preceding three years (Daemen Library [2023], University of South Florida Libraries [2024]). And because the records originated from diverse disciplines, we classified them according to the scientific journals in which they were published. For grey literature, we categorised them into disciplines based on the type of organisation from which the author(s) emerged. For example, if the record is a thesis, we choose based on the subject or department it graduated from.

All the graphs in this chapter, except for Figure 3.6, were created using the Tidyverse package in R Software (R Core Team [2023]. Figure 3.6 was created using the built-in tools in ResearchRabbit, and the map was created using ArcGIS Pro licensed to the Department of Biology - University of Oxford.

3.4 Results

We identified 184 records that had been published between 1996 and 2023 (Figure 3.2). The majority of the records belong to the biodiversity conservation discipline (n=123), and the rest are distributed between disciplines such as anthropology (n=13), food and health (n=8), animal health (n=6), ethnobiology (n=6), theology (n=4), ethnozoology (n=3), veterinary science (n=3), food science (n=3), human ecology (n=3), environmental and resource economics (n=2), forestry (n=2), law (n=2), and one of each from animal production, animal science, meat science, microbiology, nutrition, and public health. Of

the sources, only 133 are journal articles, 15 are books and book chapters, and the rest are grey literature: reports (n-14), theses (n=9), conference papers (n=10), bulletins (n=2), and a class project. Among those 184 records, 90 are written (first-authored) by international authors and affiliations, 75 are from national authors and affiliations, 15 are from national authors but international affiliations, and four by international authors but local affiliations.

3.4.1 The trend of themes and regions in published records over years

We demonstrated growth in the number of publications on the themes of hunting, consumption, and trade, and a peak of interest, especially during and after COVID-19 in 'One Health' in 2020-2021; literature on both food sustainability and sustainability was sparse (Figure 3.3a). Geographically, most of the research had been conducted in Sulawesi (Figure 3.3b), but at least some had been undertaken on all of Indonesia's major islands, the minor Sunda islands, and the Maluku islands, apart from Bali (Figure 3.3b, d, and e). Our inclusion/exclusion criteria included research in which wild meat was mentioned but was not the primary focus: of the 184 records only 26% (48 publications) focused primarily on the topic of wild meat.

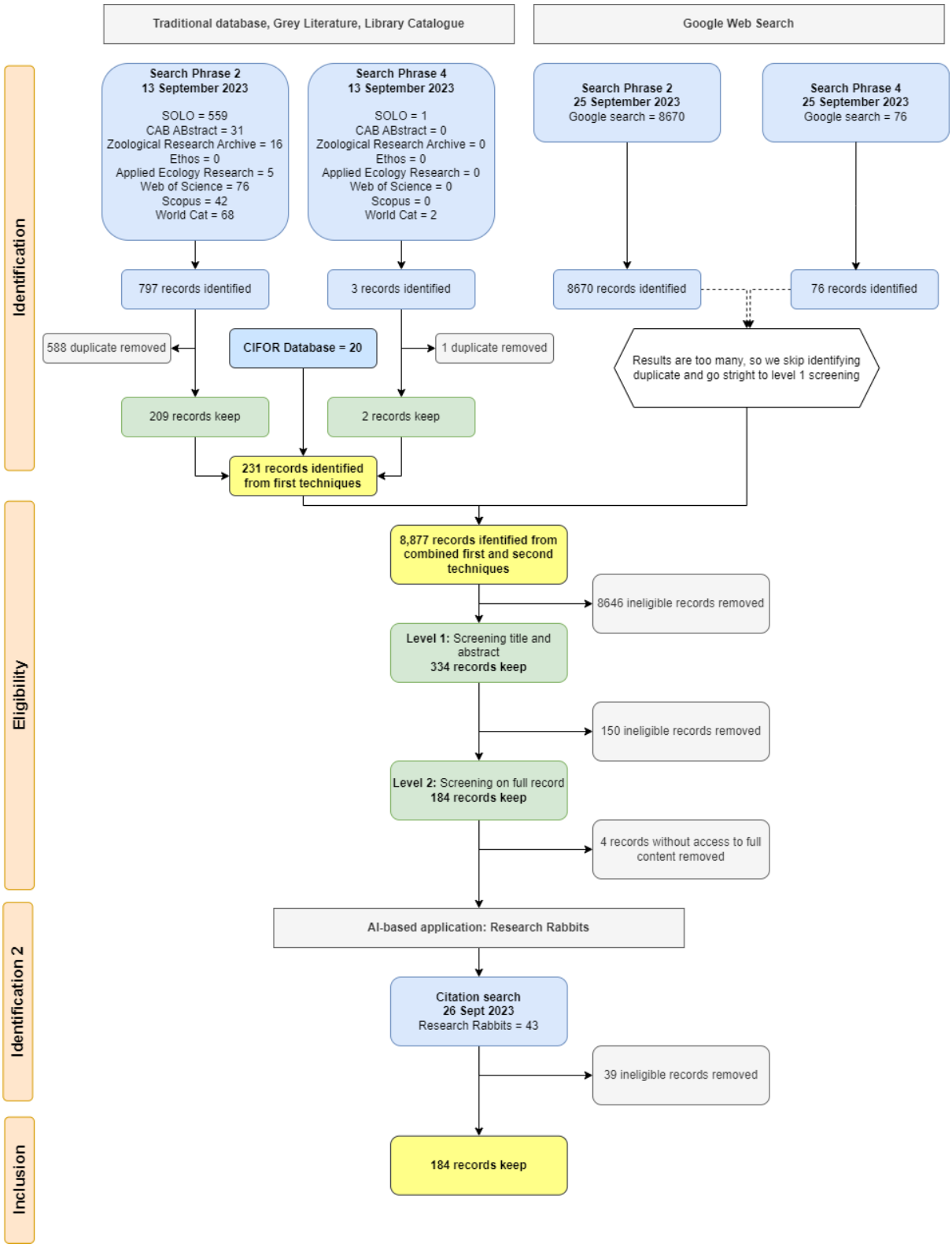


Figure 3.2: Flow diagram of records through the levels of identification, eligibility, and inclusion criteria of 184 records (1996-2023) which associated with wild animals or meat with any mention of consumption.

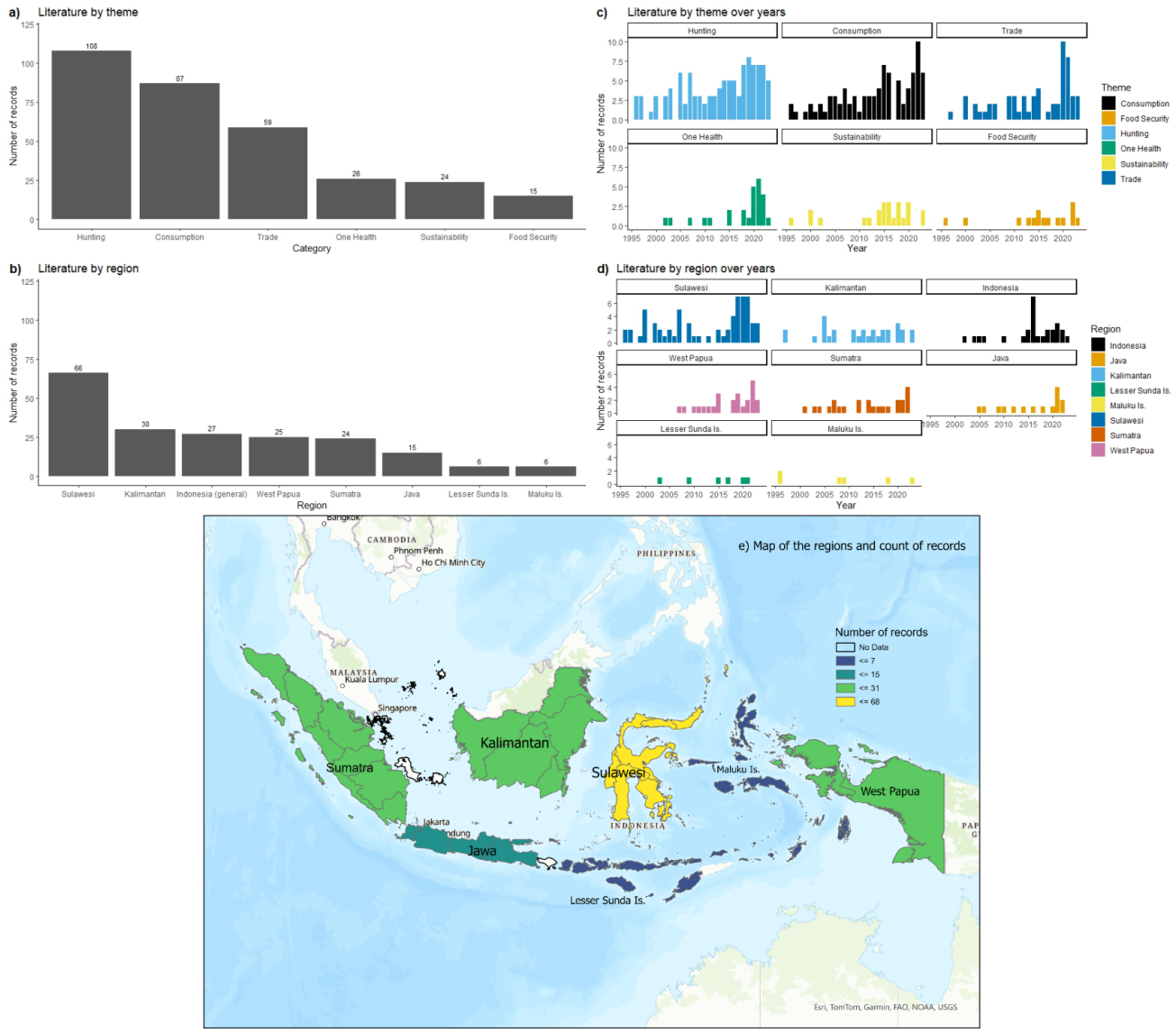


Figure 3.3: The records grouped by theme (a), region (b), the temporal frequency of the papers published (c-d), and the map of Indonesia's regions in this study (e). Plot (c) shows how people's focus has changed over time, especially regarding one health and sustainability.

3.4.2 Animals reported being consumed throughout the archipelago.

Figure 3.4 depicts all animals reported to have been used in the wild meat supply chain more than three times, either in one or more records (this filter is necessary to make the graph interpretable; full details are in Table A.2. Bat is the only category mentioned sufficiently frequently to be included in the plot of national publications. Regionally, bats, wild pigs, deer, monkeys, and unexpectedly, cuscus, are the most reported. Wild pigs were the most frequently reported, being utilized on all four major islands (Sulawesi, Kalimantan, Sumatra, and West Papua), deer predominated in records from Kalimantan-Sumatra-West Papua, and cuscus was reported throughout its geographic range in eastern Indonesia. Reports of other species being used as wild meat also reflected their biogeography, with the consequences that anoa *Bubalus depressicornis* (EN) and babirusa *Babyrousa* sp. (four species, all VU) were reported only in Sulawesi, and bandicoot *Peroryctes raffrayana* (LC), dusky pademelons *Thylogale brunii* (VU), and tree kangaroo *Dendrolagus* sp. (six species, VU, EN, and CR) only in West Papua. These species reported regionally, are all endemic, and the anoa is endangered (anoa) and the Wondiwoi tree kangaroo *Dendrolagus mayri* is critically endangered according to the IUCN Red List.

3.4.3 The identified information gap in the study of the wild meat supply chain in Indonesia

Table A.1 summarises knowledge from our records database. Hunting is the most prevalent subject in published records, with a focus on unsustainable hunting and law enforcement. However, there are several records of Indigenous People and Local Community (IPLC) hunting operations, including the type of animal hunted and the hunting technique. One record discusses hunting in an urban context as a leisure activity, but another aspect that is critical for assessing the sustainability of hunting, namely the quantification of how many animals are hunted, is only covered by two records. There are also records on animals used to hunt widely for meat decades ago, but not so much now, for example, the great apes. The second most recorded issue is consumption. The consuming theme's most discussed issue is wild meat eating in traditional society, as well as the types of animals consumed. Aside from consumption as food, additional reasons for consumption on record include cultural motivation, luxury, medicine, recreation, and pest control (conflict animals). Two topics that have received less attention but are critical for assessing sustainability are the quantification of the amount of wild meat consumed and the signals of changing diets among IPLC as animal populations diminish. We found little evidence of records concerning the perspectives and features of wild meat consumers. The trading of wild meat, as the third most discussed topic, is primarily concerned with the quantity and trends of animals sold in the market, the monetary profit generated, and the identification of the animals sold. Some records focus primarily on illicit trade, re-

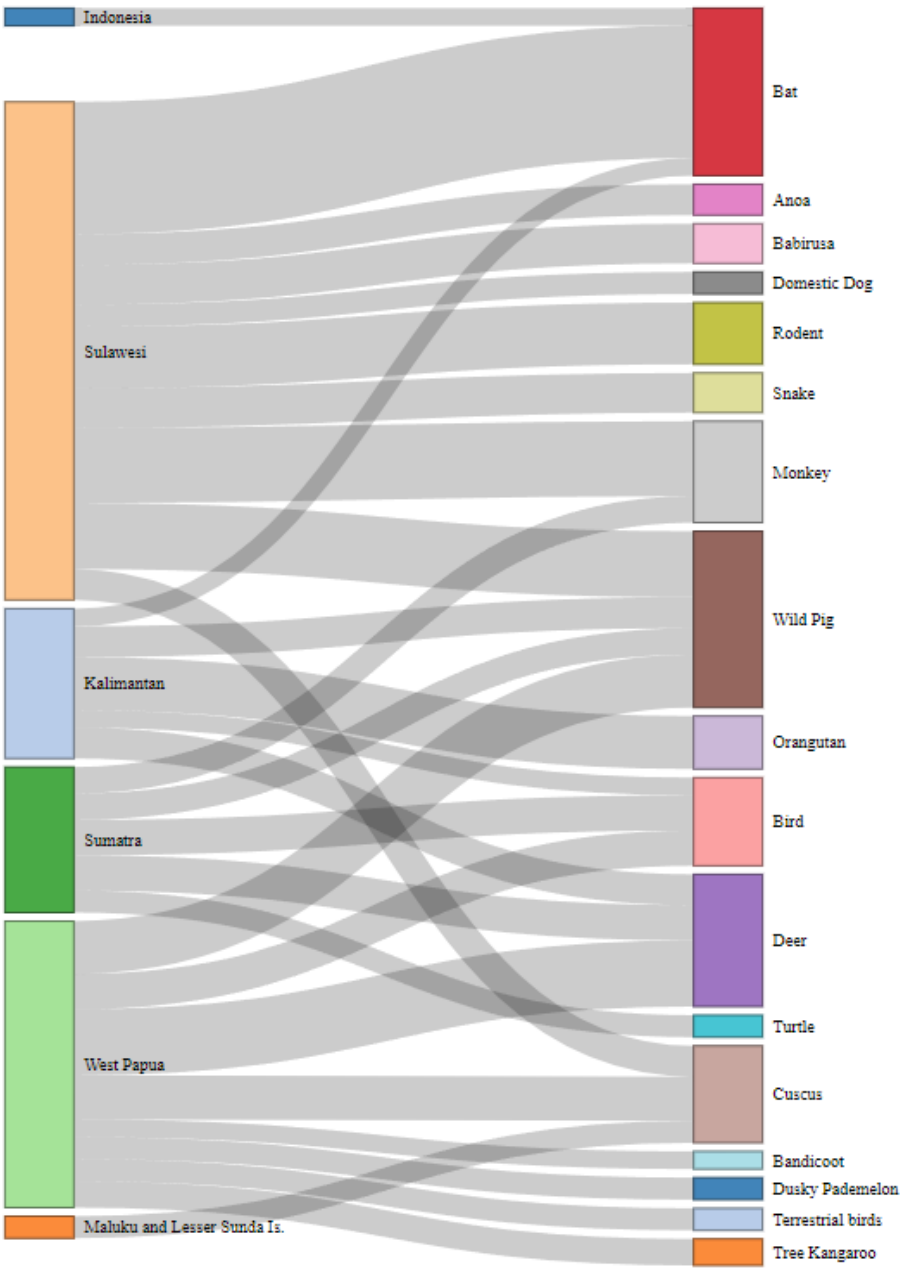


Figure 3.4: Various wild species reported more than three times to be consumed/used. The animals (right) and region (left) are depicted as nodes, connected by lines whose width is proportional to the frequency of records. Because Maluku Is. and Lesser Sunda Is. have only a few records each, we present them together, and Java is not depicted on the map because none of the species recorded as being used there for wild meat was recorded more than three times. For full details see Table S2.

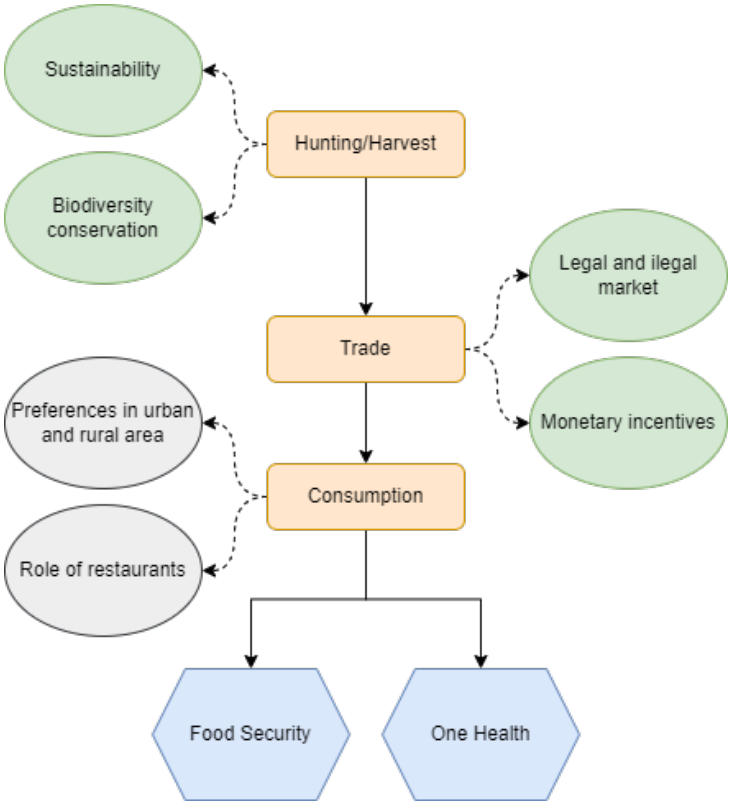


Figure 3.5: Conceptual flowchart of the wild meat commodity chain; orange rectangles represent the main commodity chain steps, green ellipses represent the issues surrounding these main supply chain steps, blue hexagons represent the benefits/drawbacks of eating wild meat, and grey ellipses represent issues not covered in this review.

gional commerce, Indonesia's position as a source for worldwide trade, the quantification of total animals traded, and the global north's bias towards the 'wet market' concerning the COVID-19 epidemic. The remaining three categories, one-health, sustainability, and food security are not extensively covered in our records.

Based on the content analysis, above, we schematized each step of the wild meat supply chain in Indonesia (Figure 3.5). This revealed that two themes frequently addressed in other countries about wild meat or bushmeat issues, but not in Indonesia, are consumer preferences and the distinction between urban and rural drivers of consumption. Another issue, conspicuous by its absence, is the role of wild meat restaurants. Most other issues generally associated with the wild meat trade are addressed in the Indonesian sample to at least some extent, although the rigour of methodologies may sometimes be questioned (e.g. for estimating the monetary profit circulating in the wild meat supply chain (hunting and trade)). Our schematic of the conceptualized supply chain is generalised across the regions of Indonesia; it is more completely represented in some regions (i.e., Sulawesi, and perhaps West Papua), and less so in others where the disproportionate focus has been on hunting (i.e., Maluku and Lesser Sunda Islands).

3.4.4 The authors and inclusivity

A visual examination of the network graph based on the papers in our database (Figure 3.5), revealed one big cluster of papers and authors, and smaller stand-alone papers/authors not connected to the main cluster. Only 87 records are cited at least once (46%) by the other records in the pool of 188, and the rest are not cited by any of the other records. Among those not cited (n=101, Table S5), 54 are from national first authors at national institutions, 39 are international authors and institutions, seven are national authors at international institutions, and one is from an international author at a local institution. Most (52%) of these (n=101) uncited records were published in SCImago-ranked journals (50 out of 96), revealing that the lower the rank of the journal the greater the percentage of uncited articles (Q1 to Q4 percentage from the total in the database: 24%, 63%, 67%, 100%). An even higher percentage of uncited records had been published in journals not ranked by SCImago (n=23/38, 61%). Similarly, citation was low for records sourced from the grey literature (n=21/38, 55%) and book/chapters (n=7/16, 4%).

As many as 40% of the uncited records from SCImago-ranked journals, and all of those from the non-SCImago journals, had been written by national first authors with local affiliations. Regarding the category of discipline, as many as 44% (56 out of 126) of records came under the heading of Biodiversity Conservation had been uncited, 60% (n=34) had been first authored by national authors and affiliations, 50-74% of the papers from anthropology, food science, ethnobiology, and ethnozoology, are uncited, and the remaining disciplines are 75-100% uncited in our database. Most of the highly cited records ($\geq$ 10 citations) had been published from 2020 onwards. Besides low-impact journals and grey literature, information on wild meat from other islands outside Sulawesi appears in writings that are not specifically focused on wild meat. Based on the Scimago Journal Rank, 11 of the 15 papers from Java are peer-reviewed but only three are from journals in the top quartile (Q1; which includes the most prestigious journals in a field; (SCImago) and all of these are primarily about animal hunting. This is also true for Sumatra and Papua, which have 15 and 19 peer-reviewed papers, respectively (six for Sumatra and four for Papua are Q1 SJR).

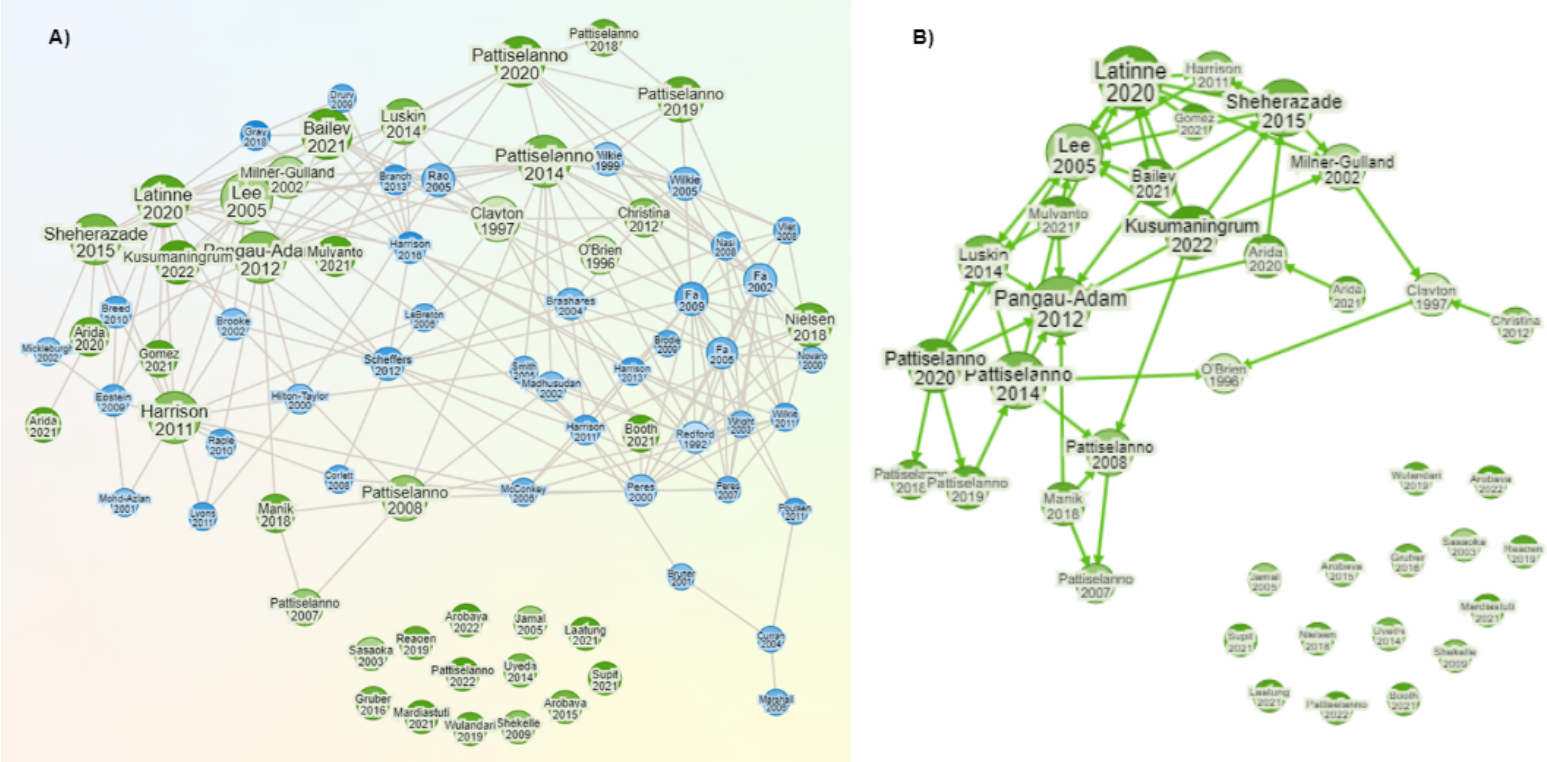


Figure 3.6: A) The records included in the study are represented by green circles, while similar work that excluded are the blue circles. B) Connections among papers in this study database. The size of the circle indicates how many linkages each paper has with other circles/papers, with each link representing one citation.

3.5 Discussion

This review highlighted the lack of international attention to the broad topic of wild meat consumption in Indonesia. The records we identified confirmed that throughout the entire Indonesian archipelago, people hunt, trade, or buy wild animals for food, and even though the records we found largely concern indigenous people and local communities (IPLC), other parts of society were also identified as consumers. According to records recruited to our database, Sulawesi remains the focus of the study of wild meat harvest and consumption in Indonesia, but we cannot be confident about how much this primacy is affected by reporting bias. Reporting bias, reflecting an understandable prioritisation, seems likely to explain the fact that 35% of the literature from Kalimantan concerns the killing of orangutans for consumption. An example of the patchy provenance of data is that most publications from West Papua emanate from the commendably productive team led by Dr Freddy Pattiselanno at Universitas Papua (https://www.researchgate.net/profile/Freddy-Pattiselanno-2). Not surprisingly, the professional discipline of biodiversity conservation dominates as the provenance of records on hunting and trade ($\geq$80%); 64% of records concerning consumption also came from sources focused on biodiversity conservation (64%) whereas 9% came from anthropology.

Most records in this systematic mapping focused on hunting wildlife, particularly on cases which are probably unsustainable. Unsustainable hunting, by definition, leads sooner or later to dwindling populations, cascading impacts, and ultimately extinction. Inevitably, these threats are more imminent for threatened species which, by the nature of their small populations are already closer to the brink, and the growing human populations, technological progress, and commercial wild meat trade can drive unsustainable harvest rates (Cawthorn and Hoffman [2015], Ingram [2020]). This applies particularly to two iconic species in Sulawesi — anoa and babirusa — and several more in Papua, notably the dusky pademelons and tree kangaroo. The reports in our database make it clear that hunters in North Sulawesi hunt anoa (10%), babirusa (5%), and, more recently, snakes (Latinne et al. [2020]). Various species of bat, particularly but not exclusively Megachiroptera, dominate wild meat markets in North Sulawesi, and their colonial roosting behaviour means they can be hunted in high volume even by single hunters (Summers et al. [2021]). The nocturnal nature, slow reproduction, and colonial behaviour of bats make them vulnerable to hunting pressure (Mildenstein et al. [2016]). In comparison, rodents have a high fecundity (Dwyer [1975]) and can therefore probably withstand higher harvest rates, facilitating more sustainable consumption (Cawthorn and Hoffman [2016], Gruber [2016]). Nonetheless, there is a limit to the sustainable harvest even of wild rodents, and the belief in Sulawesi that endemic forest rodents are "healthier" and "better tasting" than the much cheaper paddy field rodents (Latinne et al. [2020]), raises an alert

against complacency that even the harvest of these species is sustainable.

Wild meat significantly contributes to food security in Africa, Latin America, and Asia (Mambeya et al. [2018], Ingram et al. [2021], Fa et al. [2006]) and this also true for some parts of Indonesia. The dependency on protein from wild meat largely exists in regions where with majority of indigenous people and local communities reside, such as the West Papua where wild meat is far more popular than fish, farmed animals, and vegetables (Pattiselanno and Lubis [2014]) where they generally meet their protein requirements through subsistence hunting (Pattiselanno and Arobaya [2011]). The same cannot be said for communities in Sulawesi as they are not dependent on wild meat as a source of protein and alternatives are widely available (Lee et al. [2005], Rejeki [2018], Lee [2000]). In Sulawesi, the North Sulawesi province is home to the Minahasa and Sangir tribes, who have significant links to wild meat consumption (Sheherazade and Tsang [2015]). As stated before, our review is limited to records that have been published and might missed information on protein dependency in other areas of Indonesia such as Sumatra and Kalimantan. Therefore, it is helpful to loosely categorize species in the wild meat supply chain into those consumed widely, and those on the menu only locally. The latter may be of particular concern in terms of biodiversity conservation as they tend to be species with restricted distributions, often with the poorest data on population parameters, carrying capacity and offtake. Those categories of species consumed widely include wild pig, deer, bats, and cuscus, and may also include island endemics e.g. 'wild pigs' consumed in Sulawesi are endemics of conservation concern (babirusa and Sulawesi wild Pig) and that eaten on Java (Javan warty pig) is endangered (Linkie et al. [2016]); all facing the challenge from the global epidemic of African Swine Fever (de Rosary [2021a], Luskin et al. [2021], Sybille de La Hamaide [2023], Phoebe Weston [2024]). Regarding cuscus, Indonesia is home to four of the five genera worldwide. All of Indonesia's 18 cuscus species occur in the eastern part, and all are consumed. The genera Phalanger and Spilocusucs occur on the islands of West Papua and Maluku Is. while Strigocuscus and Ailurops are endemic to Sulawesi (Flannery and Schouten [1994]). All Indonesian species of cuscus are protected under the decree of the Indonesian Ministry of Environment and Forestry No. 5/1990 and PP. No. 7 of 1999 concerning Preservation of Plants and Animals. However, wild pigs and deer in West Papua are regarded as non-native species there, and thus not protected (Pangau-Adam et al. [2022], Pattiselanno et al. [2023]). Even a decade ago, data from certain locations, such as North Sulawesi in Indonesia, indicated that wild meat markets in the region were already dominated by small-bodied mammals, such as bats (47%) and rodents (44%) (Lee et al. [2014]), reflecting local declines of many larger-bodied species (Corlett [2007]).

This decline in the traded population has been detected since the early 2000s (Milner-Gulland and Clayton [2002]). The trade of non-protected wild mammals increased by 30% in 2001–2003 even though trade in some protected mammals declined significantly

in Sulawesi (Lee et al. [2005]) as the sales of endangered species, such as babirusa and wild pigs, are heavily influenced by law enforcement activities (Milner-Gulland and Clayton [2002]). Aside from local and regional consumption, Indonesia is also a supplier to international trade (Kusrini [2005], Kusrini and Alford [2006], Schoppe [2009], Nijman [2010], Chaber et al. [2021]) and a major centre for illegal wildlife trade (Shepherd [2008], Nekaris et al. [2010], Nijman et al. [2012], Indraswari et al. [2020]). The trade is commonly referred to as a multibillion-dollar industry (Rosen and Smith [2010], Lee et al. [2020]), while its status as one of the world's greatest illicit companies is questionable ('t Sas-Rolfes et al. [2019]). Aside from the illegal trade, there is worry over the 'legal' trade of frequently eaten non-protected species. Over-exploitation of wildlife, both legal and criminal, is common in places with limited human resources and finance to monitor trade and enforce current rules (Lee et al. [2020]).

The topic of zoonotic spillover from wild meat in Indonesia is much less represented in the published records. During 2020-2021 we saw an increase in the number of papers published on the issue of one health, particularly on pathogen transmission risk between humans and animals. As many as 18 papers were published, with 11 of them published in 2020 onwards. There has been much focus on flying foxes, which have traditionally been a favoured wild meat source in Sulawesi (Latinne et al. [2020]). Flying foxes are also widely consumed in Kalimantan and, despite the significant risk of zoonotic disease transmission, most hunters and market vendors are unaware of the associated health risks (Harrison [2011]). A lack of information on these health risks, as well as the normalization of generations' time spent hunting and eating wild meat, increases the risk of zoonotic transmission (Macdonald and Laurenson [2006]). There is a need to improve the capacity of people in these areas to prevent, detect, and control disease spread, potentially by incorporating behavioural science into zoonotic disease surveillance (Saylors et al. [2021]). Furthermore, a short supply chain from the hunter directly to the consumer for example the consumption of *Sus barbatus* by Dayak people in West Kalimantan, minimizes the risk of zoonosis (Zhou et al. [2022]). Nijman (Nijman [2010]) reported that mammal exports for wild meat markets may decline following the outbreak of SARS and avian influenza. However, as we report here, Nijman also stated that the extent of this decline is unclear as most of the wild meat trade is unreported and/or does not involve CITES-listed species. Banning the trade and consumption of wild meat will not solve trade/consumption-induced declines in wildlife populations (Booth et al. [2021b], Coad et al. [2019b]) not least because the communities that depend on wild meat are not uniform (Montgomery and Macdonald [2020]). For example, such bans would have the largest impacts on indigenous communities, while those in urban and rural areas with direct access to livestock would be less affected. Further, possible bans on the trade and consumption of wild meat are projected to cause significant food security issues in several African countries, such as Cote d'Ivoire and Cameroon (Booth et al. [2021a], Fa et al. [2009]). Removing

wild meat from the diets of indigenous communities will deprive some of them of crucial protein sources with no feasible alternatives; meat from livestock is typically hard to access in the remote areas where some such communities live. Additionally, if such a ban were to occur, livestock agriculture would need to expand to keep up with the demand for meat, possibly leading to increased habitat loss and degradation. Emphasising the negative image of wild meat consumption due to its associations with zoonosis, such as the COVID-19 pandemic, is unlikely to dissuade consumers (Bonwitt et al. [2018]). The intertwined challenges of balancing food security with health risks while reversing biodiversity loss and tackling climate change are among the greatest issues of the 21st century (Macdonald and Laurenson [2006], Baldwin-Cantello et al. [2020], Montgomery and Macdonald [2020]). Solutions for the wild meat crisis, which is linked to the broader economy, cannot focus on hunting alone and require a better understanding of the cross-sectoral linkages that drive wild meat trade and consumption (Milner-Gulland et al. [2003], Macdonald and Laurenson [2006], Montgomery and Macdonald [2020]). Considering the wild meat supply chain in Indonesia, the 184 records we review have covered almost all stages from the hunting, trade, consumption, and their relations with food security and health risks from zoonotic disease spillover, although to widely different depths. However, we found there are some aspects of consumption, which had not been covered, the first is there is no study so far on the different preferences between rural and urban consumers, and the role of restaurants in the supply chain.

Overall, this study demonstrates that there are two blind spots in Indonesia regarding wild meat as a global concern. The first one is the gap in knowledge of wild meat in Indonesia. And the second blind spot is the lack of exposure of the national authors publishing on this issue, whether they put biodiversity concerns or the human dimension as the focus of their study. We are convinced that these blind spots have within them a remedy for each other. For example, even if sometimes with methodological shortcomings, the topic of monetary incentives to sell wild meat has been covered more by national authors than is reflected in international journals. However, even among the community of national authors, our network analysis revealed that publications by local Indonesian authors were often somewhat disarticulated from the network (green circles at the bottom of Figure 3.5). In short, local authors are not citing each other, possibly because they work in different parts of Indonesia and with different species, and they are cited infrequently by other interconnected research on wild meat by researchers with more publications (in the big cluster). This may be because most of their work is published in low-impact journals or grey literature, perhaps partly reflecting the barrier of the high cost of publishing in higher-tier open-access journals (Matheka et al. [2014]). The paradox of high-quality research published in low-impact journals being overlooked is problematic, and exacerbated by the added challenges of publishing in English to a non-native, with further impacts on inclusivity in science (Amano et al. [2023], Arenas-Castro et al.

[2024]).

3.6 Limitation of the study

Further relevant papers and sources may only be available in print (e.g., grey literature or older journal articles), whereas we analysed only digitally available resources. Regrettably, I unintentionally omitted 'Molluca' and 'Seram' from the search keywords during the study for this chapter.

4

A Bolder Conservation Future for Indonesia by Prioritising Biodiversity, Carbon and Unique Ecosystems in Sulawesi

4.1 Abstract

As more ambitious protected area (PA) targets for the post-2020 global biodiversity framework are set beyond Aichi Target 11, renewed thinking into spatial prioritisation is required to enable PA expansion that maximises environmental values. Our study focuses on the biodiverse and forest-rich Indonesian island of Sulawesi, which has a terrestrial PA network that covers 10% of the island. We used Marxan to investigate trade-offs in the design of an expanded PA network that prioritised different conservation features (biodiversity, forest cover, carbon stock, karst and valuable metal-rich areas) under varying island-wide coverage targets (17%, 30%, and 50%). Our first scenario, which required existing PAs to be selected, required larger areas to meet these coverage targets, in contrast to our second scenario, which allowed for any part of the island to be chosen, irrespective of PA status. The vast Mekongga and Bangkiriang Landscapes and Gorontalo corridor were consistently identified as a high priority for protection under all scenarios. To meet our conservation targets by expanding current PAs, creating new PAs, and creating corridors that connect existing PAs, we used a spatially explicit three-phase approach. Our findings identified 26,508 km^2 of priority areas to be included in the current PA network, potentially assisting Indonesia in meeting its post-2020 GBF target, if our approach is replicated across Indonesia as a national or sub-national analysis. We discuss various land

management options through other effective area-based conservation measures (OECMs) and the costs to deliver this strategy.

4.2 Introduction

Protected areas (PAs) are a mainstay nature conservation strategy (Jepson et al. [2017]). While they may not be a perfect solution (Joppa et al. [2008], Rija et al. [2020], Tyrrell et al. [2019]), PAs often represent the last strongholds for threatened species and intact habitats and provide a buffer against environmentally damaging development (Gaveau et al. [2009], Grantham et al. [2020], Setyawati et al. [2020], Naidoo et al. [2019]). Terrestrial PA targets are typically set as a percentage of total land area, even though focusing on quantitative aspects while ignoring qualitative aspects and robust indicators may fail to fully recognise differences in biodiversity richness and habitat types (Adams et al. [2021], Banks-Leite et al. [2021]). Nevertheless, over the past 10 years, most countries have been working towards the Convention on Biodiversity (CBD) Aichi targets, in particular, Target CBD [2011], which calls for the protection of at least 17% of terrestrial and inland water areas CBD [2011]11. A forthcoming post-2020 Global Biodiversity Framework (GBF) will likely include a revised PA target of 30% of land conserved by 2030 (CBD [2021], Hannah et al. [2020], Waldron et al. [2020]) and an ambitious target of 50% by 2050 (Dinerstein et al. [2017], Wilson [2016]). This raises the question of how and where this can be achieved and how it can be done in a way that complements the current PA network in each country.

As a signatory to the CBD, the Government of Indonesia is working to achieve the various Aichi targets and may further commit to the new post-2020 GBF 30% target. However, with 21.3% of its land area already under some form of protection, Indonesia has surpassed the Aichi Target 11 for terrestrial protection (Dwiyahreni et al. [2021], KSDAE [2018]). The Government of Indonesia is currently formulating a new set of national PA targets as part of its efforts to update its National Biodiversity Strategy and Action Plan 2015–2020 in response to the post-2020 GBF. Setting meaningful targets for 2030 requires increasing the representativeness of PAs in Indonesia and their management effectiveness, rather than simply expanding the network by only using an area-based approach. Here, we provide an Indonesian case study, using systematic conservation planning to explore how best to achieve the post-2020 GBF target by increasing the coverage and representativeness of important conservation features inside Sulawesi's PA network.

Sulawesi is the eleventh largest island in the world. It is renowned for its biogeographical importance ever since Alfred Russel Wallace first explored it in the 18th century (Wallace [1869b]). It is part of the Wallacea biodiversity hotspot (MacKinnon and MacKinnon [1986], Myers et al. [2000]) and one of the 200 global ecoregions for conservation (Olson and Dinerstein [2002]). Despite its proximity to the islands of Borneo and Java, Sulawesi's biodiversity is unique (Hunowu et al. [2019], Johnson et al. [2019], Joyce et al. [2020],

Middleton et al. [2019], Trethowan et al. [2019]), with 98% of its non-flying mammal species, 37% of its bird species, and 26% of its reptile species being endemic (MacKinnon and MacKinnon [1986], Junaid et al. [2021], Whitten et al. [1987], Maryanto et al. [2019]). Its extensive forests and mangroves store and sequester globally significant volumes of carbon (Chen et al. [2018], Culmsee et al. [2010]). The terrestrial area of Sulawesi spans 186,404 km2, of which 18,822 km2 (10.1%) is assigned within the island's PA network. Of the 79 PAs in Sulawesi, Lore Lindu National Park (NP) was the first to be designated (in 1982) and Gandang Dewata NP the most recently created (2016), which indicates the government's willingness, commitment, and ambition to expand its PA network. Sulawesi also has the world's largest nickel deposit (van der Ent et al. [2013]), which is currently the most sought-after element for the development of electric vehicle batteries (Pandyaswargo et al. [2021]).

In this study, we conduct an island-wide spatial priority setting analysis for Sulawesi to inform PA planning and, more broadly, land-use management decision-making. A recent study (Zhu et al. [2021]) identified synergies between carbon and biodiversity conservation planning at a broader scale across Asia, including Sulawesi. Cannon et al. (Cannon et al. [2007]) carried out a similar study in Sulawesi, which was restricted to forest conditions (old growth, good, fair, poor, and converted) and a data set from more than 20 years ago. This foundational study showed that the priority conservation areas for that period were consistent with the areas chosen by government and non-governmental organisations, with several additional priority areas identified outside of the PA system. Our analysis builds on these two studies by incorporating more recent and detailed data sets and using a spatial approach that, in addition to forest conditions, considers other critical ecosystem types, biodiversity, and carbon stocks, with detailed data layers at a finer resolution, that enables site-specific management recommendations to be made. In contrast to the Key Biodiversity Areas (KBA), which only uses biodiversity data in its prioritization, spatial conservation planning can combine biodiversity and other conservation features that are relevant for species and habitat management 36. Our study aimed to identify priority areas by setting targets under different conservation planning scenarios by 1) performing a PA gap analysis; 2) selecting high-priority areas in addition to the current PA network; and, 3) identifying implementation opportunities and strategies for forest conservation across Sulawesi.

4.3 Methods

We used Marxan version 2.43 simulated annealing optimisation, with an iterative improvement method (Ball et al. [2009], Game and Grantham [2008]), to enable systematic conservation planning for Sulawesi. Our goal was to determine how to prioritise potential new conservation areas when faced with multiple candidate sites (termed Planning Units and referred to as PUs, hereafter). We used a hexagonal grid of 1.3 km2 that served as

the basic PUs within the landscape.

4.3.1 Study Area

The human population of Sulawesi in 2020 was 19.9 million people (BPS [2021]). Two provinces in Sulawesi rank fifth (Gorontalo) and ninth (Central Sulawesi) highest for poverty amongst Indonesia's 34 provinces (BPS [2020]). In Indonesia and Sulawesi, there are 13 different types of conservation areas (Table S1) that are under different management authorities. The Ministry of Environment and Forestry (MoEF) is responsible for National Parks, Nature, Wildlife and Game Reserves, Nature Recreation Parks, and Hunting Parks, whereas Forest Management Units (such as Grand Forest Parks), whilst still the responsibility of MoEF, have devolved management to provincial government agencies.

The Wallacea biogeographic region, which includes Sulawesi, lost 10,231 km^2 of forest between 2000 and 2018 (Voigt et al. [2021]) and 373 km^2 of forest in 2017-2018 (KLHK [2019]). These losses are unevenly distributed across the island, with the highest rates having occurred in the west and southeast lowland parts (Supriatna et al. [2020]). The threat of forest loss in Sulawesi, particularly in Central Sulawesi, is largely attributed to the occurrence of anthropogenic fires and past deforestation (Voigt et al. [2021]). A more recent threat to conservation areas is legal and illegal mining, especially for nickel (Kadir et al. [2020]). Most of this deforestation, and predicted future deforestation, occurs outside of the PA network (Voigt et al. [2021]). To effectively mitigate these threats and protect Sulawesi's species and ecosystems, an island-wide spatial prioritisation approach is urgently needed.

4.3.2 Conservation Scenarios and Priority Setting Objectives

Our goal was to identify potential PAs across Sulawesi. Our conservation values included forest cover, high carbon storage, distribution of endangered and critically endangered species, ultramafic soil, and karst. We included karst because it is a threatened ecosystem type, with limestone quarrying as the primary threat (Clements et al. [2006]) and high levels of species endemism (Clements et al. [2006], Albani et al. [2020], Coleman et al. [2019], Thomas et al. [2018]). Ultramafic soil is included because of its high plant endemicity (Galey et al. [2017], Rahbek et al. [2019]), and being rich in valuable, often-mined, metals such as nickel (CBD [2021]).

The target was met by balancing with the estimated cost of protection in each PU. We investigated three scenarios for selecting priority conservation areas. The first scenario aimed to protect 17% of the identified conservation targets based on features such as carbon, karst, and forest cover. This goal is based on Aichi Target 11, which calls for the protection of 17% of terrestrial and inland water by 2020. The second scenario, which is based on Target 3 of the post-2020 Global Biodiversity Framework (CBD [2021]), aimed

to protect 30% of the identified conservation targets. The third scenario, based on the 'Half-Earth concept', sets the most ambitious target because it aims to protect 50% of the identified conservation targets in Sulawesi (Noss et al. [2012], Dinerstein et al. [2017], Wilson [2016]).

Conservation features

We used eleven conservation features and set targets based on the proportion of each feature under the three management scenarios (Table S2, Fig. S1). We classified conservation features into five categories: i) carbon stocks (i.e., above and below ground, ABG, terrestrial carbon and soil carbon), using a data layer developed by Soto-Navarro et al. [2020] to identify areas with high carbon stocks; ii) forest types defined from the government's official Land Use Land Planning 2018 dataset (MoEF (Ministry of Environment and Forestry of Indonesia) [2019]); iii) karst (MoEF (Ministry of Environment and Forestry of Indonesia) [2019]); iv) distribution of important animal species (IUCN Red List website); and, v) ultramafic outcrops (MoEF (Ministry of Environment and Forestry of Indonesia) [2019]).

We combined primary dryland and secondary forest into a single forest cover layer and reclassified this based on their elevation range to include lowland (0–150 m asl), low elevation hill (150–500 m asl), medium elevation hill (500–900 m asl), sub-montane (900–1,400 m asl), lower montane (1,400–1,900 m asl), montane (1,900–2,500 m asl), and tropical upper montane/sub-alpine ($\geq$ 2,500 m asl) (Laumonier [1997]).

We obtained species distribution maps from the IUCN Red List website (https://www.iucnredlist.org/search, accessed on March 16, 2022) using the following advanced search categories: Animalia is the Kingdom; Amphibia, Aves, Mammalia, and Reptilia are the Classes; CR and EN are the Red List Categories; and Sulawesi is the Land Region. We eliminated four species because they are not found in Sulawesi, possibly due to an error in the IUCN database (*Vanellus gregarious* and *Pterodroma baraui*), or because their distributions cover the marine area rather than the terrestrial (*Chelonia mydas* and *Eretmochelys imbricate*). We excluded VU species because several species, such as the Sulawesi giant squirrel, lacked fine-scale data and had distribution maps that were simply allocated to any forest patch on the island, rather than species occurrence. The final search yielded 12 mammals, 4 birds, 14 reptiles, and 3 amphibians (Table S3). The inhabitable area (non-forest area that has been developed or modified by humans) was removed from the spatial data composite of these 33 species distributions.

Ecological condition

We created a cost layer by combining land use and land cover with the 'Forest Landscape Integrity Index' developed by Grantham et al. (Grantham et al. [2020]; Table S4). The cost layer refers to the loss or cost incurred by an area should it be assigned as a PA. No standard approach exists for determining the amount of penalty and cost, so we assigned

a score to each PU that was proportional to how much of the area had been modified, less naturally intact or degraded. For example, the land use and land cover data contained 22 distinct categories designated by the Government of Indonesia (MoEF (Ministry of Environment and Forestry of Indonesia) [2019]). We ranked them according to their natural habitat state: with natural habitats, such as primary and secondary forests, assigned a cost score of '1', highly modified habitats, such as plantations and farming areas, assigned a score of '10', and shrubs assigned a score of '5'. Eight of the 22 classes were either heavily developed or not a terrestrial system and were therefore left out of the analysis (i.e., settlement, bare land, water bodies, airport and seaport, transmigration area, mining concession, fishpond, and paddy field). The Forest Landscape Integrity Index combines observed and inferred forest pressure and fragmentation data to produce a continuous index ranging from 1 to 10, indicating the degree of anthropogenic modification (Grantham et al. [2020]). We inverted the value of intact forests so that the most integrated had the lowest cost. We created a single cost layer from multiple factors (Ardron et al. [2010]) by averaging the 15 cost factors (Table S4) in each PU, yielding a single cost value for each PU (Fig. S1).

4.3.3 Priority Area and Gap Analysis

To meet the conservation features targets, ensure connectivity between areas, and reduce the total cost of priority area management (Figure 4.3), we used Marxan v.4.0.6 to identify priority conservation zones through QMarxan Toolbox (2.0.1.), a QGIS 3.18.3 plugin (https://qgis.org/en/site/). We defined a total of 140,906 PUs on mainland Sulawesi and its outer islands, with each PU being a 1.3 km2 hexagon. Multi-edged PUs, such as hexagons, are more efficient in creating priority areas because they have a lower edge:area ratio than square grid cells. We ran the analysis in QMarxan for each scenario, starting with a Species Penalty Factor (SPF) of 1 and a constant boundary cost (1). The connectivity cost, also known as the boundary cost, is a value that represents connectivity; the higher the PU value, the more likely that it will be connected. By starting the analysis with a constant value, the algorithm ensures that all PUs are treated equally. We then calibrated the SPF and the Boundary Length Modifier (BLM). The SPF is calibrated to ensure that the penalties for missing conservation features are appropriately scaled and relative to one another. While the BLM is calibrated to find the best value that strikes a balance between area compactness and cost (as the value of the BLM increases, the algorithm will prefer a 'single large' design over a 'several small' designs, or increase 'connectivity'). To compare the spatial arrangement within and between scenarios, we used the kappa statistic (Zhang and Vincent [2019]).

4.3.4 Representativeness of Sulawesi's Protected Area Network

We ran each of the three protection scenarios in two ways: with a requirement that all existing PAs be included (scenario 'a'); and, without such a requirement (scenario 'b'). PAs were included to identify new priority areas outside of those already protected. In scenario 'b', PAs were excluded to allow for spatial assessments based on representativeness, allowing for comparisons with existing PAs to assess their efficacy in meeting the conservation targets (Ardron et al. [2010]). We included 79 PAs (Table S1) from the World Database on PAs (Bingham et al. [2019]). We ensured these were accurate and aligned with the official MoEF PA list. We based our recommendations to increase current PA coverage in Sulawesi on scenario 'a', which required all PAs to be included in the selection procedure. Nonetheless, because scenario 'b' is not biased towards the existing PAs, it is useful for highlighting gaps between the current PA network and the identified priority areas. If both scenarios select the same area, the weight is greater than if only scenario 'a' selects the area. We compared spatial similarities between scenarios using weighted kappa (κ) statistics, where 0 denoted no agreement, 0.01–0.20 low agreement, 0.21–0.40 fair agreement, 0.41–0.6 moderate agreement, 0.61–0.80 substantial agreement, and 0.81–1.00 the highest agreement McHugh [2012].

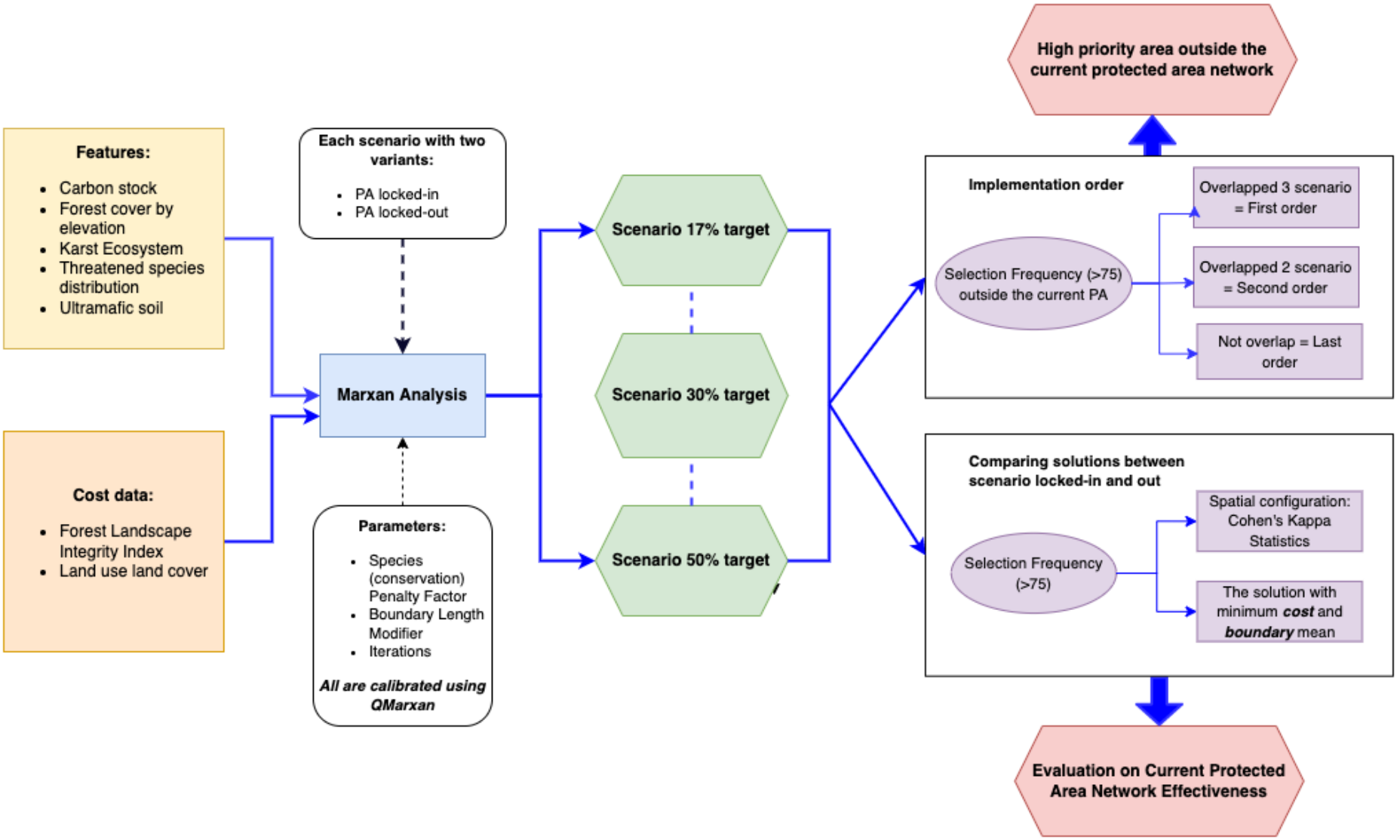


Figure 4.1: Workflow for identifying priority conservation areas in Sulawesi under three protection scenarios.

4.3.5 Identifying High-Priority Areas Outside the Current Protected Area Network

Marxan works by continually repeating the analysis to identify PUs that best achieve objectives. Due to the nature of the algorithm often each run can be slightly different. Selection frequency is the sum of how many times a PU was selected across all the runs. Areas designated as a priority have a high degree of selection frequency of more than 75 out of every 100 iterations. We merged the priority areas from the three percentage area scenarios and devised a plan for sequential implementation to make meeting this goal more realistic. We began by identifying high-priority areas outside of the current PA network, as determined by the 17% scenario, and then expanded on this for the 30% and then 50% scenarios.

Based on provincial delineation and governance structures, we divided the study area into six geographical regions (Figure 4.2): 1) North Sulawesi Province; 2) Gorontalo and Central Sulawesi Provinces, covering Nantu Wildlife Reserve (WR) in the east and Gunung Sojol in the west; 3) Central and West Sulawesi Provinces, extending from Pegunungan Tokalekaju in the north and connecting Lore Lindu NP and Gandang Dewata NP as a large landscape, and Faruhumpenai Nature Reserve (NR) in the east; 4) Central Sulawesi Province's eastern region, which includes Balantak in the east, Gunung Lumut and Bangkiriang in the centre, and Morowali in the west; 5) Southeast Sulawesi Province, which includes the Routa KBA and Mekongga landscape in the north, and Buton Island in the south; and, 6) South Sulawesi Province.

The identified priority areas were overlaid on the KBAs (CEPF [2014]) to evaluate them in the context of landscape conservation in Sulawesi. We overlaid the identified priority areas with current active concessions to assess the potential threats of establishing the priority areas as conservation areas. Priority areas that fall within the scope of a concession are regarded as being under threat of clearance. Using MoEF data, we identified plantation concessions: 1) Natural Forest Management Permit (Hak Pengusahaan Hutan); 2) Palm Oil Concession; and, 3) Industrial Plantation Forest (Hutan Tanaman Industri). The mining concessions are public data made available by the Directorate General of Mineral and Coal, Ministry of Energy and Mineral Resources.

4.4 Results

Given the same iterations, all percentage coverage targets under scenario 'b' (PAs are not required to be included) had a lower mean cost and were more compact with less edge. Except for the 17% target, they also had lower mean boundary lengths than those under scenario 'a' (PAs must always be included) (Table S5). Under scenario 'a' the total size of the priority areas was slightly larger than scenario 'b'. When only those from outside the current PA were considered, the selections under scenario 'b' were always

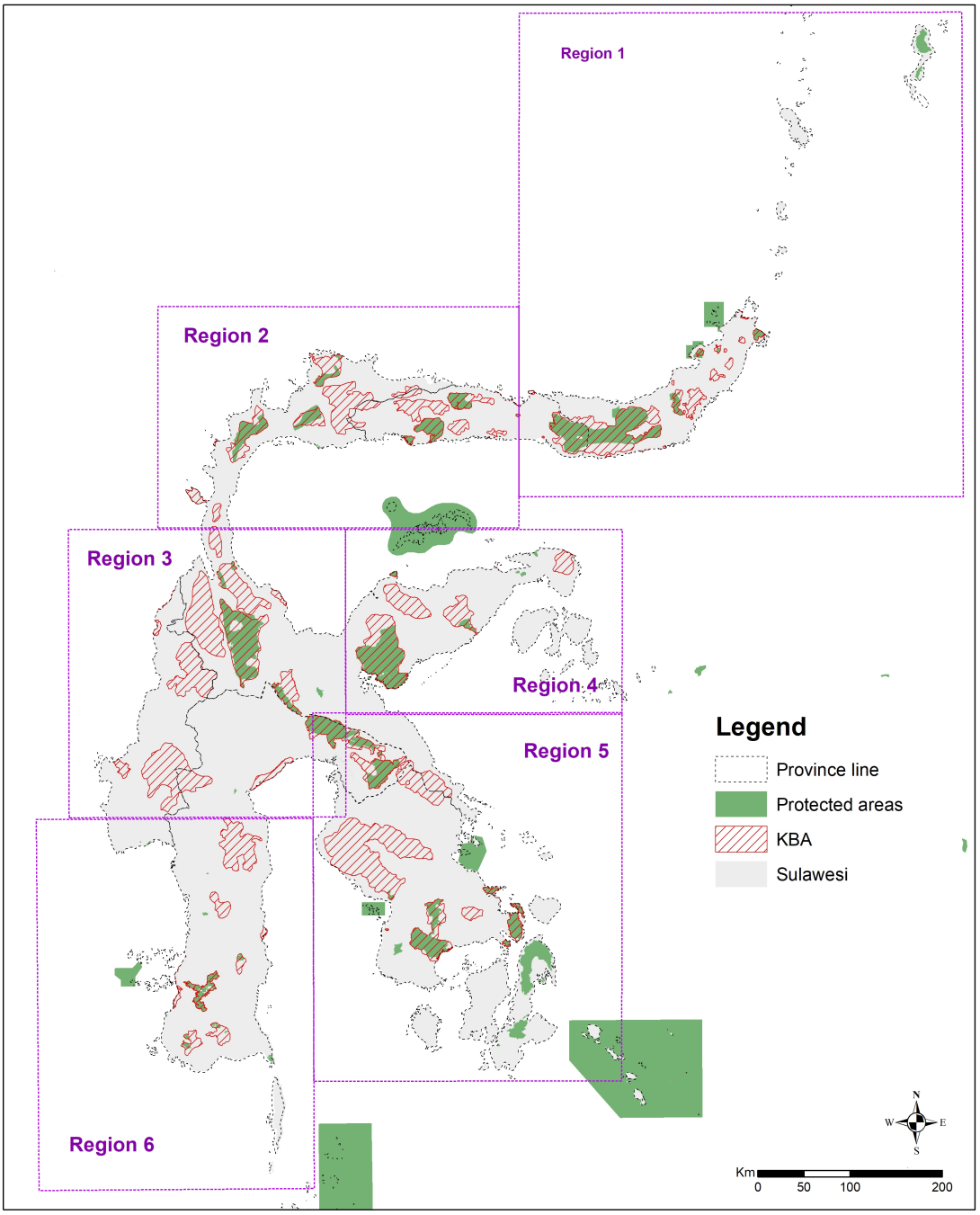


Figure 4.2: Geographic regions we used to define and identify new priority areas in Sulawesi.

Table 4.1: Size of the priority area (for planning units with a selection frequency ≥75) in scenarios 'a' and 'b'.

Scenario target	**Total priority area (km^2)**	**Priority area outside current PA (km^2)**
	Scenario 'a'	
17%	26,162	8,007
30%	44,008	25,829
50%	76,398	58,019
	Scenario 'b'	
17%	23,480	18,058
30%	42,018	33,358
50%	74,626	61,430

larger (Table 4.1). Scenario 'b' revealed a disparity between what we have and what should be. Scenario 'b' revealed gaps in the PA network by selecting a larger expanse of priority areas outside of this network than under scenario 'a', which was required to include these PAs. Scenario 'b' met the 17%, 30% and 50% targets through selecting a smaller number of PUs (Figure 3).

Figure 4.3 shows that the size of all scenarios 'a' inside the PA is equivalent to the current PA size (the dashed line). In scenario 'b', the size of priority areas inside PAs for all targets is less than the total area of the PAs. Due to the small size of the total priority area within PA in scenario 'b', several of the existing PAs were partially chosen or not chosen at all.

Within the same target, the weighted Kappa statistic between scenarios 'a' and 'b' describes the spatial congruence of the two scenarios. The weighted Kappa statistic was the lowest for the 17% target ($\kappa = 0.30$), moderate for the 30% target ($\kappa = 0.58$), and significant for the 50% target ($\kappa = 0.75$). The lower percentage target would result in the algorithm prioritizing noticeably different areas to meet the target since the current PAs did not adequately represent the five conservation features (forest, carbon, karst, species, and ultramafic soil). As the percentage targets increased, there was increasingly closer alignment between scenarios 'a' and 'b' for the size of the priority areas required to be selected to meet those targets.

Sulawesi's network of 79 PAs currently covers 16% of the island's 2018 forest area (15,375.3 km^2), 9% of its karst (2,260.9 km^2), 15% of the distribution of important species (16,023.4 km^2), and 12% of its ultramafic soil (15,362.9 km^2). Only 18% (8,109 km^2) of the island's top quantile for soil carbon organic is located in its PA network. Including these priority areas in the current PA network increases the representation of conservation features (Figure 4.4). Even the modest target of 17% increases area representativeness for important species (biodiversity), carbon, and the sub-montane – lower montane forest. The more ambitious targets of 30% and 50% increase the representation of all conservation features, apart from lowland forest, which is almost entirely included in the current PA

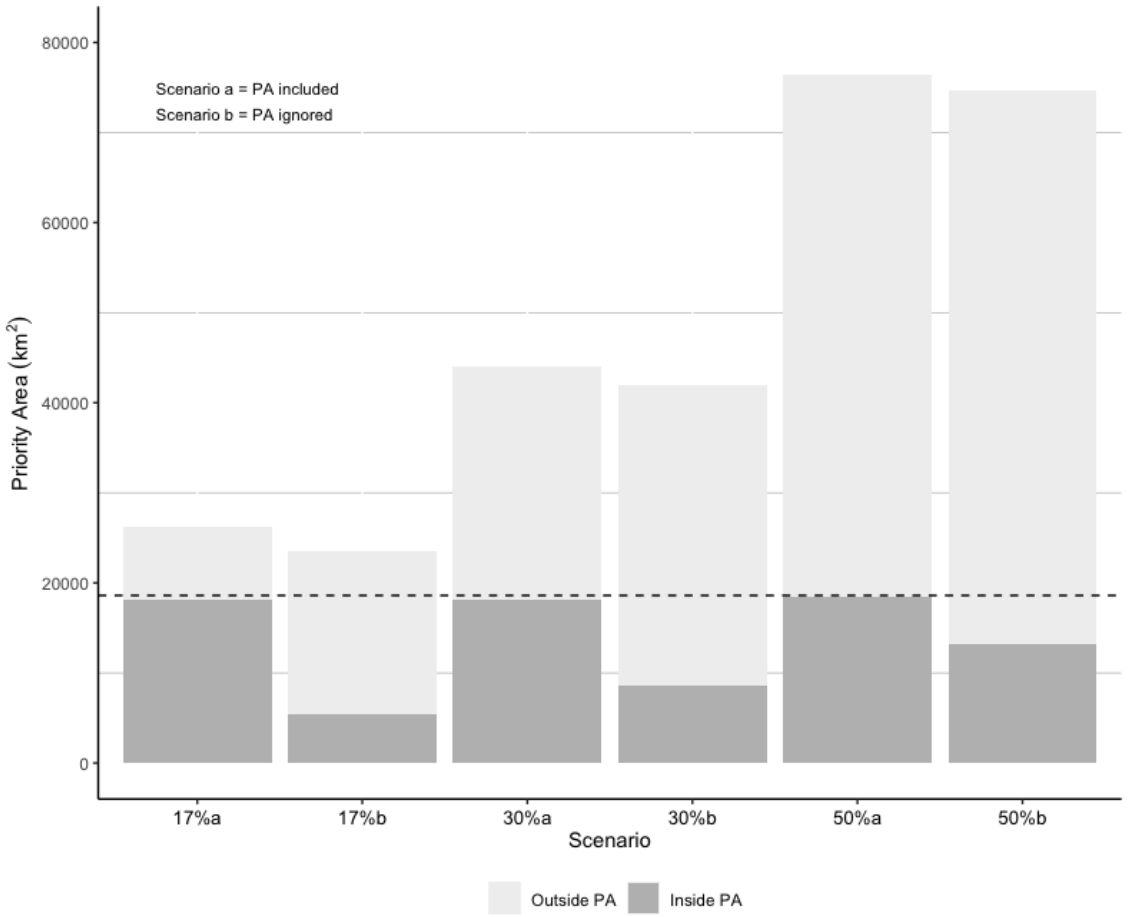


Figure 4.3: Sulawesi priority area size under six scenarios (two scenarios, 'a' and 'b', for protected area selection and three protection targets of 17%, 30%, and 50%). The dashed line denotes the total size of Sulawesi's current protected area network.

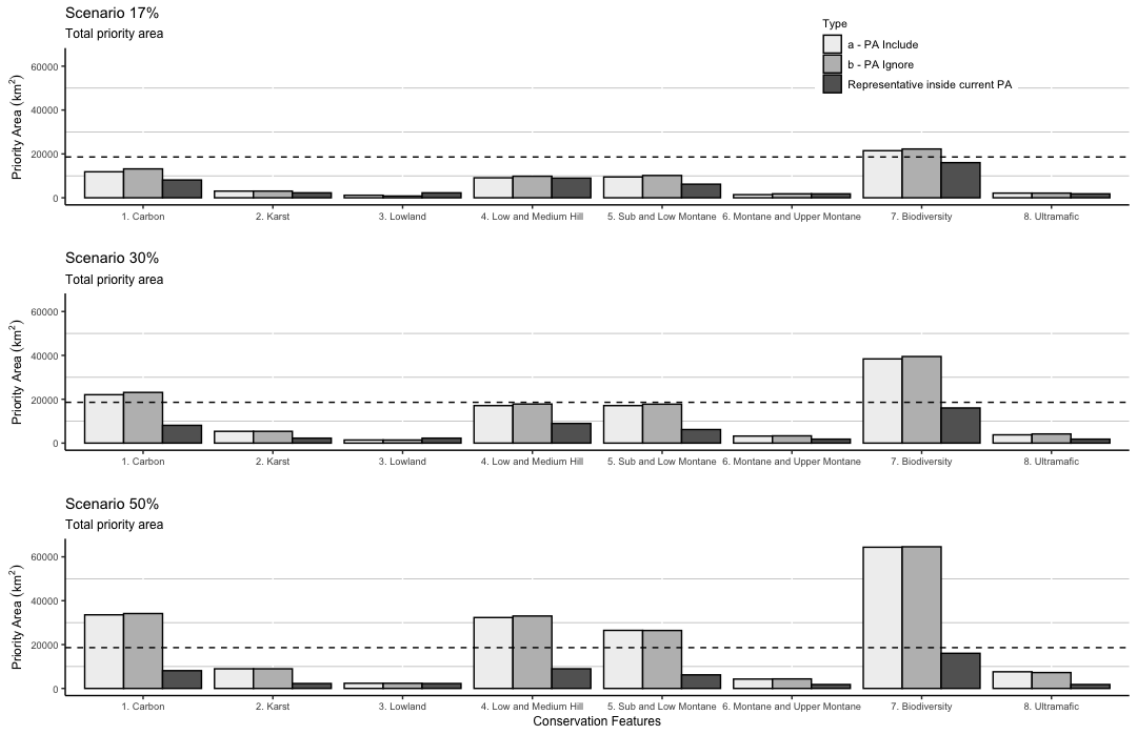


Figure 4.4: Sulawesi conservation features representativeness for all target scenarios (17%, 30%, and 50% protection target). The dashed line denotes the current protected area network on Sulawesi (18,602.4 km^2).

Table 4.2: Recommended order for assigning protection to priority areas outside of Sulawesi's current protected area network.

Order	**Scenario 'a' (km^2)**	**Scenario 'b' (km^2)**
First	6,864	14,911
Second	19,644	20,565
Third	31,975	26,982
Total area	58,483	62,458

network.

The size of the priority areas identified outside of the current PA network is 58,483 km^2 in scenario 'a' and 62,458 km^2 in scenario 'b' (Table 4.2). These areas are vast and would require more than three times the current land area that is presently assigned for PAs. To achieve this expansion goal, we propose a three-stage implementation plan based on the overlap (i.e. order of importance) amongst the three percentage target scenarios under 'a' and 'b'.

Our first recommended implementation order prioritises 6,864 km^2 under scenario 'a' (Table 4.2, Figure 4.5) with 35% of this area being located within three large clusters that are not connected to the current PA network. The largest area is the Mekongga landscape (Region 5) with the single largest first-order priority site (609.4 km^2) being outside of the PA, followed by the 580 km^2 Bangkiriang landscape (Region 4), and 892.6

km^2 Gorontalo corridor (Region 2) (Figure 4.5).

A compilation of areas covering 19,644 km^2 is prioritized in the second order under scenario 'a' (Table 4.2). These areas are significantly more extensive than the current PA network. To make achieving this goal more feasible, we propose prioritizing five clusters. The first three are those mentioned above in the first-order description, with the remaining two being the Tokalekaju landscape and the Central Sulawesi corridor. Under the second order, the Mekongga landscape (consisting of three patches) extends further to cover a 3346.9 km^2 which combines with the first order area, and additionally the 1652.1 km^2 Bangkiriang landscape with the first order area as its core. The extensive Gorontalo corridor (Popayato-Paguat-Buol-Tolitoli-Dako Mountain) spans 4729.6 km^2, with the first order area serving as the core (892.6 km^2). The Tokalekaju Mountain landscape (1145.4 km^2) is a large single second-order area (with 63 km^2 of the first order), and the central Sulawesi corridor (2751.1 km^2) that connects Gandang Dewata NP, Lore Lindu NP, and Pamona NR (KBA Danau Poso. The second order under scenario 'a' aligns with Target 3 of the first draft of the post-2020 GBF by adding a buffer area to the existing PAs; creating new standalone PAs; and, creating corridors that connect pre-existing PAs.

Focusing on the first and second-order priorities of scenario 'a,' which together create 26,508 km^2 priority areas that are additional to the current PA network, we describe these results in greater detail for each region, considering comparisons to scenario 'b' and potential impacts from different land management sectors.

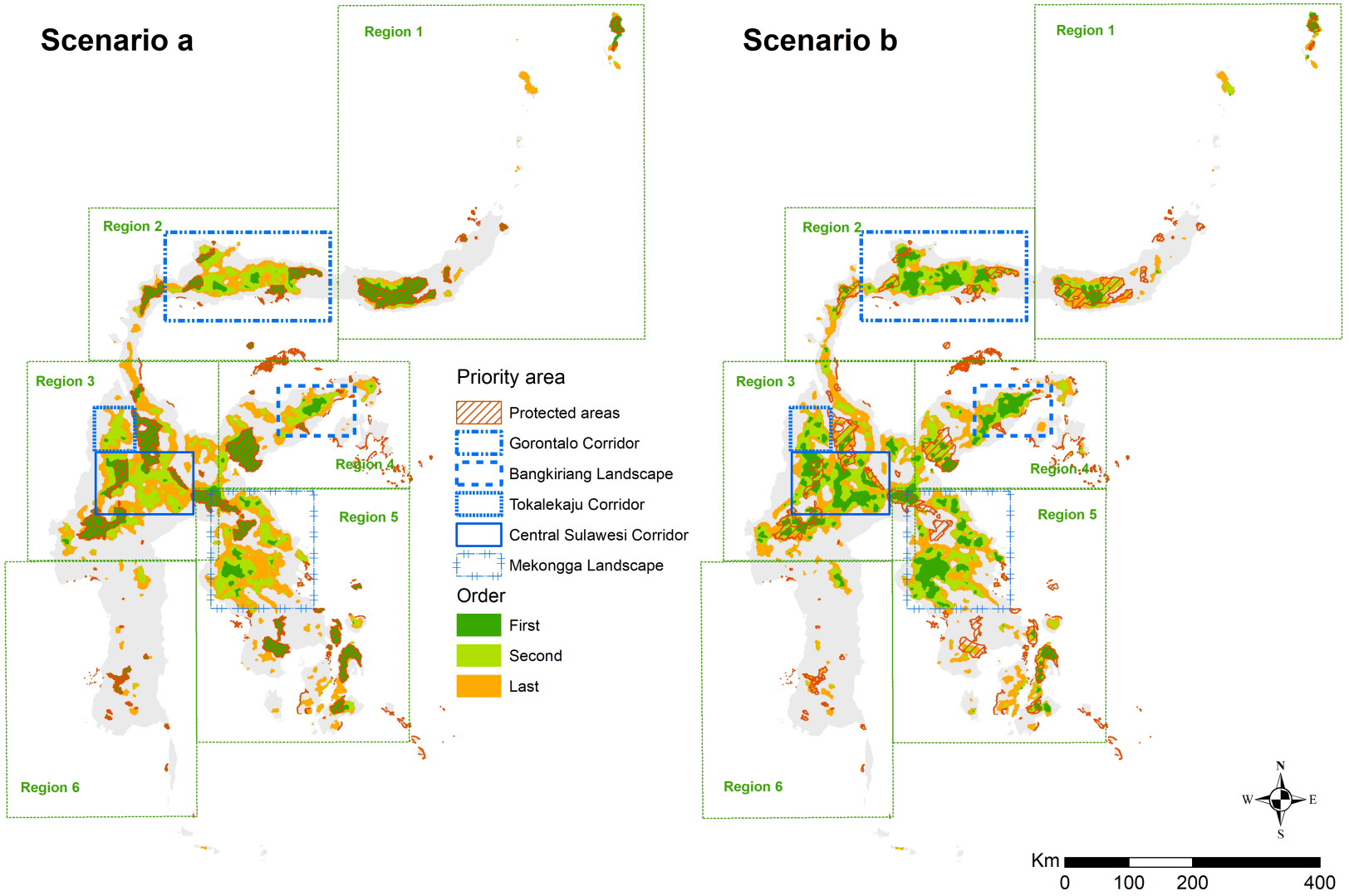


Figure 4.5: Priority areas in Sulawesi based on scenarios 'a' (in which the current PA network had to be included in the selection) and 'b' (in which any area could be selected), as well as the proposed order of selection for protecting these areas.

4.4.1 North Sulawesi (Region 1)

Aside from the PAs, the first order scenario 'a' adds 1,121.4 km^2 to the low and medium hill forest border of Bogani Nani Wartabone NP and Karakelang WR (420.1 km^2) (Fig. S2). In comparison, scenario 'b' emphasizes the significance of KBA Gunung Simbalang, with a third-order priority area that is larger than the KBA itself and a first and second-order priority area at its centre. Scenario 'b' highlights the significance of Sangihe Island as a second-order priority rather than the last order in scenario 'a' (Fig. S3). The PT Tambang Mas Sangihe concession, which covers half of Sangihe Island (https://geoportal.esdm.go.id/minerba/), is located in the southern extent of this area. Another potential threat is the priority area along the northern boundary of Bogani Nani Wartabone NP, which overlaps with the PT Huma Sulut Natural Forest Management Permit area, suggesting that it could be logged in the future. This region's karst is located within the Karakelang landscape, outside a PA.

4.4.2 Gorontalo and Central Sulawesi (Region 2)

Outside of the PAs, the first and second-order priority areas of scenario 'a' include 4,729.6 km^2 that overlaps with KBA Popayato-Paguat (first-order priority area of 461.4 km^2) and KBA Buol-Tolitoli (first order priority area of 317.4 km^2) which we term as the Gorontalo corridor, dominated (68%) by low and medium elevation hill forest. The first-order priority area in this landscape extends the border of Nantu NR, Gunung Dako NR, and Tinombala NR (Fig. S2). Outside of the PA network, this region contains a large portion of the top quantile for carbon stock. This condition is illustrated by scenario 'b' in which the priority areas of the first and second-order areas are located outside of the PAs and heavily overlap with the KBAs (Fig. S3), which covers all of the high carbon areas. The Gorontalo corridor of scenario 'b' encircles the area, with an oil palm concession in the centre (251 km^2). This region includes PT Sentral Pitulempa and PT Taman Hutan Asri's logging concession areas (HPH), as well as PT Inti Global Laksana and PT Cipta Cakra Murdaya's oil palm concessions. Furthermore, the mining concession of PT Gorontalo Sejahtera overlaps with the southern part of Panua NR (Fig. S2 and S3, code PA ID 15).

4.4.3 Central Sulawesi (Region 3)

Outside of the PAs, this is the largest region and covers the most extensive priority areas. Based on scenario 'a', there are two stand-alone priority areas worth mentioning: the Tokalekaju landscape and the Central Sulawesi corridor (Fig. S2). The Tokalekaju landscape covers 1,146.7 km^2 and is dominated by sub and low-montane hill forest types. The Central Sulawesi corridor spans 3,645.5 km^2 and is dominated by low montane forest. The first-order priority of the Central Sulawesi Corridor (872 km^2) is mostly an extended border of Lore Lindu NP, Gandang Dewata NP (PA ID 37), and a small polygon west of

Pamona NP (PA ID 28). The Tokalekaju landscape, KBA Pambuang, and the Central Sulawesi corridor are connected as one large landscape in scenario 'b' with a significant amount of first-order priority areas outside the current PAs (Fig. S3). The overlap of Pegunungan Tokalekaju KBA with the Natural Forest Management Permit area of PT Satya Sena Indratama, Pambuang KBA with the Natural Forest Management Permit area of PT Inhutani I Mamuju, and Sulawesi Tengah Grand Forest Park with the mining concession PT Citra Palu Mineral indicate the potential development impacts that may occur in this region. Some 40% of the Tokalekaju Landscape is under concessions (456.4 km^2) belonging to three companies with National Forest Management Permits. One of them, PT Satya Sena, has a concession that overlaps with 15.6 km^2 of a first order priority area. Furthermore, 560.4 km^2 of the Central Sulawesi corridor is within a concession, primarily the Natural Forest Management Permits of PT Rante Mario and PT Inhutani I Mamuju.

4.4.4 Eastern Sulawesi (Region 4)

Under scenario 'a', the Bangkiriang landscape is the only large standalone polygon of first and second priority (1,678.8 km^2) (Fig. S2). It stretches from Lombuyan I and II WR (PA ID 35) to Bangkiriang WR (PA ID 33), with a first-priority area of 602.7 km^2 at its core (Fig. S2). The Bangkiriang landscape is dominated by submontane forest (44%, 750.9 km^2), contains a significant amount of karst (56%, 934.3 km^2), and because it is part of the East Sulawesi crescent geology area, it has a significant amount of ultramafic soil (32%, 531.4 km^2). Scenario 'b' shows the importance of priority areas outside of PAs by selecting the majority of first and second-priority areas outside of the PA network (Fig. S3), with a smaller first-priority area inside Morowali NR (PA ID 32).
Concessions with Natural Forest Management Permits (37%, 631.2 km^2), including PT. Bina Balantak Raya, PT. Dahatama Adi Karya, PT. Palopo Timber Company, and PT. Satyaguna Sulajaya may have forest impacts. The first company is the largest, with 292 km^2 of its concession overlapping with the KBA Bangkiriang. Another potential impact is from PT Sinar Makmur Cemerlang's mining concession that is located within the KBA Bangkiriang.

4.4.5 Southeast Sulawesi (Region 5)

Despite having a dense forest cover and being part of the East Crescent Sulawesi geology, this region has very few PAs. There is no PA between Danau Towuti NRP (PA ID 45) and Rawa Aopa Watumohai NP (PA ID 65). Based on our scenarios 'a' and 'b', this gap in the area is prioritized. Scenario 'a' identified three large standalone patches of first and second-priority areas that overlap the KBA Mekongga and cover 3,346.9 km^2 (Fig. S2). The largest patch, with an area of 2,406.8 km^2, is dominated by submontane forest (first order area of 874.7 km^2). This patch contains karst (854.7 km2) and Mekongga's

only patch of ultramafic soil (301.7 km^2). Scenario 'b' depicts these three patches as a single continuous landscape with a large first order and a second order in the buffer zone (Fig. S3).

The second important standalone first and second priority area is 828.0 km^2 of forest that overlaps with the KBA Routa (Fig. S2). The Routa landscape is dominated by a medium-elevation hill forest (460.1 km^2) and contains both karst (165.3 km^2) and ultramafic soil (385.5 km^2). The final significant standalone area is an unnamed landscape located east of Danau Matano (PA ID 43) and Danau Mahalona (PA ID 44) (Fig. S2). This is a 740.0 km^2 area dominated by medium-elevation hills (368.8 km^2) and a significant proportion of ultramafic soil (63%, 468 km^2). The Routa landscape and the unnamed landscape to the north are depicted as one continuous landscape in scenario 'b' (Fig. S3). There are no identified threats from concessions in this region.

4.4.6 South Sulawesi (Region 6)

This cluster has the least forest cover, the fewest PAs, and the fewest priority areas outside of the PAs. According to scenario 'a', the only large standalone areas are the second and third-order priority areas that overlap with the KBA Pegunungan Latimojong, which contains Sulawesi's highest mountain. The second-order priority area is in the landscape's centre (222.7 km^2) and contains 83% of montane and upper montane forest (Fig. S2). Scenario 'b' emphasizes the significance of the Latimojong landscape by identifying it as a first-order priority (Fig. S3).

4.5 Discussion

The Sulawesi terrestrial PA network covers 10% of the island's land surface. Our study provides an innovative approach to systematically enhance this network through three sequential stages, by incorporating new areas based on their key environmental attributes. Our results reveal that the current PA system protects less than 20% of the areas identified by our analysis as being priorities for the five conservation features (Table S2). The identification of 26,508 km^2 (first and second order areas combined, Table 4.2) under the 30% target outside of the current PA network exemplifies this lack of representation. Assuming that all signatory Parties will adopt the CBD's 30% target, addressing the funding gap to achieve this is critical, yet challenging. Obtaining the first-order priority areas would increase PA coverage by 14% of the island and adding the second-order priority areas would increase this to 24%. Adding all the areas identified from first to third order would cover 42% of the island's land area.

Mackinnon and Mackinnon MacKinnon and MacKinnon [1986] evaluated PA effectiveness in the Indo-Malayan Realm in the 1980s. Except for Dumoga-Bone NP (now Bogani Nani Wartabone NP), Tangkoko Dua Saudara NR, and Lore Lindu NP, they concluded that Sulawesi's PAs were generally inadequately protected. Our work reveals a shifting

baseline concerning the essential areas to protect. It also benefits from detailed data layers and analytical techniques that have recently become available. There are considerable gaps in the areas identified as priorities in the PAs exclusion scenario ('b') compared to those considered when Sulawesi's PAs were established nearly 40 years ago. Three of the six PAs identified as essential by MacKinnon and MacKinnon MacKinnon and MacKinnon [1986] are not identified as priorities under scenario 'b' (Tangkoko Dua Saudara, Bantimurung, and Rawa Aopa). Nonetheless, both our research and that of MacKinnon and MacKinnon MacKinnon and MacKinnon [1986] identify Lore Lindu NP and Bogani Nani Wartabone NP as conservation priorities.

Tangkoko-Dua Saudara is an important area due to its high conservation value. For example, it is home to a significant portion of the Critically Endangered black-crested macaque (*Macaca nigra*) population (Johnson et al. [2020]). The *Macaca nigra* distribution was included in our analysis (Table S4), but the Tangkoko-Dua Saudara is still excluded under scenario 'b', possibly due to its small size and low irreplaceability in comparison to other larger patches. The omission of Bantimurung-Bulusaraung NP from our priority list may be explained by the Mekongga and Bangkiriang landscapes incorporating most of the karst, the primary feature of this park. Rawa Aopa NP has lost nearly half of its forest cover since it was gazetted in 1990, lowering its priority for selection and resulting in the selection of large landscapes such as Mekongga. The PA exclusion scenario is useful because it highlights important areas that are outside of the current PA network. We stress that our findings do not imply that the PAs not included in our analysis have no conservation value because they still serve many other important functions, such as for endemic species and ecosystem services. There is considerable overlap between the critical areas highlighted in our study (Figure 4.5) and KBAs, which further validate the prioritisation exercise conducted by the Critical Ecosystem Partnership Fund (CEPF [2014]). However, both the KBA and priority areas highlighted in our study are not included in the existing PA network. The same situation was encountered when we assessed connectivity as one crucial aspect of PAs. Many priority areas identified in this study were also part of the KBA corridor. For example, the KBAs of Bangkiriang and Mekongga were identified by our study as being part of the much larger Bangkiriang and Mekongga landscapes, respectively. The islands of Sangihe and Talaud, were identified in this study as a priority and were also part of the CEPF priority corridor for North Sulawesi Province 61. KBAs are based on species data, whereas our analysis extends beyond just biodiversity. One novelty in our approach is the inclusion of ultramafic soil, which alongside altitude often shapes the diversity of plants, the kingdom of species rarely considered in biodiversity prioritization exercises (Rahbek et al. [2019], Darbyshire et al. [2017], Trethowan et al. [2021, 2020]). Our approach, de facto, would increase the focus on the many endemic plant species that continue to be described in Sulawesi (Rustiami and Henderson [2017], Trethowan et al. [2019]).

The priority areas identified in our analyses provide an opportunity to understand where conservation gains, in terms of coverage and ecological representativeness, could be made by expanding the PA network in Sulawesi. For example, to achieve the 17% protection target, the first-order selection areas are located in the existing PA buffer zones. We propose that the most feasible approach to conserving these areas is a government-led PA enlargement and buffer management strategy. Once this has been achieved, the next step will be to protect the second-order priority areas, mainly by designating a corridor system in Region 2 (Gorontalo and Central Sulawesi). Many PAs in Region 2 (Gunung Dako NR, Tinombala NR, and Gunung Sonjol NR) would benefit from increased protection status beyond their current designations.

For a continuous large landscape that is not connected to any PA, notably Mekongga and Bangkiriang, another type of protection is required. Parts of the two landscapes are also managed by the local government as part of Indonesia's watershed forest, also known as the Protection Forest (Hutan Lindung). They typically have a lower protection status than national parks because there is no technical implementation unit, unlike national parks, that is directly responsible for them and, as a result, no direct funding for their protection. An 'Essential Ecosystem Area' is another plausible option, although its size is generally much smaller than that of a PA. For example, in 2017 the 0.15 km^2 Taman Keanekaragaman Hayati (Biodiversity Park) Oheo Essential Ecosystem Area in North Konawe Regency MoEF Ditjen KSDAE [2018], was established near the Mekongga landscape. Given their size and importance, the Mekongga and Bangkiriang landscapes may even merit national park status and the increased resources that this would bring. This study supports Mekongga's previous effort to promote the area's status as a national park (Gunawan and Sugiarti [2014, 2015]).

The post-2020 GBF Target 3 aims to protect at least 30% of all land and sea, globally, and will likely be adopted by all CBD signatories (CBD [2021], Waldron et al. [2020]). Under the Mitigation and Conservation Hierarchy (Milner-Gulland et al. [2021]), our work would contribute towards the first of four steps — 'Refrain' — by avoiding impacts to and therefore retaining biodiversity. Our work identifies high-priority areas to be considered for protection. To achieve the target of increasing the existing 10% area protected in Sulawesi to 17%, 30%, and 50%, the principles of equity and collaboration with neighbouring communities prioritised under various MoEF initiatives, such FOLU Net Sink 2030, should be followed.

One option would be through OECMs with long-term conservation effectiveness outside of the designated PA network (IUCN-WCPA [2019]). Community-managed forests, such as Village Forest (Hutan Desa) schemes, offer an option for expanding the conservation area network (Alvard [2000], Hilser [2021]), as do privately managed restoration concessions, which could be managed under an Ecosystem Restoration Concession licence. Another framework such as indigenous lead conservation area could also be considered.

Currently, there is 207,000 km^2 of indigenous land in Indonesia, however, only 15% of it is certified (Hariandja [2022]). In Sulawesi there are 16,000 km^2 of indigenous land with the largest in the South Sulawesi province with 8,188.4 km^2 BRWA [2022b]. The second largest is in the Central Sulawesi province with 6,298.2 km^2, this includes five indigenous lands overlapping the Bangkiriang landscape: Taa Mpoa (168.5 km^2), Taa Salaki (236.7 km^2), Taa Vananga Bulang (220.1 km^2), Lipu Wana Posangke (305.8 km^2), and Wana Kayupoli (179 km^2) (BRWA [2022a]).

Increasing PA coverage is a key first step towards meeting the target of being nature-positive by 2030 set by the Global Goal for Nature (www.naturepositive.org). Following the first 'Retain' step, the Mitigation and Conservation Hierarchy's subsequent steps are to 'Reduce' the impact (e.g. through an agri-environment scheme), 'Restore' (e.g. ecosystem restoration concession), and 'Renew' (e.g. ecosystem creation or rewilding; (Milner-Gulland et al. [2021]). Reducing the environmental impact of mining and plantation concessions is a top priority. This is particularly important for the conservation of many species, such as the critically endangered Cerulean paradise flycatcher (*Eutrichomyias rowleyi*) that is endemic to Mount Sahendaruman, Sangihe Island. This species is highly vulnerable to habitat change because its entire range is within the PT Tambang Mas Sangihe gold mining concession, which encompasses half of Sangihe island. The Sangihe Island's significance was recognized as early as the early 80s by (MacKinnon and MacKinnon [1986]), who prioritised it for reserve establishment. The mitigation hierarchy's third step of restoring degraded areas aligns with the post-2020 target of restoring 20% of degraded terrestrial land and ensuring landscape connectivity. Indonesia may still fall short of this goal, with 7.6% (1,917 km^2) of degraded land on Sulawesi being assigned for protection. The final mitigation hierarchy step of renewal, or rewilding, is still a foreign concept in Indonesia, but one that is gaining popularity (Carver et al. [2021], Jepson and Blythe [2020]).

No set number for protection percentage will guarantee that the PA network ensures the survival of ecosystem processes and biodiversity. However, in the case of relatively small, safeguarded areas, it appears safe to say that, in general, the higher the percentage target, the better. Decisions must be science-based while also considering equity for rural communities that rely on natural resources and benefit from healthy ecosystem services (Sheherazade et al. [2019]). Although the focus of this study is on potential governance models, such as strictly managed PAs, to protect these vital but currently unprotected areas, it should be noted that protection does not always imply a fenced park. Other more participatory options, such as local community and indigenous people participation in conservation area management, are important and could be accommodated under future OECM designation, should this become an option. In the meantime, advancing Indonesia's FOLU Net Sink 2030 strategy remains vital to safeguarding Sulawesi's rich natural capital while providing critical benefits to its people.

4.6 Data Source and Software Used

All data used in this study is publicly available. The boundaries of protected areas can be found at protected planet website. Sulawesi's Land Use, Land Cover, and Forest Cover and the geology – ultramafic soil layer can be found here. The Forest Landscape Integrity Index can be found here. Sulawesi's karst layer can be found here. Carbon data can be obtained from Soto-Navarro et al. [2020]. Concession maps can be found at: i) industrial plantation forest, ii) natural forest management permit, iii) palm oil. The mining concession data are from here. The maps in this study, including those in the Supplementary Information, were created using GQIS Desktop 3.18.3 (https://qgis.org/en/site/). The priority area polygons resulting from this study are available at here.

5

Predictive and Causal Inferences for Investigating Species Richness Against Wild Meat Consumption in Sulawesi

5.1 Abstract

The foundation of ecological resilience is biodiversity, and islands generally exemplify both high biodiversity and endemicity. Because of their endemicity, island species are significantly more vulnerable to extinction than mainland species. We evaluate the vulnerability of such species in Sulawesi to determine: i) how species richness changes along environmental gradients; and ii) what effect hunting has for wild meat consumption and trade has on species richness. A Bayesian hierarchical multispecies occupancy model is used to draw predictive inferences from camera trap data and environmental variables. Most of our environmental predictors had a weak association with species richness and community occupancy. Elevation, however, was associated significantly with species occupancy: a higher altitude was positive for lowland anoa (*Bubalus depressicornis*), Sulawesi palm civet (*Macrogalidia musschenbroekii*) and the Malayan civet (*Vivera tangaluna*), and a lower altitude was positive for red junglefowl (*Gallus gallus*) and maleo (*Macrocephalon maleo*). Furthermore, areas with a high vegetation index are significantly related to the presence of the Sulawesi babirusa (*Babyrousa celebensis*). Further, we use a socioeconomic model in a causal inference framework and utilise expected species richness in Structural Causal Modelling (SCM), to determine what is causing its increase or decrease in connection to pressure from animal exploitation. This socioeconomic model demon-

strated that species richness increases with greater distance to, and difficulty of accessing, an area, and decreases with the presence of a wild meat market but, paradoxically, increases with the presence of a human population consuming wild meat. This apparent contradiction could be due to unknown, unmeasured variables, emphasising the need for caution when considering complex system elements. Our results show that even within protected areas (such as a national park), ecosystems are nonetheless affected by surrounding human-modified landscapes. This demonstrates the importance of conservation of landscape approaches across various scales.

5.2 Introduction

Bogani Nani Wartabone National Park is one of the areas highlighted in Chapter 4 (Pusparini et al. [2023]) as a conservation priority. Here, we examine the role of this park in conserving Sulawesi's rich biodiversity concerning two ecological parameters: species distribution and richness. In our model, we use community occupancy as a surrogate for species distribution. Community occupancy refers to the presence or absence of species within a specific habitat or geographical area, and is a crucial concept in ecology, reflecting the distribution patterns of different species across landscapes (Kery and Royle [2009], Rich et al. [2016], Tingley et al. [2020]). The distribution of species in each landscape is determined by biotic and abiotic interactions, known as ecological niches (Hutchinson [1978], Holt [2009]). Terrestrial species are influenced by a myriad of factors, including habitat suitability, resource availability, and ecological interactions (Hutchinson [1978]). Understanding community occupancy provides insights into the spatial dynamics of ecosystems and aids in conservation efforts by identifying areas of high biodiversity (Wainwright et al. [2018], Chase et al. [2020]).

Understanding species richness is crucial for assessing the overall health and stability of an ecosystem. A rich and diverse array of species can increase ecological resilience, offering stability and adaptability to environmental shifts, such as climate change (Mackinnon [2008]). However, ecological resilience is particularly vulnerable where there are many endemic species; for instance, where species are uniquely adapted to specific island environments (Manes et al. [2021]). Islands, such as Sulawesi, exemplify an intensified connection between endemicity and species richness (Kier et al. [2009]). Despite its proximity to Borneo and Papua, Sulawesi has a very different species makeup from these islands. For example, the proportions of amphibians, birds, mammals, and reptiles restricted to Sulawesi are 47%, 25%, 38%, and 26%, respectively, which are much higher than the neighbouring larger Borneo Island (proportion of endemic amphibians, birds, mammals, and reptiles are 51%, 4%, 9%, and 14%, respectively; data available online, Lee et al. [2007]). Sulawesi has 79 out of 127 mammals indigenous to Indonesia being endemic to Sulawesi (Riley [2010]), a majority of those are 72 known bat species in which 18 of which are endemic (Wiantoro et al. [2017]), and home to 76 native species of ro-

dents (Muridae and Sciuridae) and shrews (Soricidae), 73 of which occur nowhere else (Achmadi et al. [2023]). Sulawesi also has the highest number of endemic avifauna genera (12) globally (Lee et al. [2007]).

It was on the small nearby island of Ternate, and surrounding islets that in 1858 Alfred Russel Wallace pondered the concept of speciation, which led to his formulation, parallel to Darwin's, of the concept of evolution through natural selection (Wallace [1869a]). Consequently, the region was later named Wallacea (Myers et al. [2000]).

Despite the ecological importance of Sulawesi's biodiversity (Whitten et al. [1987]), anthropogenic factors pose significant threats to the region's species diversity. One such pervasive threat is the consumption of wild meat, which is firmly rooted in the practices and culture of the local human community of North Sulawesi (Weichart [2008], Laatung et al. [2019]). The three main ethnicities in the area are the Minahasan, Sangihe (originally from Sangir Island in the north of the main island), and the Bolaang Mongondow. The first two groups are mostly Christian, with wild meat consumption most prevalent among the Minahasan (Supit et al. [2021]). The third community, Bolaang Mongondow, is largely Muslim and has a prohibition on the consumption of wild meat. Due to its proximity to wild meat markets and the major hubs of the illegal wildlife trade in North Sulawesi, this feature sets BNWNP apart from other national parks in Sulawesi and is one of the reasons we decided to conduct our study there.

Investigating the influence of wild meat consumption on species richness in Sulawesi is critical for implementing effective conservation strategies. However, the first step is to undertake a reliable assessment of the local species richness and then to analyse the causal relationship with wild meat consumption. The Multi-species Occupancy Model (MSOM) is one of the most advanced approaches to predicting species distribution and richness without the bias of detection probability (Dorazio and Royle [2005], Kéry and Royle [2016]). The MSOM provides an accurate estimate of species richness in cases where not all species are observed during surveys (MacKenzie et al. [2018], Guillera-Arroita et al. [2019], Tingley et al. [2020]). A methodological advantage of occupancy models is that they explicitly account for 'imperfect detection' (MacKenzie and Kendall [2002], Mackenzie et al. [2002]), based on a hierarchical approach which partitions sources of errors between ecological and observational processes Mackenzie et al. [2002]. This acknowledges that not all species may be detected during field surveys due to diverse reasons, which may include elusive behaviour, limited sampling effort, or environmental conditions. By incorporating detection probability into the analysis, researchers can obtain more accurate estimates of species richness (Kéry and Royle [2016]).

Having ascertained species richness, it is possible to attempt the second and more challenging step of identifying underlying cause-and-effect relationships. Although the application of causal inference to achieve unbiased inference is hardly new (Marshall et al. [1948]), the science of exploring cause and effect using observational data only started

gaining traction when Joshua Angrist, Guido Imbens, and David Card received the Nobel Prize for their work on this subject in 2021 (Ball [2021]). This scientific breakthrough is especially significant because, whereas applying causal inference to experimental data is relatively simple (e.g. using the Randomized Control Trial - RCT (Stolberg et al. [2012]) it is difficult, and ethically challenging, to do so using observational data as in economics (hence the Nobel prize in the discipline), or, in our case, ecology and biodiversity conservation (Larsen et al. [2019]). This rekindled interest in causation is particularly exemplified by the work of Judea Pearl (Pearl [2009, 2010, 2012, 2016], Pearl et al. [2016]), who also pioneered the Bayesian Neural Network. The application of causal inference in ecology is both new and fruitful, as illustrated by the work of Suchinta Arif (Arif [2022], Arif and MacNeil [2022a,b, 2023]); it offers a solution to the long-standing problem of separating cause from effect on biodiversity observational data.
Drawing upon these recent advances in statistical inference we delve into the nuances of predictive inference and causal inference, demonstrating how both approaches contribute to a full understanding of ecological system dynamics. Specifically, we assess the vulnerability of endemic species to anthropogenic stressors by answering two questions: i) how species distribution changes along environmental gradients, and ii) how harvest—wild meat consumption and trade—affects species richness. The answers to these questions help us develop unbiased conservation plans.

5.3 Methods

5.3.1 Study Area

This study was undertaken in Bogani Nani Wartabone National Park (BNWNP), Sulawesi and its surrounding forest. The BNWNP is a 2,871 km^2 forested area (BTNBNW, n.d.). The landscape falls within the Wallacea ecoregion: a biodiversity hotspot that is rich in endemic and threatened species, such as babirusa (*Babyrousa celebensis*), anoa (*Bubalus depressicornis*), maleo *Macrocepahlon maleo*, black-crested macaque (*Macaca nigra*, and *Macaca nigrescens*) (BTNBNW). It is a rugged mosaic of lowland-montane primary rainforest that is buffered by secondary forest and agroforest systems and encompasses 130 rural villages (BPS-Statistic [2021, 2022]), which exerts anthropogenic pressures on the local biodiversity. It spans the two forest-rich provinces of North Sulawesi and Gorontalo, of which the latter ranked, socio-economically, as the fifth poorest province in Indonesia (BPS-Statistic, 2022). There are ethnic and religious differences between these provinces that affect biodiversity. North Sulawesi is predominantly (63%) Christian and exhibits significant wild meat consumption, compared to the Gorontalo which is primarily (97%) Muslim and religious prohibition has resulted in low wild meat consumption (BPS-Statistic, 2021, 2022). Overall, the predominant anthropogenic pressure on biodiversity in this region is the hunting and consumption of wild meat (She-

herazade and Tsang [2015], Rejeki [2018], Latinne et al. [2020]).

5.3.2 Data Collection

To collect species presence data, we conducted a camera trap survey in BNWNP and the surrounding forest (total of 3,000 km^2; Figure 5.1) from 15th September 2016 to 17th November 2019. We deployed 234 camera traps systematically in a random checkerboard pattern, each within a 4 km^2 grid cell, to collect detection/non-detection data from three different area blocks in BNW. Six camera traps with trap days less than 3 were discarded, and in total, we analysed 228 cameras: Southeast (n=61 cameras), West (n=53 cameras), and North (n = 114 cameras). Cameras were placed, without bait, 3–4 m from animal trails and 50 cm above the ground. Most cameras were continuously active for 3 months/station, and the mean distance between cameras was 2.9 km (Table A.4). The sampling design was optimised to increase the detection of terrestrial species by placing the cameras beside animal trails, openings, or areas with clear animal signs. Based on availability, we used a mix of three different camera brands — Reconyx, Bushnell, and Cuddeback — and considered this as a factor in species detection.

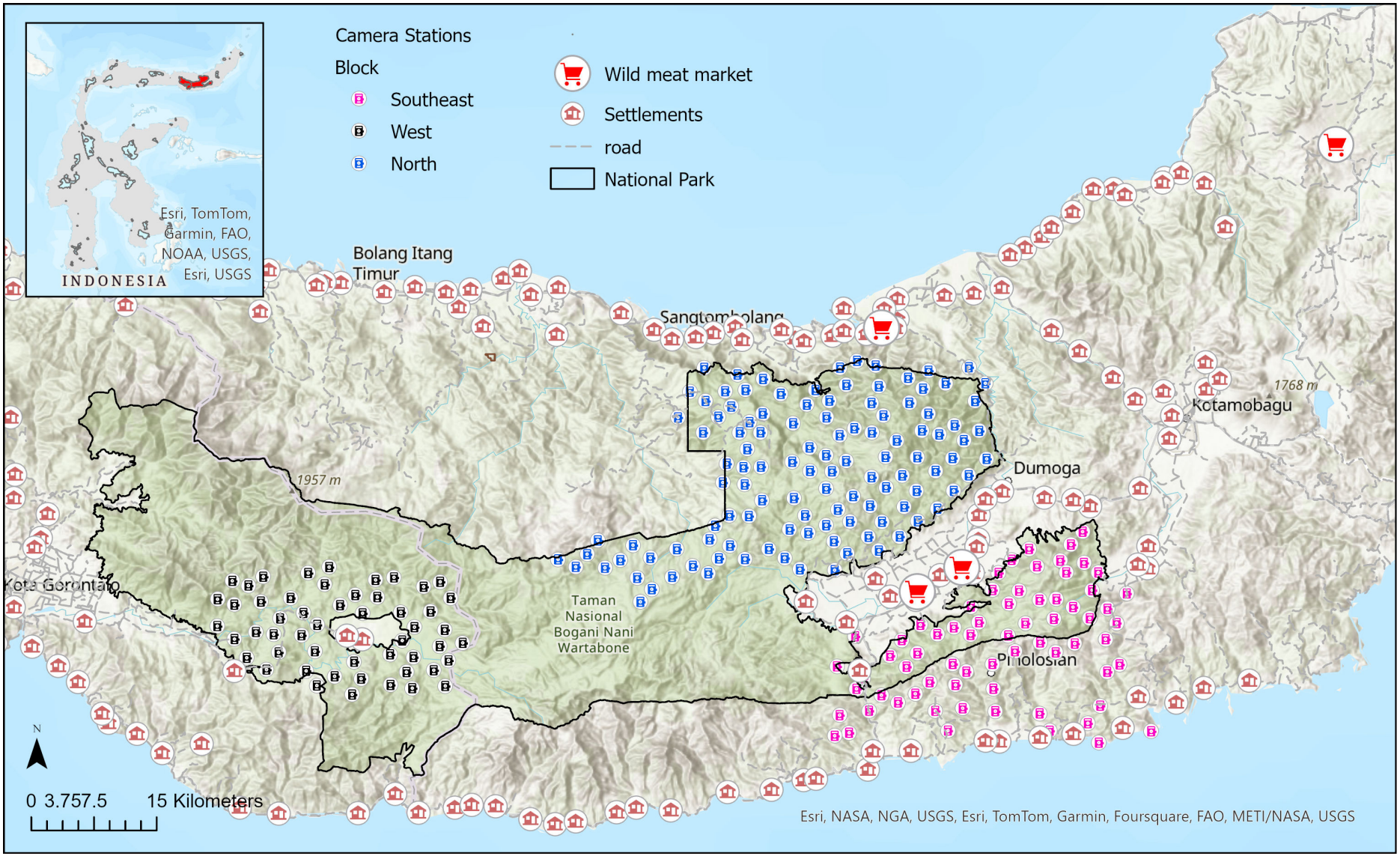


Figure 5.1: Camera trap stations in the Bogani Nani Wartabone Landscape, Sulawesi, Indonesia.

5.3.3 Analysis and Modelling Framework

The response variable and covariates

The response variable in the predictive inference is a detection-non-detection matrix from terrestrial species for which the data included three or more independent photographs (defining independence to include photographs timed at intervals of greater than 30 minutes, O'Brien et al. [2003]). Detection/non-detection matrices were developed from repeated, continuous 24-hour camera recordings, with a total of 148 replications. The photographs were identified to the species level if possible. The Wildlife Conservation Society and BNWNP staff worked together to identify all pictures, however, the rodent family proved difficult to identify. Therefore, specifically for rodents, the identification was done by a rodent expert from Esselstyn's Lab, Louisiana State University Museum of Natural Science, and a research assistant from Indonesia Technology Institute - Faculty of Bioscience. The first identification stage divides the photographs into three categories that lead to genus identification: body size (small, medium, large), tail length relative to head length (equal, long), and tail colour pattern (all dark, base bright-top dark, base dark-top bright). The research assistant completed this stage, while the rodent expert completed the last stage of species identification. To account for the influence of rare species on the analysis, we only included data from species detected $\geq$ three times during the 148 days of replication.

We then evaluated the following geographic factors as predictors: elevation, slope, vegetation index (NDVI), water (distance to the river), and edge effect (distance from the forest edge) (Table 5.1). All continuous covariates were standardised to have a mean of 0 and standard deviation of 1, checked for collinearity, and extracted to each camera station within a 500 m buffer radius from the camera point. Using Land Use and Land Cover data (Ministry of Environment and Forestry, Indonesia), we classified the study area into seven habitat types and further grouped these into three: primary forest, secondary forest, and non-forest, which included agriculture, bushes, grassland, open space, and water bodies. Additionally, we estimated how detection probability varied with different camera brands. When calculating species richness, we limit our analysis to those terrestrial species for two categories of reason: statistical and technological reasons associated with positioning each camera trap to optimize the capture of these types of species; and the fact that these terrestrial species are the type that mostly hunted for consumption.

Using parameter estimate from the first stage as the response variable (species richness (var = SpRich), we then ran a causal inference to answer the question of whether the wild meat hunter and/or consumer affected the change in species richness. We use four proxy covariates (Table 5.1). The presence of wild meat markets (var = Market) and the proportion of villagers who can eat wild meat (var = Demography) – are both factors potentially characterising wild meat consumers. The index of humans (excluding surveyors)

captured per trap nights of the camera (var = Intrusion), and an index of accessibility (var = Access_Dist) are factors potentially relevant to wildlife hunters. The accessibility index was built from Euclidean distance from villages, Euclidean distance from roads, and terrain slopes using the Principal Components tools in the Spatial Analyst toolbox of ArcGIS Pro. We used the 1st component of the PCA with the percentage of Eigen Values 95.7%. The Euclidean distance between the village and the road provided a proxy (since it is 2D rather than 3D) for how far a site is from human habitation. The third factor, ruggedness, indicates how 'difficult' the location is to access. Ruggedness is the difference in elevation between adjacent units of land. Using ruggedness with roads and villages means that the 3D terrain information is taken into consideration when generating 'accessibility' variables.

Table 5.1: The list of covariates used, their extraction method, and their source.

Covariates	**Extraction Method**	**Source**
Elevation	Extracted the raster value of the DEM (Digital Elevation Model) SRTM (Shuttle Radar Topography Mission) 30 m to the camera location in ArcGIS Pro.	United States Geological Survey (USGS) - `https://earthexplorer.usgs.gov/` and `https://www.indonesia-geospasial.com`
Slope	Generated from the DEM SRTM 30m layer above using Slope Tool in ArcGIS Pro, then extracted to the camera location	
Landsat Normalized Difference Vegetation Index (NDVI)	Extracted the NDVI layer value to the camera location in ArcGIS Pro.	United States Geological Survey (USGS) - `https://earthexplorer.usgs.gov/` and `https://www.indonesia-geospasial.com`
River	Extracted the Euclidean distance from the river to the camera location in ArcGIS Pro.	`https://geoaccess.id/dataspasial/`
Land Use Land Cover	Categorical value for seven classes. Each camera point corresponds to a certain class.	Indonesia Ministry of Environment and Forestry - `https://tanahair.indonesia.go.id/portal-web/inageoportal/#/`

Table 5.1: Covariates Extraction Methods and Sources (continued)

Covariates	**Extraction Method**	**Source**
Forest Edge	A Euclidean distance measured from the forest cover layer's border. Forest cover is one of the seven Land Use Land Cover classifications listed above.	Indonesia Ministry of Environment and Forestry - `https://tanahair.indonesia.go.id/portal-web/inageoportal/#/`
Market Location	The presence and absence values of camera traps in the block adjacent to the wild meat market. Essentially, all cameras in the north and southeast have a value of one, while those in the west have a value of zero.	Badan Pusat Statistik Sulawesi Utara – Central Agency of Statistic
Demography	The percentage of the community who identify as Christian, Catholic, or Hindu within each village.	Badan Pusat Statistik Sulawesi Utara – Central Agency of Statistic
Human Index	Capture rate of people who are not survey participants or national park employees. The rate is calculated as the number of independent photographs captured per trap night.	Data from this study camera traps array
Accessibility:	Accessibility: The principal component layer was created using the spatial PCA in ArcGIS Pro's Spatial Analyst tool, using input from the three layers below: village, road, and TRI.	
- Village	Village - A Euclidean distance layer from each village's centroid.	Village: Badan Pusat Statistik Sulawesi Utara – Central Agency of Statistic
- Road	Road - A Euclidean distance layer from the road.	Road: `https://www.indonesia-geospasial.com`

Table 5.1: Covariates Extraction Methods and Sources (continued)

Covariates	Extraction Method	Source
- Terrain Ruggedness Index (TRI)	TRI - A spatial layer representing ruggedness (the amount of elevation variation between neighbouring cells of a DEM), created from the DEM SRTM 30m using the Spatial Analyst Tool in ArcGIS Pro.	DEM: USGS - `https://earthexplorer.usgs.gov/` and `https://www.indonesia-geospasial.com`

5.3.4 Making the hypotheses explicit with a graph

In Figure 5.2, we explicitly graphed our assumptions on the predictive estimate of parameters associated with species and community occupancy, as well as the causative relationship between wild meat customers and wildlife hunters and species richness. Subsequently, we test the relationship between variables in the graph more formally by using a Directed Acyclic Graph (DAG). The DAG for the predictive inference is, as Richard McElreath expressed it, a 'causal salad' (McElreath [2020], Arif and MacNeil [2023]); this suits our aim to explore the association of the three ecological indicators (species and community occupancy, species richness) with the environmental covariates. For the causal inference DAG, we test the DAG consistency and adjust it as needed (Pearl et al. [2016], Textor et al. [2016]). We appreciate that the model is a simplified representation of reality; for example, we neither measured, nor took account of, urban wild meat consumers, and since we could not measure the direct effects of hypothesised independent variables, wild meat consumers and hunters, we used proxy variables.

Predictive inference using hierarchical model to estimate occupancy and species richness.

To assess the effect of environmental variables on species richness and habitat use, we used the Bayesian hierarchical Multispecies Occupancy Model (MSOM) (Dorazio and Royle [2005], Kéry and Royle [2016]). The most basic MSOM investigates the community as a single unit, using hierarchical random effect structures on both the slope and intercept parameter to relate many different species into a single 'community', the community model or 'multi-species' occupancy model (MSOM) (Dorazio and Royle [2005], Kéry and Royle [2016]). In a hierarchical structure, MSOM connects species-specific detection and occupancy (habitat used), which are then calculated across species and at the community level (Zipkin et al. [2009]). By performing a composite analysis of communities or guilds, we rationalised the detection of each species in the community, improving inference even

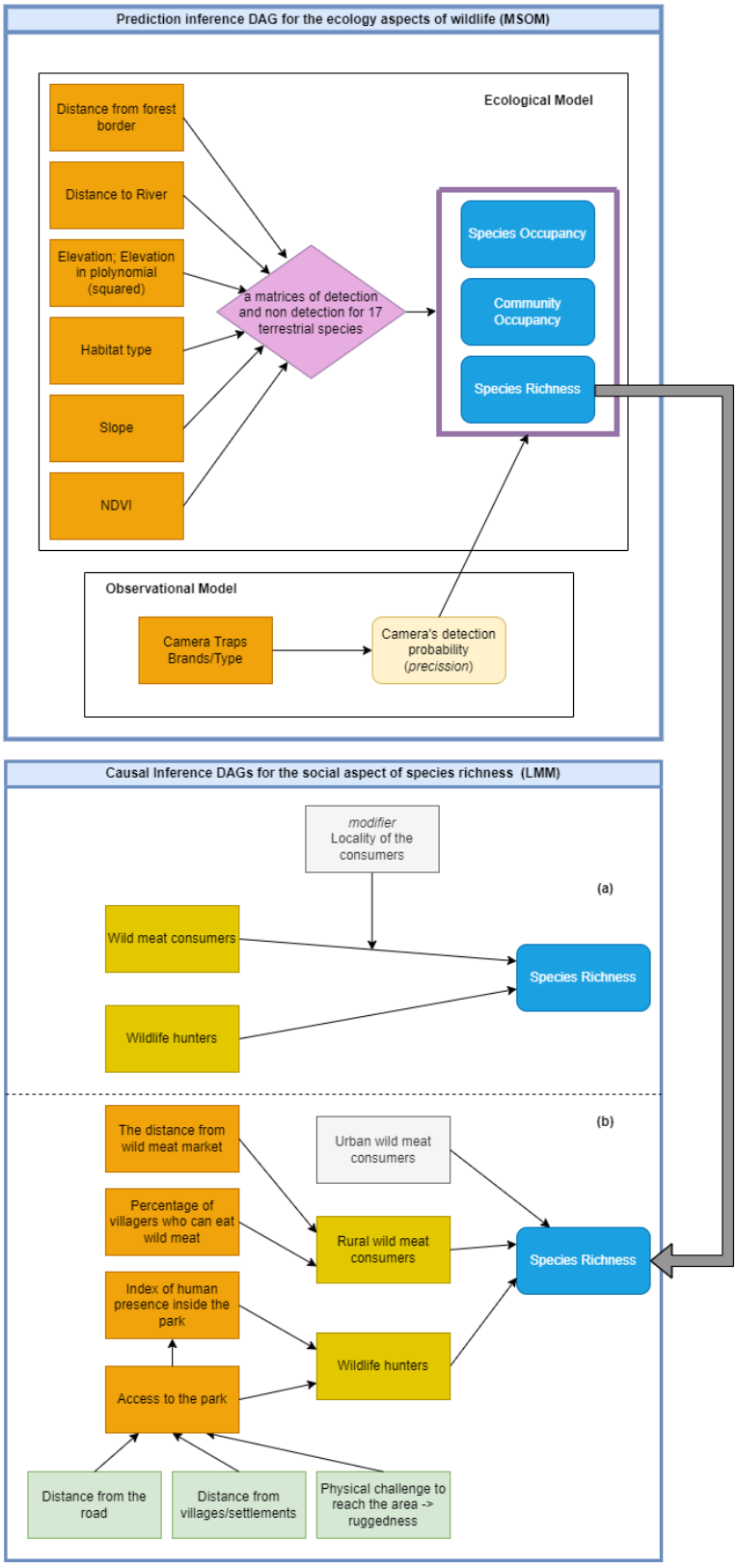


Figure 5.2: DAGs for the predictive and causal inferences. The blue box is the dependent variable, the orange box is the independent/covariate variable (or proxy independent variable for the causal inference DAG), the yellow box is the precision variable, the lime-green box is the unobserved independent variable, and the grey box is the unobserved confounding variable.

for those with low detection levels (Bayesian shrinkage, i.e. borrowing strength from the ensemble) (Zipkin et al. [2009], Penjor et al. [2021]). The key to using MSOM as a method in community ecology is the use of Data Augmentation in a Bayesian framework to estimate the true number of species (N) by accounting for both species that were detected at least once and unidentified species that were never detected (Dorazio and Royle [2005], Iknayan et al. [2014], Tingley et al. [2020]).

We then developed a model that assumed the site-specific occupancy for species to be $k = 1, 2, \ldots, N$ at site $i = 1, 2, \ldots, i$, denoted $z_{i,k} = 1$ if species k occurs at site i and 0 otherwise. The latent ecological process for the true pattern of occurrence is specified as $z_{i,k} \sim Bernoulli(\psi_{i,k})$, where $\psi_{i,k}$ is the probability that species k occurs at site i. The observational process $y_{i,k}$ is another random variable that is conditional on the occurrence of $z_{i,k}$, wherein the model is $y_{i,k}|z_{i,k} \sim Bernoulli(z_{i,k} \times p_{i,k})$ if the species present $z_{i,k} = 1$ is detected with a probability of $p_{i,k}$. The sum of Bernoulli trials results in a Binomial distribution and the observation $y_{i,k}$ can be rewritten as $y_{i,k} \sim Binomial(z_{i,k} \times p_{i,k}, n_i)$, in which n is the total number of active camera days in each site (i.e., trials). We introduced the effects of covariates cov_i at each site i using the logistic ("logit") link function as $logit(\psi_{i,k}) = \alpha_{0,k} + \alpha_{k,x} cov_i$, where $\alpha_{0,k}$ is the normally distributed, species-specific random effect (intercept), $\alpha_{0,k} \sim Normal(\psi_{\alpha_{0,k}}, \sigma^2_{\alpha_{0,k}}), \sigma^2_{\alpha_0}$ is the variance that specifies the occupancy probability of species k at site i, and $\alpha_{k,x}$ is the effect (slope) of the site covariate on species k with a normal distribution, $\alpha_{k,x} \sim Normal(\psi_{\alpha_{k,x}}, \sigma^2_{\alpha_{k,x}})$. Detection probability was modelled similarly as specified below.

We specified the following process model (ecological), with land use type and survey blocks as the random effect:

$$\begin{aligned} logit(\psi_{i,k}) = \alpha_1 + \alpha_{k,2} \times Slope_i + \alpha_{k,3} \times \\ Elevation_i + \alpha_{k,4} \times Elevation_i^2 + \\ \alpha_{k,5} \times Distancetoriver_i + \alpha_{k,6} \times VegetationIndex_i + \\ \alpha_{k,7} HumanAccess_i + \beta_{k,8} HabitatType_i + \\ \beta_{k,9} \times SurveyBlock_i \\ z_{i,k} \sim dbern\psi_{i,k} \end{aligned} \tag{5.1}$$

Whereas the following observation model was specified for replicated detection/non-detection observations:

$$\begin{aligned} logit(p_{i,k}) = \beta_{k,1} + \beta_{k,2} \times CameraType_{Reconyx} + \\ \beta_{k,3} \times CameraType_{Bushnell} + \\ \beta_{k,4} \times CameraType_{Cuddeback} \\ y_{i,k} \sim dbinp_{i,k} \times z_{i,k}, nOcc_i \end{aligned} \tag{5.2}$$

A normal prior was used for both means of hyperparameter (intercept and slope), and a weak informative folded student-t prior with 4 degrees of freedom was used for the standard deviations (Gelman [2006], Penjor et al. [2021]). The models were run in JAGS 4.3 through R 4.1.2 using the jagsUI package with three parallel chains of 200,000 MCMC iterations each, with 20,000 discarded during the adaptation phase, no burn-in, and 100 thinned. The convergence was assessed visually by inspecting the trace plots and ensuring that the Gelman-Rubin statistics were less than 1.1.

Causal inference with Structural Causal Model (SCM) to investigate the social-anthropogenic factors affecting the harvest of wild animals.

In this study we investigate the causal relationship between factors describing levels of wild meat use, such as the presence of wild meat consumers, the presence of trade activity on wild meat, the accessibility of wildlife to harvest, and the level of species richness in the forest. To do so, we borrow the concept of causal inference, widely employed in fields such as epidemiology and adapted carefully to our purpose using observational data (Laubach et al. [2021], Arif [2022], Arif and MacNeil [2023]). We used an SCM (Structural Causal Model) which specifically describes how nature assigns values to variables of interest (Pearl [2012], Arif and MacNeil [2022b]) to explore the causality between our proxy variables and the dependent variables. To achieve this, we followed the steps described by (Arif and MacNeil [2023]). First, we created the DAG using the dagitty R package (Textor et al. [2016]). Figure 5.3 depicts the DAG with SpRich as the dependent variable representing the species richness. Two proxy independent variables for wild meat consumers are Market (representing the categorical variable of whether a wild meat market exists in the vicinity), and Demography (which denotes the social characteristics (religion) of the population with the higher probability of consuming wild meat). The two proxy variables for wild meat hunters are Access_Dist (which represents an index of distance from road and settlement, and ruggedness as a matrix of how easy or difficult it is to access an area), and Intrusion (which is an index of how many times a human (non-surveyor) photographed by the camera trap per day that camera was active). Note that we indicate the possibility of intrusion as a collider, as how accessible an area is (Access_Dist) affects whether a person will go there (Intrusion), and then possibly be photographed by the camera trap.

The second step involves testing the consistency of the DAG using the dagitty R package (Textor et al. [2016]), which uses a formal test of zero correlation to test whether each identified dependency in our DAG is consistent with the data set (Textor et al. [2016], Arif and MacNeil [2023]). This is achieved by applying an adjustment backdoor criterion. We used the minimal sufficient adjustment with direct effect (the average direct effect, Pearl's single door criterion (Pearl [2009]). The third step is choosing a statistical model. We used linear mixed models with the species richness as the dependent variable, the

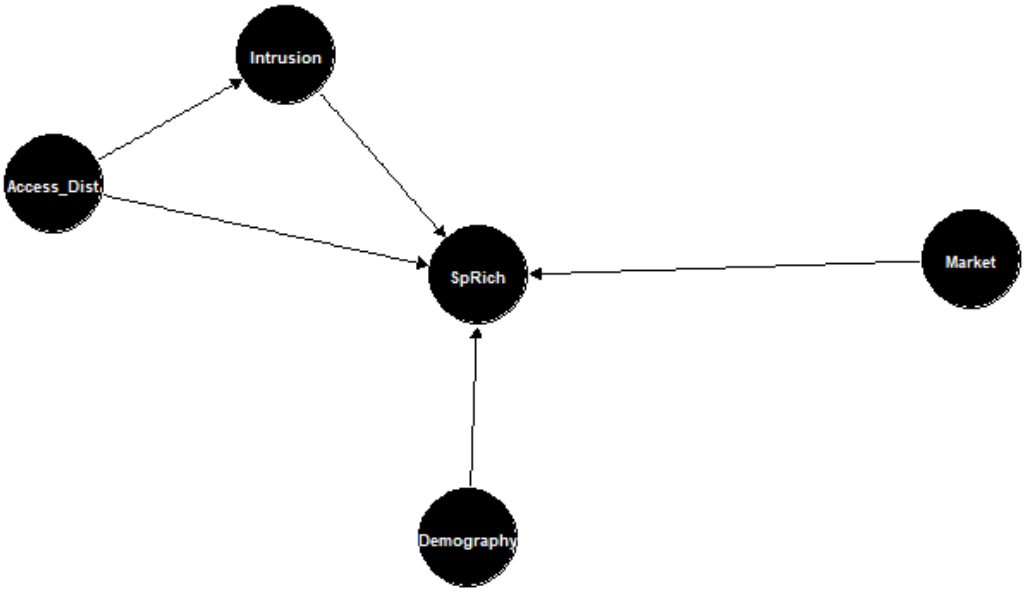


Figure 5.3: DAGs for the causal inferences. 'Intrusion' could be a collider variable which we will need adjustment.

four proxy variables as independent, and the year as the random effect variable. Instead of putting the variables all in a single model like this,

$$identity(Y_i) = x_1 Wildmeatconsumer + x_2 Wildmeathunters + \cup_i Year + \in_i \tag{5.3}$$

The final step of estimating the causal effect was accomplished with a Structural Causal Model (SCM). When a backdoor criterion is utilised, causal estimation can be performed without the need for all variables in a DAG to be available (Pearl [2009], Arif and MacNeil [2023]). For example, the effect of wild meat consumption on species richness requires observational data based solely on market and/or demographic characteristics. By only adding variables that are required to answer specific causal inquiries, researchers can improve estimation accuracy by limiting their reliance on noisy and irrelevant data (Pearl [2009], Pearl et al. [2016], Schoolmaster et al. [2020], Arif [2022]).

5.4 Results

From 18,769 trap nights and 228 camera stations, we recorded and identified 54 species, which included 31 birds, 22 mammals (half, 11, were rodents), and one reptile (Table A.5). Around 65% (n=35) of these species are endemic to either Sulawesi or Northern Sulawesi, particularly the mammals in which only three species (and the other three being feral species) are non-endemic. About one-third of the identified species (35%, n = 19) were found in all land classes: primary and secondary forest, and non-forest area (Figure A.1). Seventeen terrestrial animals, including two land birds and fifteen mammals, are

Table 5.2: Summary of the terrestrial species found and used in the analysis of this study through camera trap surveys in the Bogani Nani Wartabone Landscape, Indonesia, with their IUCN Red List status, endemicity, and body mass.

No	Scientific name	Common name	Class	IUCN	Endemic	Bodymass
1	*Babyrousa celebensis*	Sulawesi babirusa	Mammal	VU	Yes	100 kg
2	*Bubalus depressicornis*	Lowland anoa	Mammal	EN	Yes	150-300 kg
3	*Bunomys chrysocomus*	Common hill rat	Mammal	LC	Yes	55-135 gr
4	*Echiothrix leucura*	Northern Sulawesi spiny rat	Mammal	EN	Yes	215-310 gr
5	*Frateromys fratrorum*	Northeastern Peninsula hill rat	Mammal	VU	Yes	-
6	*Gallus gallus*	Red junglefowl	Aves	LC	No	1-1.5 kg
7	*Macaca nigra*	Celebes crested macaque	Mammal	CR	Yes	5.5-9.9 kg
8	*Macaca nigrescens*	Gorontalo macaque	Mammal	VU	Yes	5.5-5.8 kg
9	*Macrocephalon maleo*	Maleo	Aves	EN	Yes	1.3-1.8 kg
10	*Macrogalidia musschenbroekii*	Sulawesi palm civet	Mammal	VU	Yes	6 kg
11	*Maxomys musschenbroekii*	Musschenbroek's spiny rat	Mammal	LC	Yes	95-240 gr
12	*Prosciurillus murinus*	Celebes dwarf squirrel	Mammal	LC	Yes	42-110 gr
13	*Rattus xanthurus*	Northeastern Xanthurus rat	Mammal	NT	Yes	1.5 kg
14	*Rubrisciurus rubriventer*	Sulawesi giant squirrel	Mammal	VU	Yes	500-860 gr
15	*Sus celebensis*	Sulawesi warty pig	Mammal	NT	Yes	40-70 kg
16	*Tarsius tarsier*	Spectral tarsier	Mammal	VU	Yes	80-160 gr
17	*Vivera tangaluna*	Malay civet	Mammal	LC	No	2-5 kg

used in the analysis (Table 5.2). At each camera station, the estimated species richness (N) is on average 4 species (range 1 to 11).

5.4.1 Environmental factors associated with species occupancy and richness

The estimated species richness in each site (camera station) is a maximum of 11 species, which is less than the total number of species in our input data (17 species); this is as expected given the mix of several taxa (Mammals and Aves) with varying ecological niches. By including only those detected $\geq$3 times in the camera arrays, we consider it safe to use the expected number of species (N) as species richness. The terrestrial species community had a mean occupancy probability of 0.15 (95% Bayesian credible interval (CRI) 0.04–0.27) and a mean community detection probability of 0.052 (0.03–0.07) (Table A.6). Specific for each species, the Gorontalo macaque (*Macaca nigrescens*) is the most widespread in distribution with an occupancy value of 0.78 (0.73-0.83), and the second most widespread is the Sulawesi wild pig (*Sus celebensis*) with occupancy value 0.76 (0.70-0.82) (Table A.7, Figure 5.4). The most restricted in distribution are the Sulawesi spiny rat (*Echiothrix leucura*) with an occupancy value of 0.013 (0.001-0.03) and the yellow-haired hill rat Bunomys chrysocomus with 0.017 (0.003-0.03). This is aligned with the differences in the biomass, with the species with restricted distribution, rats, having body weight almost 1,000 times lighter than the widely distributed wild pig.

Distance from the edge of the forest is the only predictor that has a medium strength of association with community occupancy (0.14, 0 – 0.32), the remainder having only

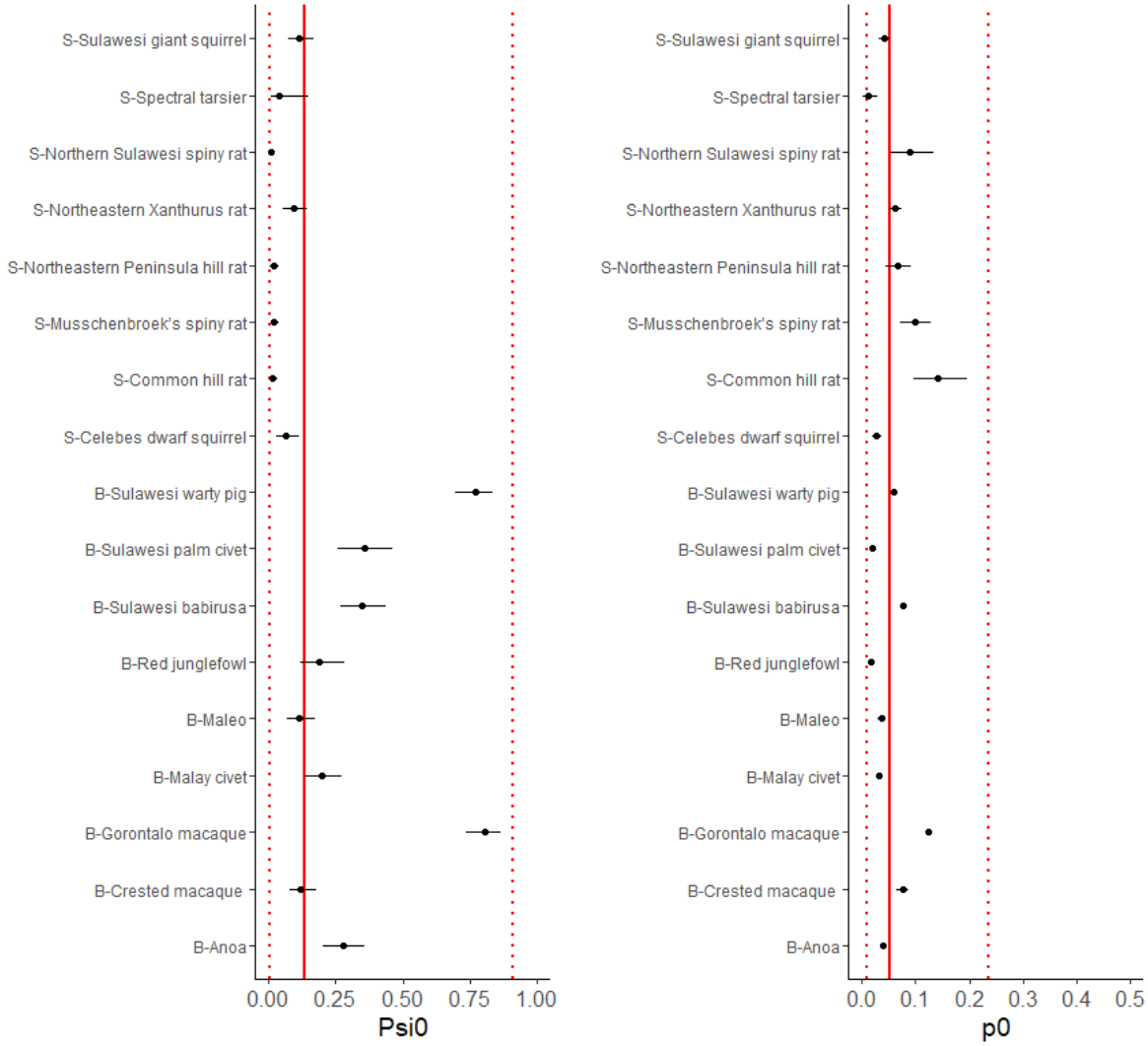


Figure 5.4: Estimate of individual species occupancy (Psi0) and detection probability (p0). The community occupancy (0.15, SD 0.07) and community detection probability (0.05, SD 0.01) are represented by the red vertical line. The species with names starting with "B" are classified as having a large body size, while those beginning with "S" are classified as having a small body size. The large-bodied species have a higher occupancy (due to their larger home range) than the small-bodied species, but they are generally less common (lower detection probability) than the small-bodied species.

weak association: elevation, polynomial elevation, vegetation index and distance to the river are weakly positive, while the slope is weakly negative (Table S3, Figure 5.5). None of the habitat types has a strong association with community occupancy (both primary and secondary forests are associated negatively, and the non-forest area positively).

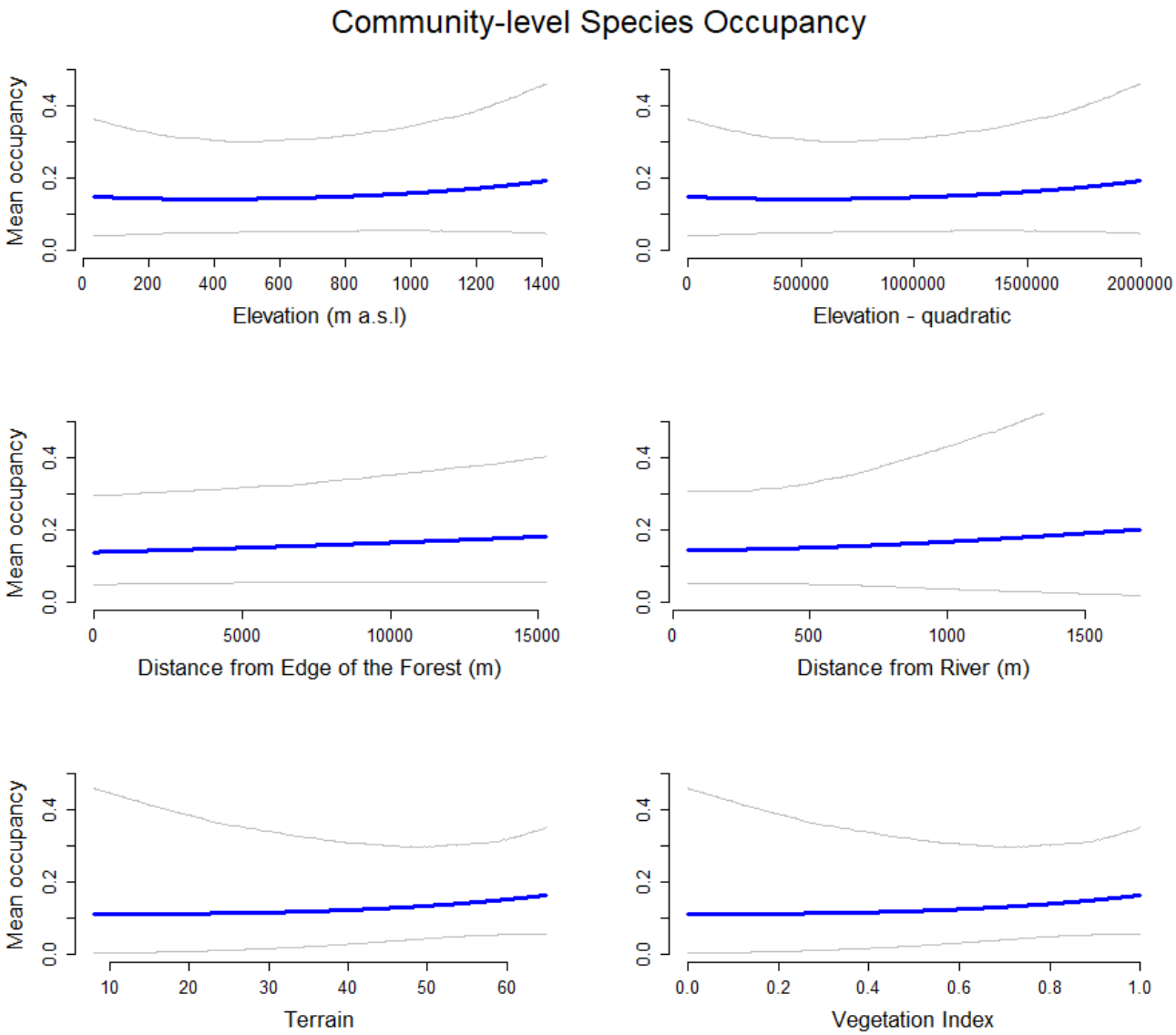


Figure 5.5: The mean occupancy probability of 17 species in this study, as well as their responses to environmental conditions. Occupancy reflects the probability that a specific species is present or occupies the region of Bogani Nani Wartabone National Park, with one indicating presence and zero indicating absence. The blue lines show the mean posterior distribution, while the grey lines bound the uncertainty, expressed using the 95% Bayesian Credible Interval (CRI).

Elevation in a quadratic term, distance from forest boundary, distance to the river, and slope all have a weak positive relationship with species occupancy (Figure 5.6). Elevation in a linear term, on the other hand, has a significant relationship with species occupancy: higher altitude for lowland anoa (*Bubalus depressicornis*) and Sulawesi civet (*Macrogalidia musschenbroekii*), and lower altitude for red junglefowl (*Gallus gallus*) and maleo (*Macrocepahlon maleo*). Furthermore, locations with a high vegetation index have a significant relationship with Sulawesi babirusa (*Babyrousa celebensis*).

5.4.2 Effect of harvesting and consuming of wild animals to species richness.

The Access and intrusion model:

On the Access distance effect on Species richness, the minimal sufficient adjustment with direct effect demonstrates that we must additionally account for Intrusion (Figure 5.7, left). A linear mixed effect model indicates that increasing the difficulty for people to reach an area increases the species richness in that area by 0.27. In contrast, increased human interference in each area reduces species richness by 0.16.

$$\begin{aligned} Sp.richness = -0.16 + 0.27 \times AccessDistance + -0.16 \times Intrusion + \\ 0.08 \times Year_{2016} + 0.84 \times Year_{2017} + \\ -0.67 \times Year_{2018} + -0.25 \times Year_{2019} \end{aligned} \tag{5.4}$$

The same application of adjustment to the intrusion model below (Figure 5.8), leads to the same conclusion that Intrusion is a collider variable in which its direct effect depends on the presence of Access distance. The magnitude of the effect then aligns with that of the previous model, with increasing intrusion by humans causing the decrease in species richness.

The Demography model:

The minimum sufficient adjustment revealed that no other variables needed to be adjusted to evaluate Demography's causal effect on Species richness (Figure 5.9). We infer that a rise in Demography, or the fraction of the population that consumes wild meat, causes a 0.09 increase in species richness. This conclusion is counterintuitive and could be due to other unmeasured variables (for example, the demographics of urban customers).

$$\begin{aligned} Sp.richness = -0.20 + 0.09 \times Demography + -0.22 \times Year_{2016} + \\ 0.90 \times Year_{2017} + -0.72 \times Year_{2018} + \\ -0.40 \times Year_{2019} \end{aligned} \tag{5.5}$$

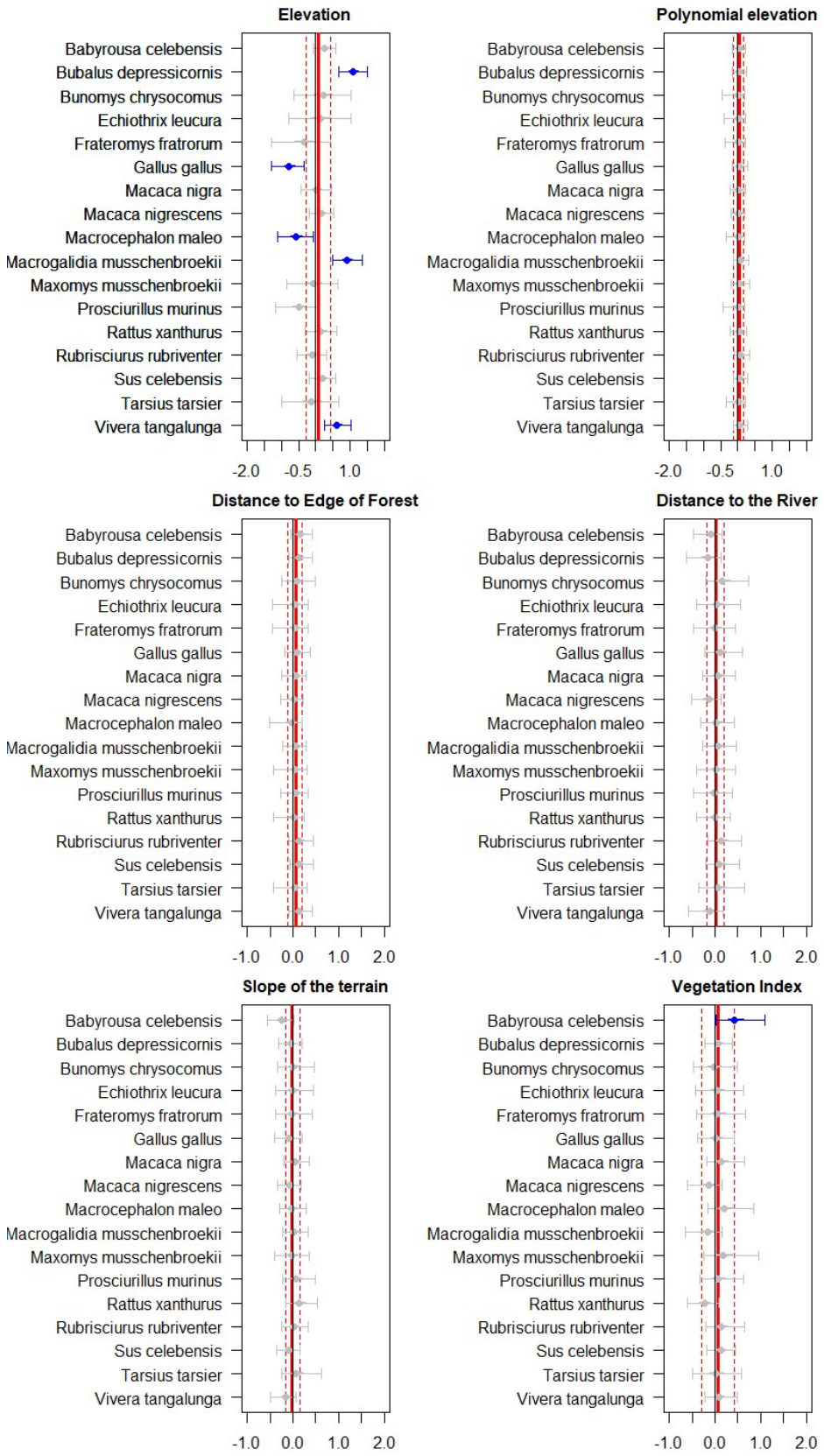


Figure 5.6: Association of the species occupancy with the environmental covariates. The closed circle points reflect the linear predictor's beta coefficient ($\beta 1$). Blue circle points represent a significant relationship. Error bars show 95% Bayesian credible ranges for coefficient estimations. Apart from elevation and vegetation index, none of the other covariates has a strong association with the species occupancy.



Figure 5.7: The backdoor paths for the direct effect of Access distance to Species Richness.

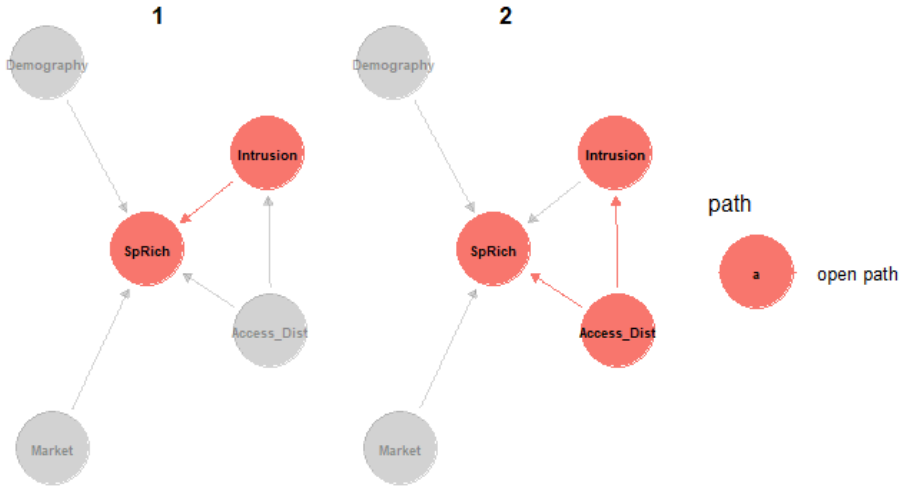


Figure 5.8: The backdoor paths for the direct effect of Intrusion to Species Richness.

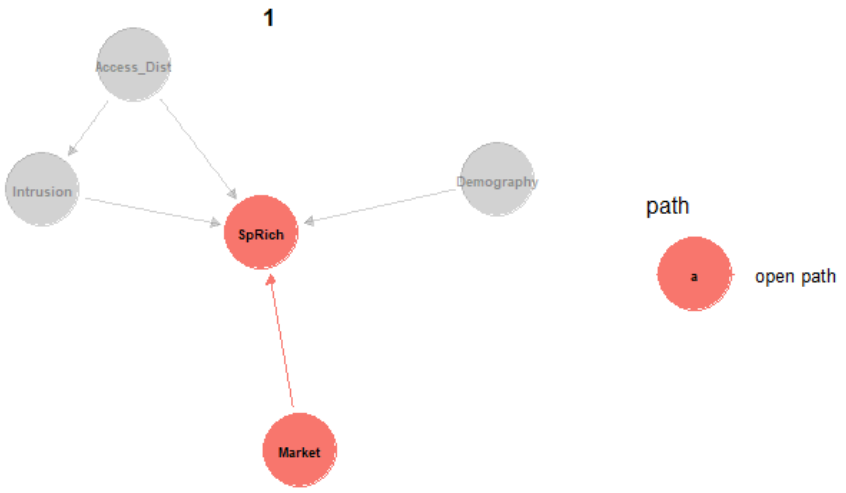


Figure 5.9: The backdoor paths for the direct effect of Demography to Species Richness.

The Market model:

The minimum sufficient adjustment revealed that no additional variables were required to evaluate the causal effect of the Market on Species richness. We find that the presence of a wild meat market reduces species richness by 1.16.

$$\begin{aligned} Sp.richness = -0.67 + -1.16 \times Market_{presence} + 0.55 \times Year_{2016} + \\ -0.00 \times Year_{2017} + -0.44 \times Year_{2018} + \\ -0.11 \times Year_{2019} \end{aligned} \tag{5.6}$$

Overall finding

Overall, the SCM demonstrated that the more people intruded into the park and the less accessible the location, the greater the species richness (by factor of -0.16 and 0.27). The SCM also revealed that the presence of wild meat markets reduced species richness (by a factor of -1.16), but with the unexpected conclusion that a higher number of wild meat consumers in the local vicinity increases species richness (by a factor of 0.09). Compare this number to the coefficient that comes from running the model without SCM:

$$\begin{aligned} Sp.richness = 0.80 + 0.29 \times AccessDistance + -0.15 \times Intrusion + \\ -1.20 \times Market_{presence} + 0.12 \times Demography + \\ 0.27 \times Year_{2016} + -0.00 \times Year_{2017} + \\ -0.28 \times Year_{2018} + 0.01 \times Year_{2019} \end{aligned} \tag{5.7}$$

The coefficient estimates without SCM underestimated the effect of human intrusion (-0.15) while overestimating the effects of access (0.29), market presence (-1.2), and wild meat consumers (0.12). However, the direction of the effects is still the same.

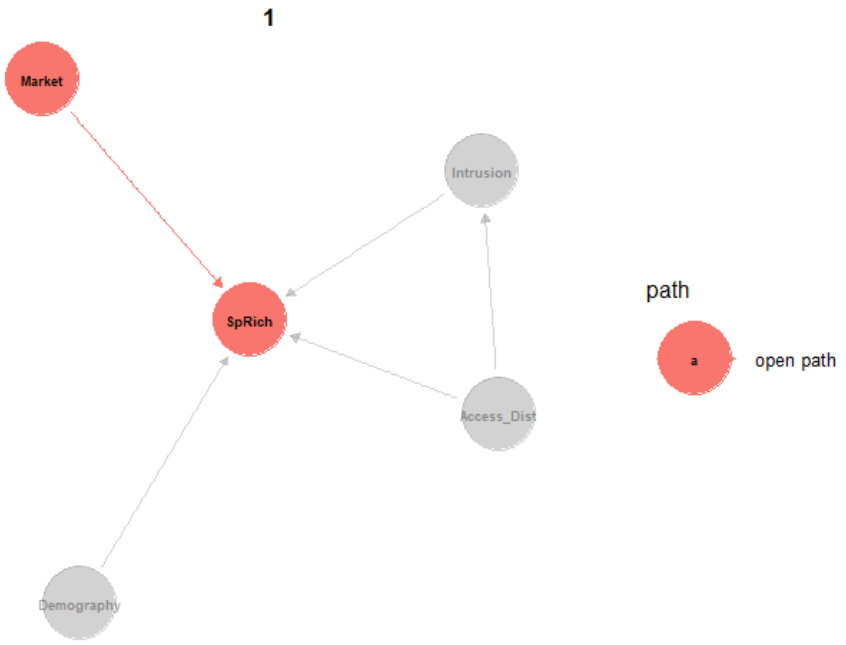


Figure 5.10: The backdoor paths for the direct effect of Market to Species Richness.

5.5 Discussion

Our findings emphasize the need to use both predictive and causal inferences to answer questions regarding diverse elements of terrestrial animal-human interactions. The survey we undertook using camera traps in BNWNP was also the first systematic assessment at a large spatial scale in any Sulawesi National Park. Furthermore, our findings provide the first estimate of species occupancy as a measure of habitat usage and distribution. Using the framework presented here and combined with future surveys in this area (conducted by the BNWNP and WCS-Indonesia Program), we can provide an assessment of population trends, which is crucial for evaluating and monitoring species conservation in BNWNP.

5.5.1 Species distribution and its changes along environmental gradients.

The fact that more than half (65%) of the identified-recorded species are endemic emphasizes the importance of BNWNP. Aside from the well-known charismatic Sulawesi species such as the anoa, babirusa, and the black macaque, the great diversity of rodent species is noteworthy. Sulawesi has 69 rodent species, 59 of which are endemic (Musser [1981], Wainer [2016]). Among these, one species is Critically Endangered, four are Endangered, eight are Vulnerable, three are Near Threatened, twelve are Least Concern, and the remaining 32 species are either Data Deficient or have not yet been assessed on the IUCN Red List (Louys et al. [2018], 2018, IUCN Web page search result on 'Rodent' with 'Australasian' filter in Biogeographical realm). This latter, poorly documented,

group may very probably increase in number, as in the previous decade alone, five new species have been identified on this island: *Margaretamys christinae*, *Waiomys mamasae*, *Bunomys karokophilus*, B. *torajae*, and *Hyorhinomys stuempkel* (Mortelliti et al. [2012], Musser [2014], Esselstyn et al. [2015], Rowe et al. [2016]). In this study, we found that half of the mammal species we identified are rodents, including the endangered Sulawesi spiny rat (*Echiotrix leucura*). This highlights a challenge in their conservation insofar as rodents are among the wild animals most favoured as food in North Sulawesi (Laatung et al. [2019], Latinne et al. [2020], Bailey et al. [2021]).

Our study encompasses the BNWNP distribution of two endemic threatened macaques of Sulawesi, encompassing almost the entire range of the Gorontalo macaque and a small part of the western range for the yaki or black-crested macaques (Riley [2010]), which have no spatial overlap (Johnson et al. [2019]). Our findings revealed that the Gorontalo macaque occupies 78% of BNWNP. While the yaki have only a portion of their range in the BNWNP, they occupy only 13% of the area. The Sulawesi palm civet, which was previously assumed to be quite rare and spatially confined (Wemmer and Watling [1986], Veron [2001]), now appears to be relatively widely distributed (Lee et al. [2003], Hunowu et al. [2019]), occupying 38% of the study area in this study (coinciding closely with the habitats used by the babirusa (37%) and anoa (32%)). It is worth noting that, while one-third of the area records a relatively high distribution index for the Sulawesi civet, the index for the babirusa is low, considering that the Sulawesi wild pig occupies 76% of the study area. Both endemic wild pigs are favoured as food, although the babirusa is not been sold publicly since its sale was banned in 1993 (Clayton et al. [1997], Milner-Gulland and Clayton [2002]) and its distribution range in the island greatly reduced (Riley [2002], Leus et al. [2016]).

The heterogeneity of the niche these species inhabit is also reflected in the small number of regions they are projected to occupy, a mere 0.16, or 15% of the entire area (Figure 5.4), with no environmental predictors showing significant relationships (Figure 5.5). This low value of area occupied is mostly caused by the species occupancy of smaller animals, specifically rodents. The rodents range in size from 40 grams to 1.5 kg (Table A.5), with occupancy values ranging from 0.01 to 0.14, or 1 - 14% of the total area surveyed. The distance between cameras ($\sim$ 2 km) may not allow for proper sampling of rats and other small animals in our species list. This could also explain why, except for extensively spread large species like the Sulawesi wild pig and the Gorontalo macaque (Figure 5.4 and 5.6), only the occupancy of larger animals shows a strong association with an environmental variable. Despite this, the occupancy value reported here can be a good baseline for any future population monitoring efforts for these species (assuming comparable coverage and the same sampling protocols).

Poaching poses a severe threat to anoa, which has been exterminated from many of its former habitats (Burton et al. [2005], Arini et al. [2020]). This may explain why they occur

only in the upper reaches of the Bogani Nani Wartabone terrain, as we demonstrate; their current functional niche may not be optimal. Both civets in Sulawesi, the Sulawesi palm civet, and the Malayan civet, are also associated with higher altitude in this landscape, although the hunting pressure on them for wild meat consumption in Sulawesi is not as high. It is also hard to discern whether this represents their optimal niche. The Malayan civet, which is an introduced species in Sulawesi (Veron et al. [2014]), is associated more with lowlands and evergreen forests in their native range, to the west of Wallace's line (Jennings and Veron [2011]). Higher altitudes are frequently associated with areas with dense forest cover, or primary forest. This is intriguing because prior observations found Sulawesi civets in all land use types: non-forest, secondary forest, and primary forest, whereas Malayan civets were only found in secondary forest (Hunowu et al. [2019]). Non-forest and secondary forests are typically found at lower altitudes. The babirusa, on the other hand, is found to be strongly associated with areas with a high vegetation index, and elevation regardless of the range, and is not strongly associated with a particular habitat. Based on the assessment of habitat used by the species community, the further an area is from the edge of the forest, the more occupied by the species community and thus the greater the species richness. This is anticipated and aligned with the subsequent result revealing the effect of accessibility on species richness.

5.5.2 Effect of anthropogenic pressure on species richness

We show that the more difficult it is to enter a region and the fewer incursions by people into the park, the greater the species richness of that area. These findings are consistent with the anecdotes told locally and are so intuitive that a cynic may doubt they needed scientific investigation. Nonetheless, utilizing the SCM in causal inference, we demonstrated that there is a causal basis for these beliefs. The two variables, human intrusion, and accessibility of an area, represent a direct pressure on the species' habitat and population. This type of pressure, regardless of the presence of wild meat markets and consumers in the immediate surroundings, has always been shown to harm the animal population inside the park in the form of defaunation or empty forest syndrome (Redford [1992], Harrison [2011], Gray et al. [2017], Benítez-López et al. [2019], Deith and Brodie [2020]).

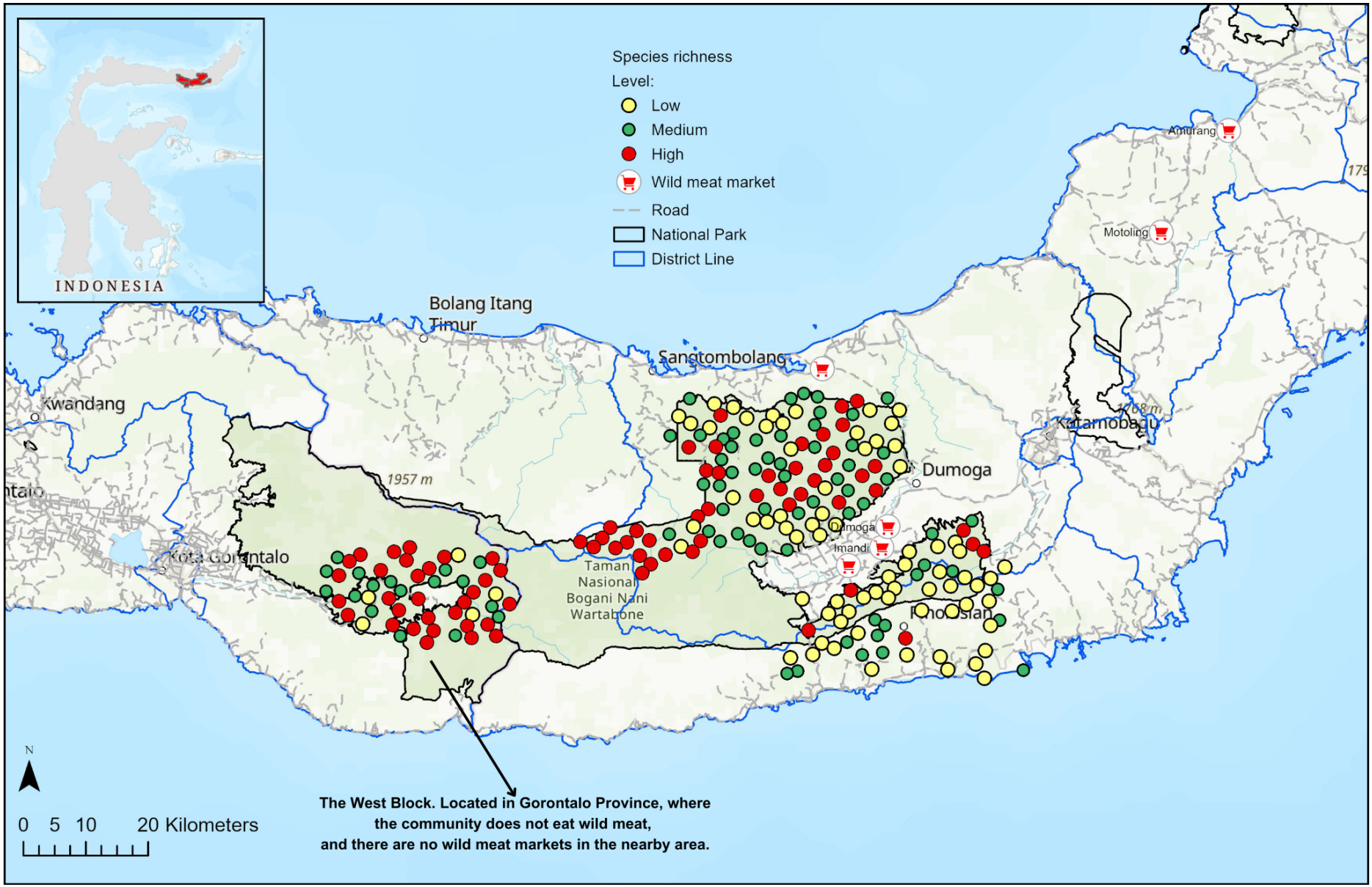


Figure 5.11: The estimated species richness level in the study area and the effect of anthropogenic pressures.

Our findings revealed that the presence of wild meat markets near the park caused a decline in species richness within the park. However, the presence of wild meat consumers near the park increased species richness. The first finding is simple to grasp, as seen in Figure 5.11, where the west block of Gorontalo province has a high degree of species richness, whereas more cameras have low to medium species richness in the southeast of the park near wild meat marketplaces (Ibolian, Imandi, and Dumoga II) and the presence of an influential middleman near the north camera block. The apparent decline of the local wildlife population and consequent dwindling supply of wild meat supply chain were first inferred almost 30 years ago (Milner-Gulland and Clayton [2002]). More current studies showed that at least for flying foxes and wild pigs, the main wild meat markets in North Sulawesi nowadays are mostly supplied from outside the province (Latinne et al. [2020], Bailey et al. [2021], Sheherazade and Tsang [2015]). The continued loss in species richness could be attributed to the local community's hunting of smaller animals, such as rats to supply the local rural wild meat markets. The large and expensive species, such as anoa, are no longer accessible because they are located deep in the park at higher elevations. Although we cannot yet confirm it, the wild pig, while still widely distributed, may be present in much lower numbers and thus also represent a dwindling supply for rural or urban markets (See also Chapter 6). A readily available supply from outside the province could explain the second puzzling finding. The frequency with which wild meat consumers consume is unrelated to their geographical location concerning the park, as they can obtain wild meat that has not been hunted in the immediate forest. For example, the one major intermediary in the North Block receives meat from across Sulawesi and even from Kalimantan, which the intermediary sells locally in their home and supplies the city's main markets (*Unpublished Data*).

5.6 Conclusion and Recommendations

Conducting a biodiversity conservation study in a region affected by wild meat consumption necessitates a detailed understanding of both the ecological characteristics and the anthropogenic factors associated with wild meat. Our two-stage modelling approach demonstrated the feasibility of separating the process of inferential statistics from the environmental and anthropogenic impact on a system. The predictive inference with MSOM revealed that elevation is the strongest factor associated with the terrestrial species distribution of North Sulawesi, whereas the causal inference with SCM revealed that the effect of the variables can be underestimated or overestimated if the confoundment between variables is not properly addressed.

Reliable population monitoring is the foundation of a sound conservation strategy; it offers a number against which all conservation interventions can be evaluated. The survey design and analysis approach for species distribution and richness in this study can be used as a model for multispecies population monitoring. Because the matrix pro-

duced by this approach represents an index of the population, strict adherence to the protocols is required to achieve an unbiased result. Using occupancy value as an index of population trend is a feasible and efficient option because estimating abundance for unmarked species is nearly impossible without recourse to prohibitively expensive and time-consuming approaches, such as a DNA-based survey. The strong predictive inference is still necessary to explain biological processes, but the variables must be chosen carefully to avoid the '*causal salad*'. If necessary, a second species-specific model can be developed and reinforced by integrating species-specific variables such as salt licks for babirusa and wild pigs. However, the best way to avoid '*causal salad*' is to understand fully how the variables interact; this is the logic behind the DAG. Confoundment can be eliminated to establish a cause-and-effect relationship between predictor and variable.
This is particularly useful when we need to assert the impact of human influence on a biological system. Predictive inference, as demonstrated by Laubach et al. (Laubach et al. [2021]), allows for exploring the associations between biological phenomena and geographical surroundings. On the other hand, causal inference delves into the causation behind observed patterns, addressing questions of why and how certain ecological changes occur (Larsen et al. [2019]). In our situation, this reveals that the principal driver of species richness is direct anthropogenic pressure from human intrusion, which is mediated by access to the region. This necessitates more park protection, especially in easy-to-access areas. The presence of wild meat markets is also significant, leading to a second proposal for more stringent protection in park areas near the wild meat markets. The presence of wild meat consumers in the park's vicinity is less important because hunters are not always the ones who eat the meat (Rejeki [2018]). Our findings support an argument for increased causal inference thinking in conservation biology. Combining both techniques gives a solid framework for extensively studying ecological systems by encouraging practitioners actively to consider the variables to be included in models. The habit of including whatever variables can be measured, but for which there is no a priori logic for inclusion is methodologically, and intellectually, sloppy and risks detriment to species conservation.

5.7 Study limitations

The animals considered in this study are all consumed as wild meat in the region, from the smallest Celebes dwarf squirrel to the largest lowland anoa; the criterion for their inclusion was thus operational rather than ecological. Therefore, we may refer to them as the richness of consumed wild species in this area. We did not include bats, which are also widely consumed since the camera traps were not positioned to detect them. We did, however, record more species of birds (31 different species) than of terrestrial mammals, but their detection was very low and anyway, birds are not much consumed, so they were not included in the analysis. Furthermore, our distribution estimate may be

unreliable for rodents since their ranges are small relative to the 2-3 km2 coverage of the cameras. Nonetheless, it is justifiable to use them as a proxy for species richness based on their presence or absence at each camera point. The usage of causal inference in this research is likewise relatively straightforward; we demonstrate its utility in addressing a cause-and-effect question in an observational data study in ecology.

5.8 Data availability

The Bogani Nani Wartabone National Park and Wildlife Conservation Society-Indonesia Program own the raw data for species detection locations, which are overseen by the Ministry of Environment and Forestry.

6

Untamed Harvest: Wild Meat Trade from Vendor Insights, Year-long Market Surveys and Three Decades of Trend Analysis

6.1 Abstract

Over-exploitation of biodiversity for food and other purposes is thought to be the second most serious threat to nature, following habitat degradation. One practical method for measuring the extent of over-exploitation is to research market dynamics. In this study, we used intensive year-long market monitoring from North Sulawesi, Indonesia, to learn that the peak of transactions for the main (large) markets in suburban regions coincides with the cultural event of Minahasa's thanksgiving, while those in rural areas are associated with religious and social gatherings. We also examined the longest available dataset, spanning three decades, which allowed us to conclude that the population reduction of endemic pigs, popular wild meat, is irrefutable. Another major impediment to monitoring and resolving these risks to biodiversity is a lack of knowledge about the actors in the supply chain. Through semi-structured interviews with vendors, complemented by key person interviews with suppliers and hunters, we concluded that the majority of those working in the wild meat sector do so as a full-time occupation that provides their primary source of income; many operate within family businesses, and the roles are not gender specific. Selling wild meat is a successful industry, with monthly profit margins per vendor of 566.5 USD in 2023, ranging from 425-647 USD (6.6 to 10.05 million IDR). These revenues generally exceed the minimum monthly wage of 226 USD typical of the

region. Plausible regulatory interventions to control unsustainable, and illegal, harvests of wild meat include more stringent law enforcement to curtail the illegal component and rigorous monitoring and evaluation of compliance of well-founded harvest quotas for the legal wild meat. However, given the magnitude of documented population loss, the most urgent priority is policy to strengthen, and policing to deliver, the protective status of the threatened species.

6.2 Introduction

Over-exploitation of biodiversity is widely considered to be the biggest threat to nature following global land use change and the destruction of natural habitat, mostly for growing food (Tollefson [2019], IPBES [2021]). One estimate is that 300 mammal species are being eaten into extinction (Carrington [2018]). Since humans are able to domesticate only a small fraction of species (Diamond [2005]), most of the mammals from that number are consumed as wild meat, or, as it is generally termed in the African context, bushmeat. We define wild meat as "terrestrial animal wildlife used for food in any part of the world", as defined by the IUCN General Assembly Resolution 2.64 (Coad et al. [2019b], Nasi et al. [2021a]). Wild meat is an important food source (Coad et al. [2019b], Nasi et al. [2021a]), yet in many countries where it is eaten, there are intersections between economically motivated trade that can drive over-exploitation and long, complicated supply chains)Fa et al. [2006]). These complexities are deepened as the potential of zoonotic spillover increases (Macdonald and Laurenson [2006], Montgomery and Macdonald [2020]).
Measuring harvest sustainability is hard. In the absence of more accurate data, the market dynamic can be used to estimate the population decrease resulting from the animal sold, as illustrated in the African context (Fa et al. [2009, 2014]). However, this is imperfect because of the risk of wastage during offtakes, consumption before reaching the marketplaces, and other informal transactions that cannot be accounted for (Milner-Gulland et al. [2003]). Furthermore, the species threatened by trade and hunting are rarely seen in markets, because they are already at low population densities (Milner-Gulland et al. [2003], Fa et al. [2006]), and are likely to be sold covertly as a response to law enforcement (Milner-Gulland and Clayton [2002], Kiroh et al. [2020]). Because of this low number, the detection of threatened species requires an adequate sample size: in Gabon, species diversity in the market was only fully documented after 10,000 sales or 6-24 months of trade (Davies [2002]). Similarly, a study in the Belen market in Peru, the largest wild meat market in the Amazon region, showed that to accurately monitor the trade of wild meat in markets, a minimum sample effort of two interviews per week to two interviews per month over 1-2 years would be needed (Mayor et al. [2019]). Another long-term study, this time from West and Central Africa, showed that the accuracy and precision of sampling will increase with sample size and these parameters will reach asymptote with an effort between 28 to 35 sampling days per year (Fa et al. [2004]).

Studies of the impact of wild meat trade in Southeast Asia are fewer than those in Africa, and in Indonesia research has largely been undertaken in the northern province of Sulawesi Island. Despite the focus of research in this one province, it is probably a good model of the magnitude and seriousness of the trade, and its implications for public health and biodiversity conservation elsewhere in the region (Chapter 3). The long history of research on wild meat in the northern province provides an invaluable opportunity to observe a long-term change in the trade and the market response to, in particular, contemporary events such as the 2020 COVID-19 pandemic (FAO et al. [2020], Booth et al. [2021a], Naidoo et al. [2021], Xiao et al. [2021]) and the regional epidemic of African Swine Fever (de Rosary [2021b], Luskin et al. [2021], Sybille de La Hamaide [2023], Phoebe Weston [2024], Meijaard et al. [2024]).

Wild meat is routinely available in 73% of North Sulawesi's markets and supermarkets (Latinne et al., 2020), with 0.8% coming from protected taxa and no significant change in encounter rate between 2011 and 2019 (Bailey et al. [2021]). The first half of the year (November-June) is typified by a higher encounter rate of wild meat sales than the second half of the year, with the peak occurring in May/June, coinciding with Manado's Thanksgiving and the run-up to Christmas-Easter (Bailey et al. [2021]). Caveats to these generalisations are warranted because the surveys were spread over several months and not all the meat was sourced from North Sulawesi. Large fruit bats, snakes, and most wild pigs and rats have been caught in Kalimantan or Southeast Sulawesi (Latinne et al. [2020]). Aside from their routine quarry, hunters also took such endangered species as anoa (10%) and babirusa (5%) (Latinne et al. [2020]). In summary, there is evidence that protected species were being sold at the market at least as recently as 2020, including some taxa not previously reported for human consumption, such as snakes. In contrast, Latinne (Latinne et al. [2020]) did not record some species found on sale previously, e.g. tarsiers, civets, and deer. Bailey (Bailey et al. [2021]) documented a general decrease in the sale of wild meat between 2011 and 2019, particularly between 2011 and 2018 (when the encounter rate fell by 99%). Despite this, bats, rats, and Sulawesi warty pigs were still abundant in markets in 2023.

Understanding wild meat market dynamics can yield a plethora of knowledge. Long-term market observations, such as ours, allow us to measure the volume of meat harvested and sold in order to draw a conclusion about stock sustainability and, perhaps, species-carrying capacity in the wild. Intensive market observation also provides insight into the motives for trade, the financial gain associated with these transactions, and knowledge of the individuals in the chain. This is the foundation of a strategic policy to reduce the supply of wild meat. our study area in North Sulawesi consists of markets in which wild meat is sold openly, thereby providing unusual circumstances to answer our research questions: i) What is the demography of the wild meat vendors and what incentives (monetary or otherwise) encourage them to pursue this occupation, ii) How are the

characteristics of the markets shaped by their geography (rural vs urban) and proximity to particular catchment areas (e.g. hunting areas), and iii) what can the market dynamics, revealed by both short-term but intensive monitoring effort and long-term monitoring of a focal species, tell us about the sustainability and the future of the wild meat supply chain in Sulawesi.

6.3 Method

6.3.1 Study Area

The study took place in North Sulawesi, a province in Sulawesi, which is the biggest island in Wallacea and a biodiversity hotspot (Myers et al. [2000]). The province can be divided into three sectors, the Eastern (Minahasa) and Western (Bolaang Mongondow) sectors, and the small islands in the North. Our study focuses on the Eastern and Western sectors, with a focus on sixteen markets from which long-term and year-long intensive data had been gathered (Table A.8). The Eastern Sector encompasses seven regencies (administrative districts below the province) and is populated predominantly by the Minahasan tribe, a people famous for their consumption of wild meat (Clayton et al. [1997], Milner-Gulland and Clayton [2002], Adams et al. [2004]). The Bolaang Mongondow tribe dominates the Western sector, which is divided into four regencies. While the people of this sector are predominantly Muslim, it is nonetheless inhabited by a mixed demographic drawn from tribes such as Minahasan and Sangihe (from the Northern (islands) sector) as well as Balinese (due to transmigration). This sector also includes the Bogani Nani Wartabone National Park (BNWNP), which provides a habitat for many wild species found in the market.

The wild meat markets in North Sulawesi are in those two sectors: the Minahasa and Bolaang Mongondow. Langowan, Kawangkoan located in Minahasa Regency, and Tomohon market (pasar Beriman) in Tomohon Municipality are the three largest and most well-known urban marketplaces. Another three urban markets are in Manado city municipality, the province capital, and comprise two traditional markets, Karombasan and Bersehati, as well as one modern market, Freshmart. The remaining markets are classified as rural, including five in South Minahasa regency, the Amurang, Motoling, Pakuure, Poopo, and Tompaso Baru, one in Bitung Municipality, the Girian, and Airmadidi market in the North Minahasa regency. The remaining rural markets are in the Bolaang Mongondow regency, including Dumoga, Ibolian, and Imandi markets.

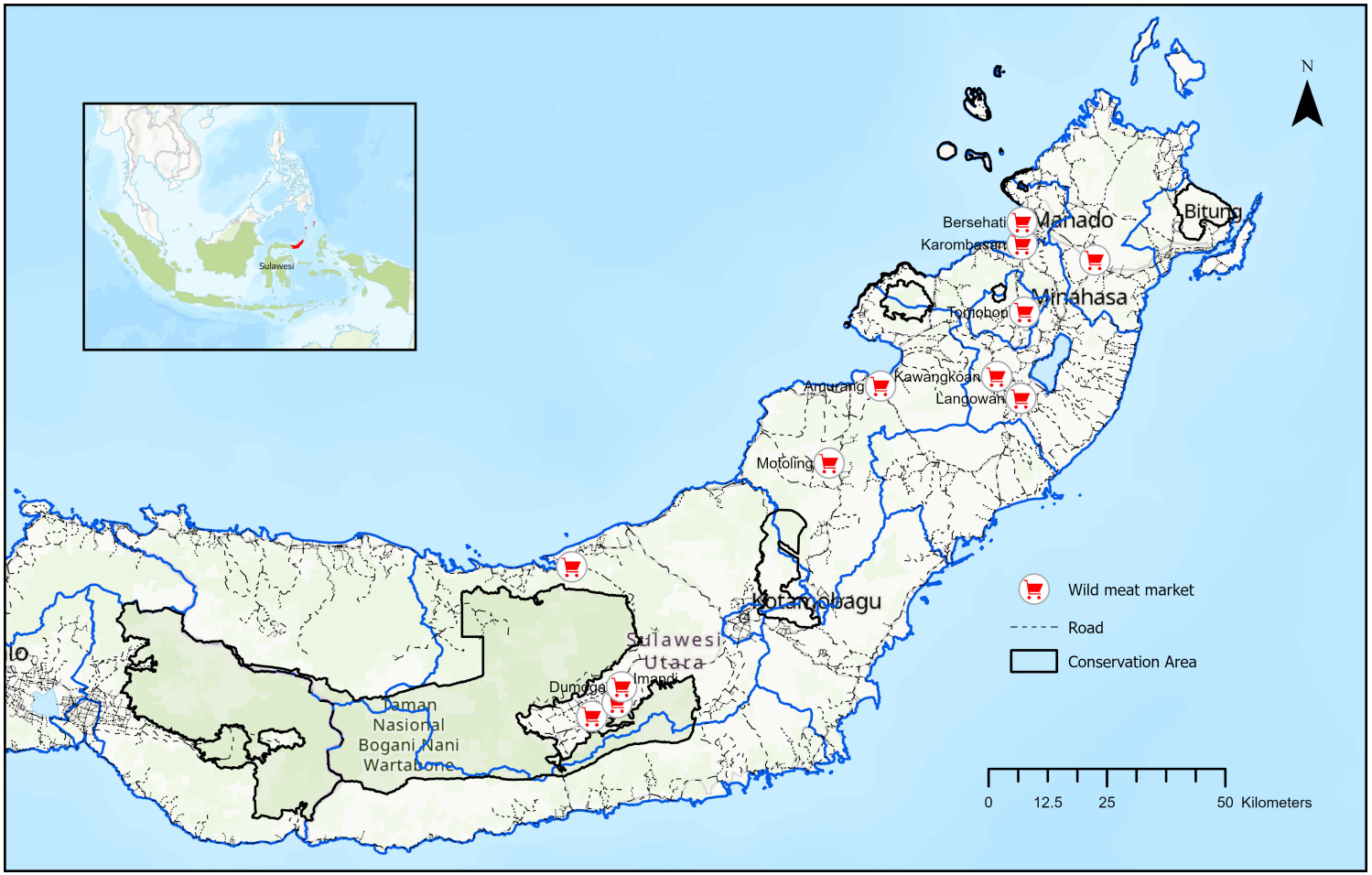


Figure 6.1: A map of the nine traditional wild meat markets where intensive year-long data collection and vendor interviews were conducted. The modern supermarket, not shown on the map, is Freshmart in Manado. The inset map shows the North Sulawesi province, which is shaded red.

6.3.2 Characterizing the Minahasan wild meat vendors

We performed semi-structured interviews with all consenting vendors, resulting in 52 respondents: 25 vendors and 2 intermediaries during the first phase of the year-long monitoring period (1 July - 29 September 2022) and 25 during the second phase (15 June - 29 July 2023). All vendor interviews were preceded by proper free, prior, and informed consent. Because the interviews were done anonymously, we cannot establish the extent to which the same vendors contributed to both phases. We also interviewed four key informants: one supplier in urban markets, one supplier/vendor in rural markets, and two hunters in rural areas. The interviews were conducted with consent; however, they declined to participate in semi-structured questionnaires, therefore the interviews were conducted through an open-ended casual chat on several occasions. All interviews were done in Minahasa or Indonesian.

The interview consists of 30 questions (A.4.1), beginning with the respondents' demographic information and progressing to questions that answer our pre-determined topic: i) the dependability of selling wild meat as a primary occupation, ii) the source of the meat and the volume of the stock, iii) the frequency and volume of the stock, iv) the monthly financial profit, and v) perceived change in profit and supply-demand. The data were summarised quantitatively according to these questions.

6.3.3 Quantifying the changes in price and trade volume

The first dataset was gathered during an intensive year-long market survey between 1st July 2022 to the 29th of June 2023, over a total of 260 survey days (Table 1). The data include weekly or biweekly wild meat prices and quantities for nine traditional wild meat markets and one modern market in the regencies of Manado City, Tomohon City, North Minahasa, South Minahasa, and Bolaang Mongondow of North Sulawesi Province (Figure 1, Table S1). The monitoring was conducted mostly (59%) in the morning (06:00-10:00), or (41%) around noon (10:00-14:00). For markets operating on multiple market days, we surveyed in the order of market day to cover all days (thereby avoiding the surge in data that would have resulted from observing only on peak market days). The monitoring was carried out by nine enumerators, all of whom were Universitas Sam Ratulangi's students, local North Sulawesi University, chosen following a two-week intensive training programme in June 2022 that culminated in a pilot survey in the Tomohon market (these pilot data were excluded from analysis).

The enumerators collected data by counting the number of meat and wild meat vendors, documenting the market situation, the type, and count of animals sold, and the price per unit of each animal (A.4.2). In any given market, the enumerator only recorded the animals that were openly displayed on the stall table; wild meat sold clandestinely, or a portion of the stock not displayed in the market, were not recorded. Before we

began collecting data, we disclosed our identity, information, and survey objectives, and obtained consent from the head market vendors we interviewed, and local government. For markets that are sensitive to outsiders, such as Langowan, the process of familiarising the enumerator team took nearly two weeks during which the enumerator visited only for informal conversations with the head of the market and vendors.

The second dataset came from Selamatkan Yaki's wild meat market monitored before and during the COVID-19 pandemic restriction in North Sulawesi. The Indonesian NGO Selamatkan Yaki (save the 'yaki', Sulawesi crested black macaque) survey was conducted in 2011, 2015, 2018, 2019, and 2020, for a total of 121 days (Table 6.1) and recorded all wild animals on sale in eleven markets (Figure 6.1, Table A.8). The data, excluding the 2020 survey, were published in 2021 (Bailey et al. [2021]). The inclusion of 2020 data from the COVID-19 lockdown in this study, despite the small sample size, provides an insightful comparison with the post-pandemic data. The final set of data is drawn from the historical records of babirusa and wild pig sales in the Langowan market, spanning seven years from 1992-1995 and 1997-1999 (gathered during a project led by Lynn Clayton) over a total of at least 158 days (Table 6.1; Table A.8) and published, excluding the 1992 survey, by Milner-Gulland & Clayton (Milner-Gulland and Clayton [2002]). These latter data were collected under a different protocol to the first two datasets, but we nonetheless include them to capitalise on the unique opportunity to draw comparisons of trade on endemic Sulawesi wild pig across three decades, which is especially pertinent given the prevalence of African Swine Fever in the archipelago.

Table 6.1: Wild meat survey days count per year. The survey can be done in ≥ 1 market (see Table S1).
* We don't know the exact number of survey days, so '1' simply indicates that there are surveys in that month.

Month	1992	1993	1994	1995*	1997*	1998*	1999*	2011	2015	2018	2019	2020	2022	2023
January	2	6	1		1	1							33	
February	3	6	1	1	1	1		9		9				
March	4	7	1	1	1	1	6						18	
April	4	7	1	1	1	1		9		11				
May	5	6	1	1	1	1	5						6	
June	4	4	1	1	1	1		4					15	
July	6	5	1	1	1	1		9		6				14
August	6	3	1	1	1	1	5		10			33		
September	10		1	1	1	1							44	
October	6		1	1	1	1	15			9			24	
November	1	8		1	1		10							12
December	6	6		1	1		5		10		9	41		
Total	7	64	44	10*	11*	12*	10*	46	13	29	24	9	168	92

For all market analyses, we use the encounter rate of the average number of animal types, or the price per unit (kg and whole) per survey day, as the sampling unit. We grouped different types of rats and bats because we couldn't identify them as separate species. We then perform descriptive statistics and simple mean difference tests among groups to identify any changes in the patterns of market trends. All graphs and statistics analysis were done using R 4.3.2 (R Core Team [2023]).

6.4 Results

6.4.1 Characterizing the wild meat vendors

From the total of 52 interviews, the interviews averaged 46 minutes and 24 seconds. The total interview time for all respondents was 40 hours and 13 minutes. All sellers/intermediaries were Christian Minahasan, 50 (96%) were married, 32 (67%) were women, 27 (52%) were aged 35-54, and 26 (50%) had completed high school, and 12 (23%) had finished junior high school. They had worked as vendors for two to forty years, with the majority (10 vendors) stating that they had worked for ten years. Except for hunting, gender played a significant role in the supply chain. One of the principal vendors in Langowan is a woman who completed a law degree but opted instead to run the family business with a monthly average profit reaching 3,150 USD (50 million IDR). The principal supplier of the main and urban markets in the Lolak district is also a woman.

The dependability of selling wild meat as a primary occupation.

The majority, (n = 45: 87%), said that being a wild meat vendor was their primary vocation, with the others identifying as farmers, miners, or both. Most (37 vendors, 71%) reported that they did not have a vendor's union, while the remainder indicated that they have, albeit only informally. A total of 47 (90%) merchants stated that they owned the business, while four indicated they worked for someone else. Aside from selling wild meat for a living, the vendors also mention that it is the only occupation, or one of the only occupations, at which they were proficient (13 vendors), that they do it to send their child to school (11 vendors), that it is a family business (9 vendors), a side job (9 vendors), or that it is simply profitable (7 vendors). More than half of vendors (30, 58%) only conducted business in one market (or selling from home, for the intermediary in Dumoga Regency), and the rest sold in multiple markets. For those selling in multiple markets, there was a distinct cluster. The merchants in the rural marketplaces of Dumoga regency that we surveyed, Imandi and Dumoga, sold alternately between these two markets and the Ibolian market. One also said they usually go as far as the Modoinding market in the South Minahasa regency to sell any leftover stock. The urban market in Manado City focuses on one market, although it may also sell in other markets, such as Karombasan and Bersehati. Vendors from the Kawangkoan market can also sell their products in

Sonder or the two South Minahasa regency markets of Tompaso and Rumo'ong. And those Motoling sellers can also sell at the South Minahasa regency's Poopo market.

The source of the meat.

When it comes to sourcing meat, there are four types of sources: the first is a supplier, which indicates that another party came to the market with their vehicle and offered their products, in which case the vendors had no role in harvesting the animal from the wild. The second source takes the form of an intermediary, which means that the vendors actively sourced the meat themselves from outside the regency and province, closer to the location where the meat was harvested, and the vendors picked the meat up from the intermediary site. The third comes from the hunter and the fourth comes from other larger vendors in the same market. Most vendors (37, 71%) procured their stock only from the supplier(s) or in combination also from the intermediary (1) and hunter (5). Three vendors directly sourced their meat from an intermediary or in combination with hunters and suppliers (4 vendors). Two vendors sourced the meat from a hunter or hunted themselves, in combination with a supplier (5 vendors), and one from another vendor.

The general trend for both suppliers and intermediaries was to source their meat from other provinces (Figure 6.2); the most frequently cited were Gorontalo Province (30 references), Central Sulawesi (Palu, 16 references and Toli-Toli, 8 references), Southeast Sulawesi (Kendari, 23 references), and South Sulawesi (Makassar, 12 references), with Tomohon, one of the main markets, also sourcing its stock from Kalimantan (2 references). The two markets (Imandi and Dumoga) and one intermediary in the Dumoga district also primarily absorb hunting results from the area surrounding Bogani Nani Wartabone National Park (Figure 6.3): The Regency of Bolaang Mongondow (8 references), South Bolaang Mongondow (6 references), and North Bolaang Mongondow (2 references). Sources from outside the provinces were mostly used to meet the demand for wild pigs, bats, and snakes, while sources from hunting activities around and in the National Park supplied mainly rodents, micro-bats, and occasionally snakes.

Our interview results are corroborated by a personal interview with a large supplier that we frequently encountered in the Tomohon and Langowan markets. The supplier, identified as Male-V, stated that he received his supply from Makassar (South Sulawesi - two days transport away) and Kendari (Southeast Sulawesi - three days transport), adding that in the 1990s and early 2000s, this supply was met by a now-defunct middleman from the nearby area of South and East Bolaang Mongondow (half a day transport). His supply from Gorontalo (one-day journey) and Central Sulawesi Province (one-and-a-half-day transport) had run out by 2005 and 2010, respectively. Male-V mostly supplied vendors at the Tomohon market, but he also sold any surplus stock to vendors in Langowan, Kawangkoan, Manado (Freshmart), and Amurang.

Our key informant interviews with a merchant in the Imandi market and two hunters in



Figure 6.2: A map of the Sulawesi Provinces where the wild meat (wild pigs, bats, and snakes) is sourced. The red dots are the areas within provinces which are specifically mentioned by the vendors.

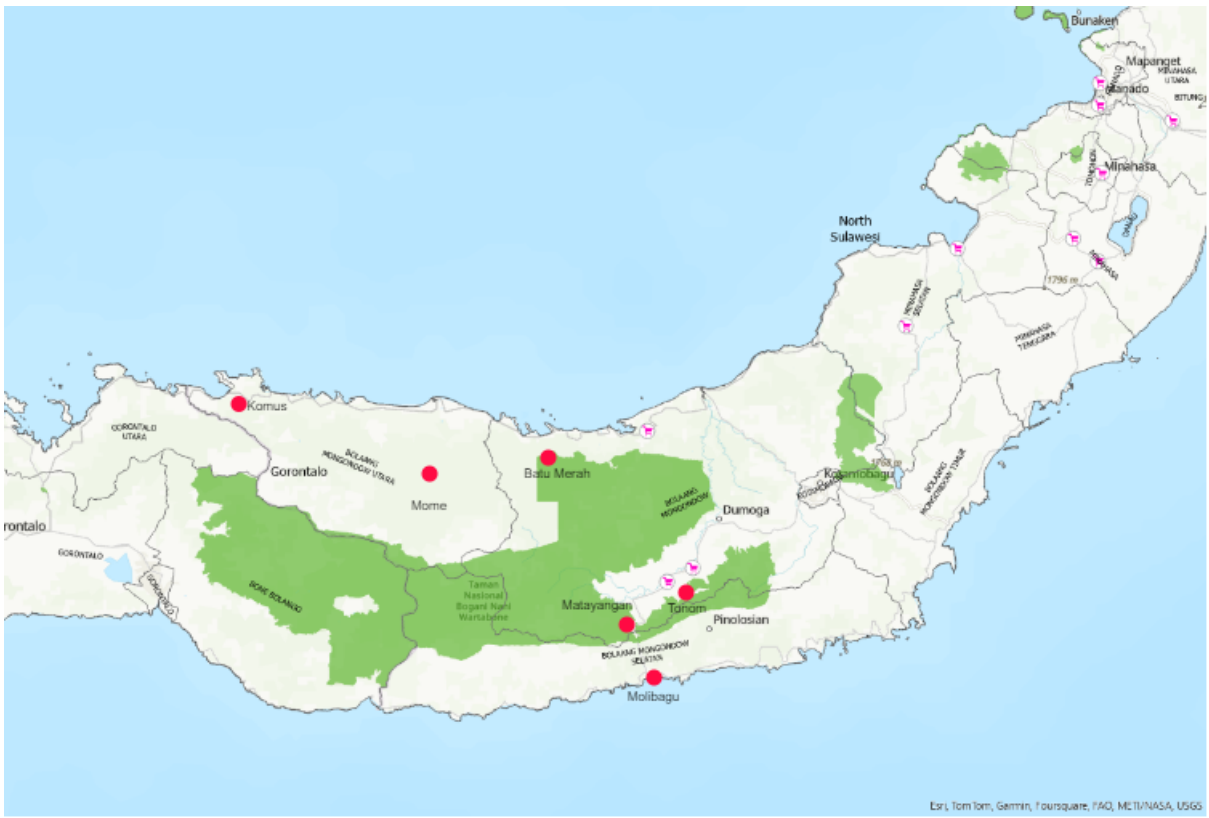


Figure 6.3: A map of the region surrounding Bogani Nani Wartabone National Park (black circle in Figure 6.2), that vendors claim is the source of their wild meat (small bats, rats, and snakes). It covers all of Bolaang Mongondow District, with red dots indicating areas mentioned by the vendors within each district. Green polygons are conservation areas.

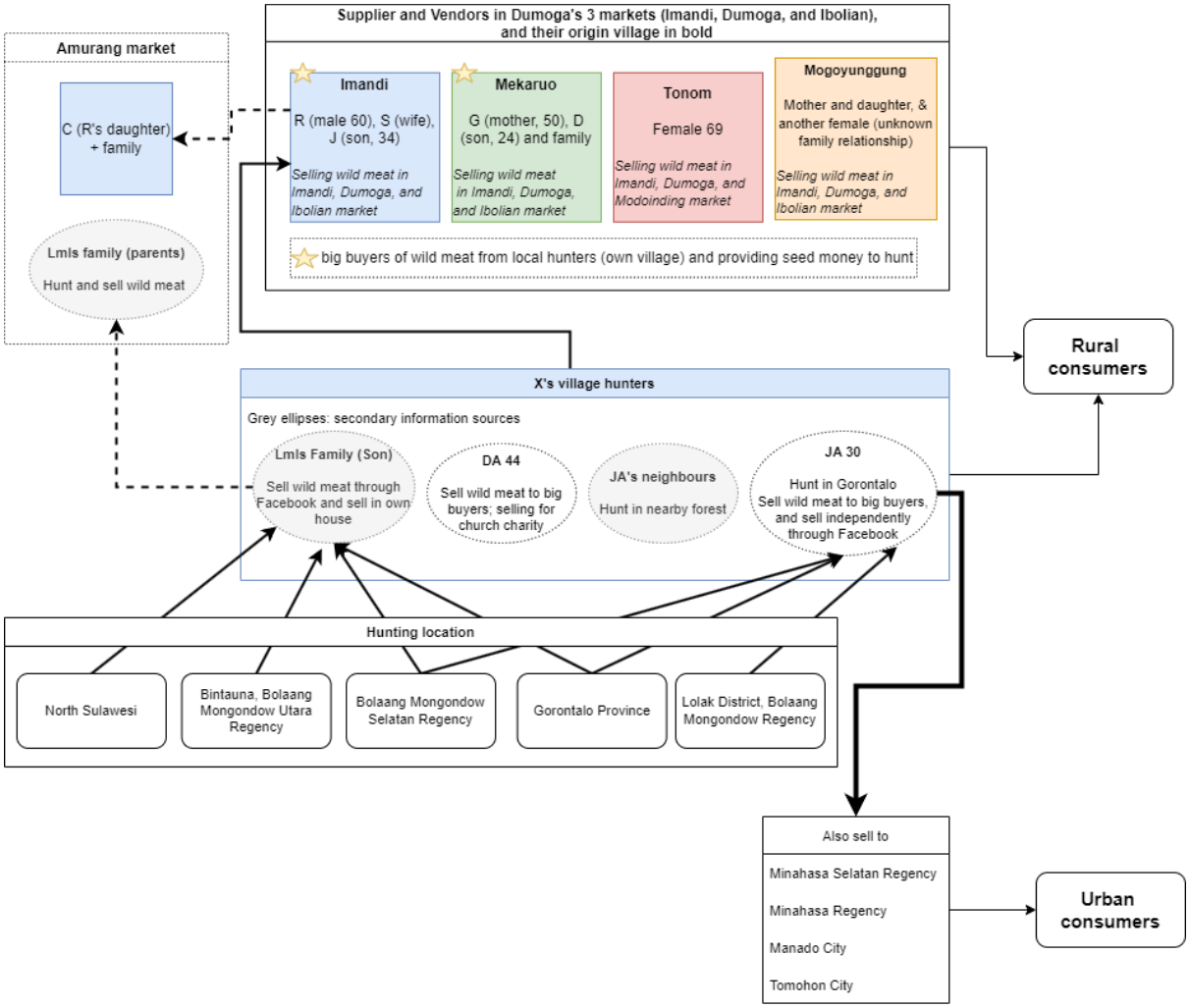


Figure 6.4: Local-level hunting and trade networks in the Dumoga Regency.

the Dumoga district confirm the strong tendency that in rural markets the wild meat was sourced directly from hunters. We discovered that the three marketplaces in the Dumoga regency had the same group of traders that shifted between markets, which was feasible because the market days rarely coincided. Selling wild meat there was largely a family business, with four main families of vendors originating from four villages in the Dumoga regency. Based on these findings, we elaborate on the wild meat supply chain of hunters to the market in the rural districts of Bolaang Mongondow (Figure 6.4).

The frequency and the volume of the stock.

The frequency and amount of meat stocked varied between each market. In all markets, in general, the predominant species on sale were wild pigs (50-500 kg) and bats (40-300 kg), which are restocked every two weeks or so. Snakes were available in all markets, except Manado's three urban markets, and the maximum was 200 kg replenished every two weeks. Cats and dogs are also available in nearly every market, except for the rural markets in the Dumoga district. The vendors in urban markets also stocked 'mixed'

meats of wild pig, bats, and snakes, and they stated that they must carry a stock of 2 tonnes during each sales period to cover the expense of securing them (that cost being approximately 5 million IDR (315 USD) if the provenance is another province in Sulawesi or 7 million IDR (440 USD) if the stock originates from the island of Buton, Southeast Sulawesi). The Dumoga districts and South Minahasa markets, which are rural, carry stock supplied by hunters from around the National Park. The rural vendors sourced the meat more frequently from hunters than big suppliers from outside the Province, where the hunters sell directly to the vendors or, in some cases, the vendors paid a 'float' in advance to commission hunters to secure a particular quarry. These advance purchases were negotiated mainly for animals like rodents (50 animals daily), small bats (30s animals daily), wild pigs when available, snakes, and cuscus. Our observation revealed that the sellers were only willing to discuss a limited range of species, which was narrower than what we observed during market monitoring. This was especially true for the rural market, where we discovered threatened species, as will be further elaborated in the section 6.4.2.

The financial profit.

The average monthly net profit of each vendor, across both stages of the interview, was 566.5 USD (8.8 million IDR) in 2022, with a range of 425-647 USD (6.6-10.05 million IDR). We notice an overall increase in monthly net profit from the start of the survey (stage 1) to the finish (stage 2) (Figure 6.6). The Manado city's urban markets of Karombasan and Bersehati both generated an average monthly net profit of 544-578 USD (8.25-8.75 million IDR). Both these markets contain fewer wild meat sellers than others (Table S2), however, they are open every day of the week. The three main Minahasa marketplaces revealed various numbers, with Kawangkoan having the lowest monthly average at 555 USD (8.4 million IDR). Tomohon, the most well-known market that operates every day of the week, recorded a higher monthly average profit of 878 USD (13.3 million IDR), while Langowan, the largest market, has the highest profit at 1,030 USD (15.6 million IDR). The Langowan market exhibited huge variation, with one seller earning only 132 USD (2 million IDR) per month in comparison to his most successful competitor earning up to 3,301 USD (50 million IDR per month). The two South Minahasan markets reported monthly profits of roughly 281-298 USD (4.25-4.5 million IDR), as did the rural Dumoga district markets, which had monthly profits of 281-347 USD (4.25-5.25 million IDR). Compared to the region's minimal monthly pay of 226 USD, these data show that selling wild meat is a profitable way to generate income.

Perceived change in profit, supply-demand, and emerging threats.

Overall, vendors stated that they have experienced a decrease in profit, supply, and demand for wild meat. Most vendors (42, 81%) reported a drop in profit because of COVID-19, either due to the lockdown that shut down several markets or people's re-

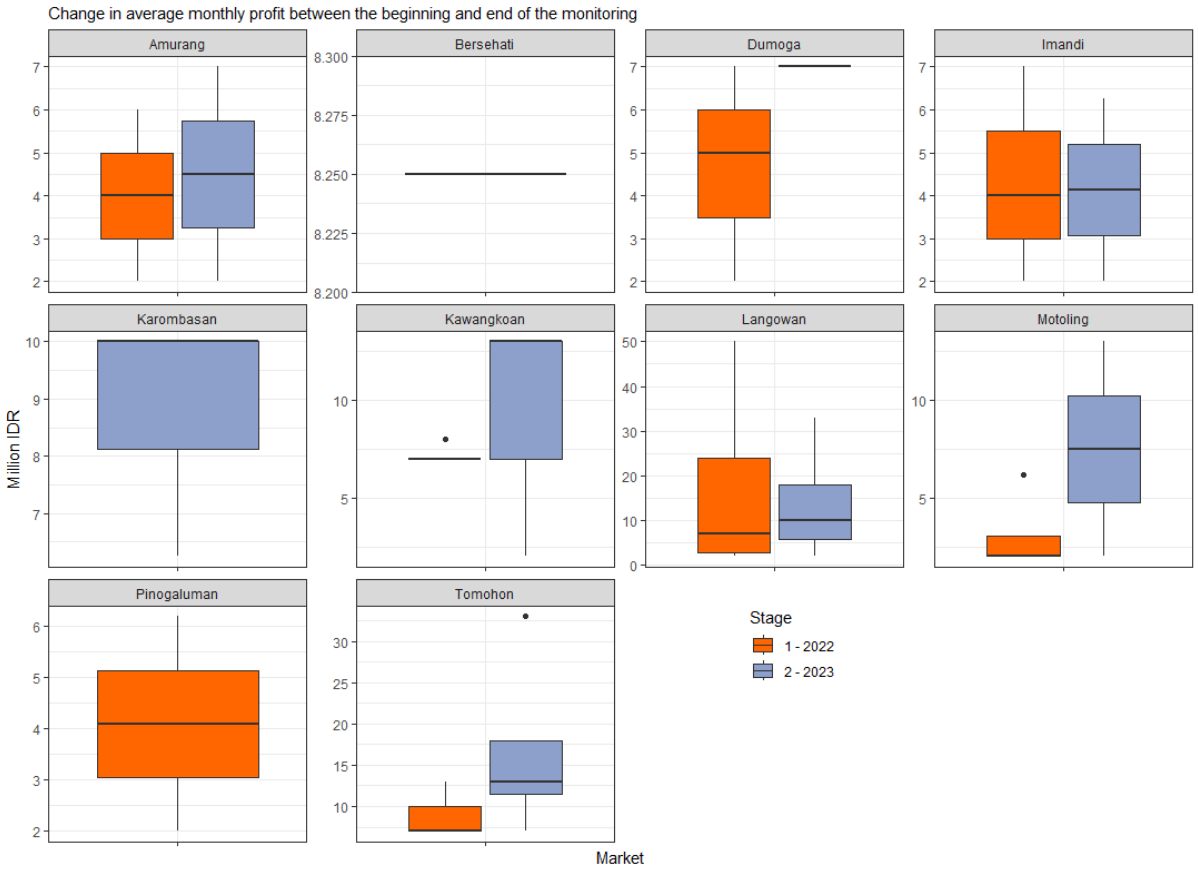


Figure 6.5: Average monthly net profit per vendor from selling wild meat.

luctance to visit public areas to avoid contracting the virus. In the second round of the interview, two merchants from Kawangkoan indicated that two years after the COVID-19 limitation, the public was still less interested in eating wild meat. Furthermore, during the second stage interview, we learnt that several traders in rural (Imandi-Dumoga) and Kawangkoan said the decline was due to rumours of African Swine Fever. In total, 47 vendors (90%) reported a fall in demand during the COVID-19 closure, while 38 vendors (73%) reported a decrease in supply, with one of the reasons being a restriction of supplies crossing the provincial boundary during the lockdown.

6.4.2 Quantifying the changes in markets' price and trade volume

Species richness and body mass of wild animals sold.

The main Tomohon market and the rural Motoling market sell the most diverse types of animals (Figure 6.6), with wild pigs accounting for the greatest body mass sold in any market on any given day. On average, the three main markets, and urban markets that receive their supply from outside the province, sell larger animals. And the rural markets, closer to the catchment area of the National Park, sell smaller animals. The rural markets (Table A.10) traded a lower volume of wild meat, but a richer diversity of species (some of them protected) than the urban markets (Table A.9). Motoling, especially, is the only market we found to sell The Sulawesi Civet (*Macrogalidia musschenbroekii*), the island's largest endemic native predator and the black macaques (M. *nigra* and M. *nigrescens*, could not be distinguished due to singeing and butchering) were sold only in Motoling. Animals were sold mostly as butchered fresh meat or singed to remove the fur. Older meat may be smoked and sold at slightly reduced prices. Various species of bats and rats generally could not be identified because they had been singed. They were priced according to size (and sometimes fur colour, if any remained), though rats tend to be priced a little bit higher. Despite the anonymising effects of carcass preparation, we were able to identify the Vulnerable and endemic Sulawesi flying fox (*Acerodon celebensis*). Overall, prices were lower in the rural market, followed by the three main markets, with the urban market being the costliest.

The effect of COVID-19 pandemic

To test for the effect of COVID-19 on the amount of meat sold, we used data from 2011-2023 gathered during both 2011-2020 and 2022-2023 which include five markets: Tomohon, Langowan, Kawangkoan, Amurang, and Motoling markets. Except for the "Threatened" category, which is primarily driven by dwarf cuscus (43 animals in one market, Motoling, 1 June 2023), and the "Anything else" category, which is driven by banded rails and python, the remaining categories show a general pattern of declining volume following the pandemic. The general trend has been a decline in volume, but not

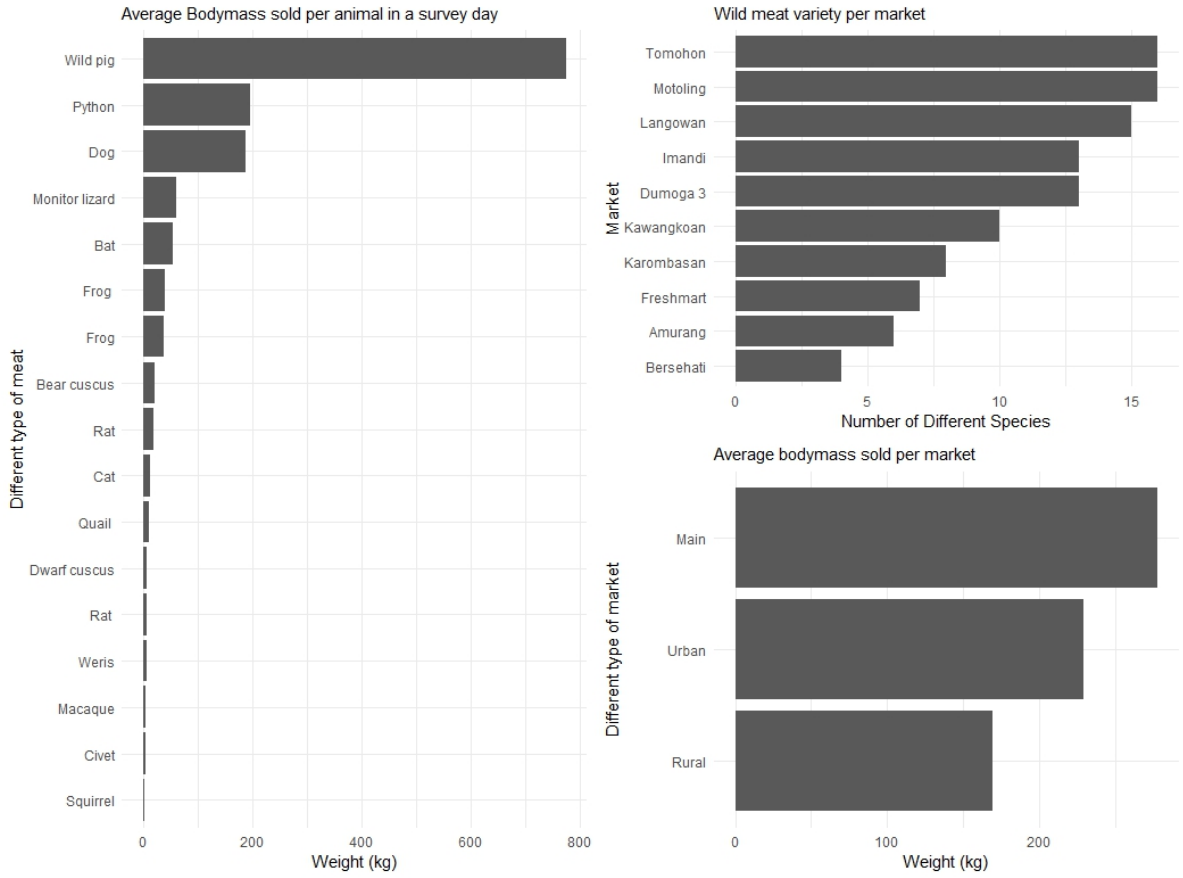


Figure 6.6: Species richness and body mass of different animals in wild meat markets.

price, before and after the pandemic (Figure 6.7). For wild pigs, there is a significant decline in volume sold (W = 147, p-value = 0.009) between before (mean = 17.5 wild pigs per survey day in a month) compared to after (11.6), but no significant decline in price (46,229.1 IDR to 42,344.5 IDR). The same significant decline is apparent for bats (W = 140, p-value 0.02), between before (173) and after (90.1 bats), but again no significant difference in price (59,645.7 IDR to 77,407.6 ID). Rats similarly reveal a significant decline in volume (W = 153, p-value = 0.004), from 146.2 to 67.8, but not in price (35,723 IDR to 31,361.2 IDR). The exception to this pattern is the python, for which we could detect no significant difference in the volume of sales before and after the pandemic – a slight increase from 3.4 pythons per survey day in a month to 3.9 – accompanied by a statistically significant decline in price from 58,370.7 IDR to 49,429.5 IDR. There was no statistically significant difference either in volume or price for either the threatened species category or the rest.

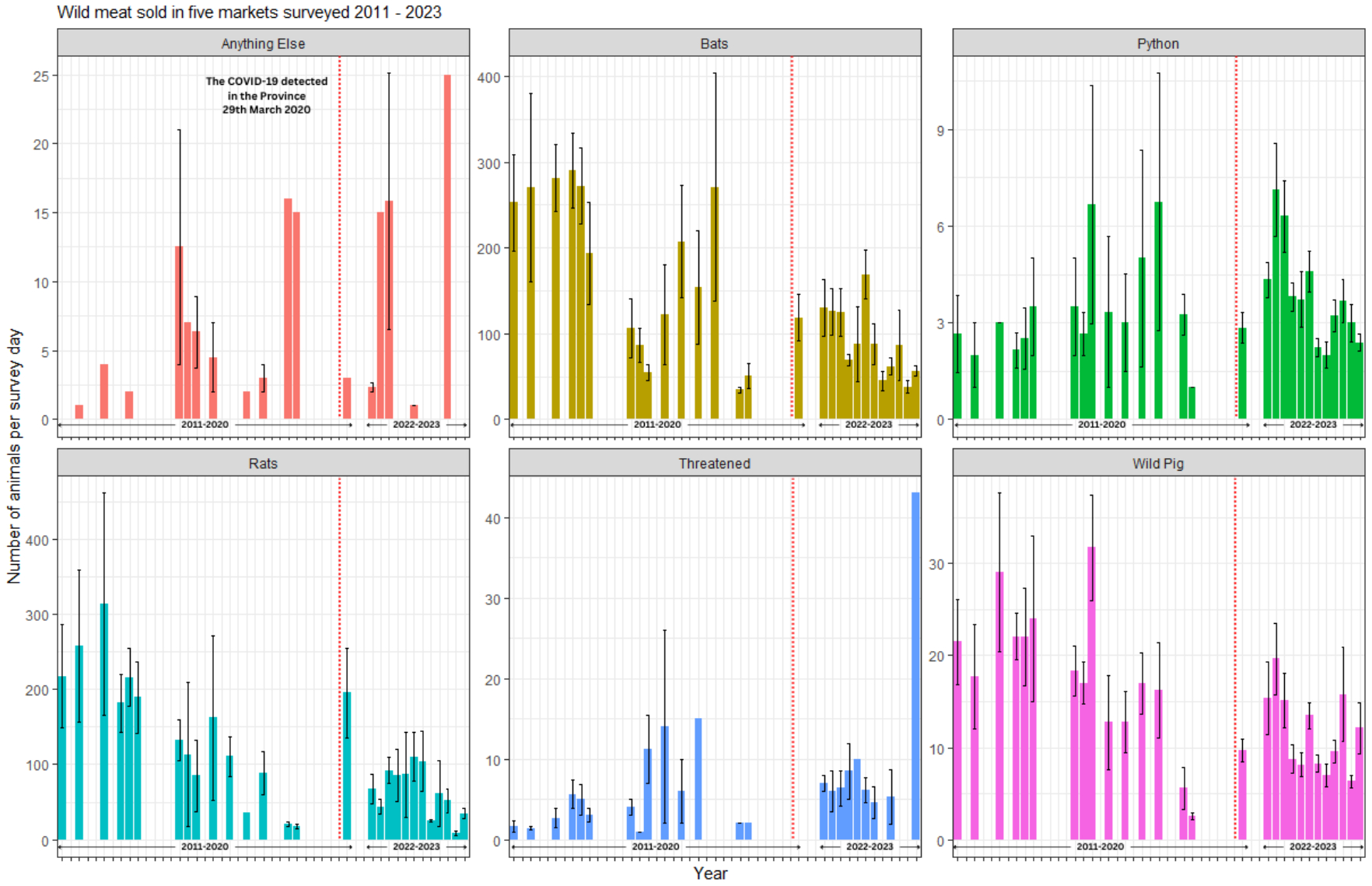


Figure 6.7: The graph shows a 12-year trend in wild animal sales with each tick in the x-axis representing the year. We excluded dogs, cats, frogs, and quail, as they were not included in the 2011-2020 data. The "Threatened" category includes bear cuscus, macaques, civets, and dwarf cuscus. The banded rail (weris), monitor lizard and squirrel all fall under the "Anything Else" group.

The seasonal effect of the market

Our year-long market survey enables us to make observations on trends in trade in all types of marketplaces. We divided the ten markets in the intensive one-year monitoring period into three, the urban (Karombasan, Bersehati, and Freshmart), main markets (Tomohon, Langowan, Kawangkoan), and rural (Amurang, Motoling, Imandi, Dumoga) (Figure 6.8). In terms of animal count, the main and rural markets sold more animals than the urban markets, but there was no substantial difference in pricing, with the exception that the meat in the urban markets was slightly more expensive than rural and main, with wild pigs selling for more than 40,000 IDR/kg all year. Among all meat, bat meat was the most expensive per unit sold (rural-main-urban: on avg. 52,756 IDR – 79,732 IDR – 61,872 IDR), with wild pigs the second (40,930 IDR – 42,817 IDR – 447,037) and rat the cheapest (rural – main: 25,945 IDR - 31,005 IDR). However, while flying fox per unit was usually close to one kg, the largest rats can only weigh up to a quarter as much (Laatung et al. [2021]), which makes the rats' price the highest per unit weight.

The peak season for sales varies; in general, rural markets peak in December-January, whereas main markets top in July-September, with an end-of-year rush. Except for a brief spike in December for wild pigs and February-March for bats, the urban markets showed no clear seasonal trend. The price trend in rural marketplaces peaked in October-December, mirroring the volume trend. The main markets have the same pricing trend, although this is not reflected in volume. Price trends in the urban market were unpredictable but almost consistent.

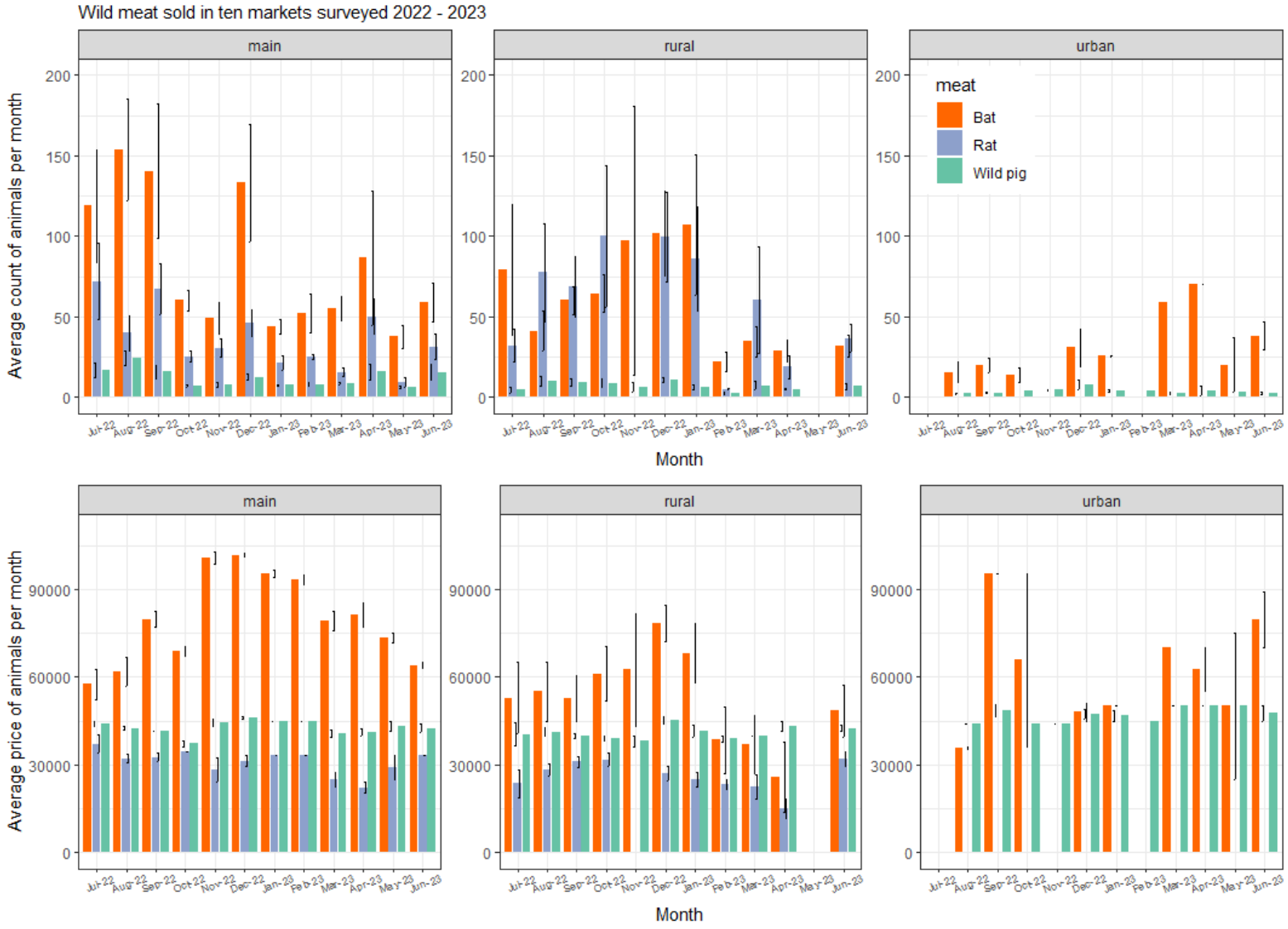


Figure 6.8: Seasonal effect on the volume of meat traded and its price. The main markets are: Tomohon, Langowan, Kawangkoan. The rural: Amurang, Motoling, Imandi, and Dumoga. The urban: Bersehati, Karombasan, and Freshmart. For the price unit, both bats and rats are for whole animals, while wild pigs are per kg.

Endemic pigs and thirty years of trade.

Long-term data from 1992 to 2023 on Sulawesi wild pigs show a general trend of increasing prices (after inflation adjustment to 2023) but decreasing market volume (Figure 6.9). Observations on wild pigs traded were made at only one market, albeit the largest in terms of trade volume and variety of animals sold, Langowan. The volume of trade decreased by 80%, from an average of 68.88 wild pigs encountered per survey day (range of 13-102 wild pigs) between 1992 and 1999 to 13.8 wild pigs (range 5-30.5) in 2022-2023. The number traded per day before the COVID-19 pandemic, 2011-2020, was 27.5 wild pigs (range 7.3-52), greater than the number traded currently. Considering three time periods, 1992-1999, 2011-2020, and 2022–2023, the peaks in sales of wild pig meats occurred, respectively, during June, August, and July. Babirusa was not openly found in any market after 1999, except for one occasion in the Ibolian market in Bolaang Mongondow Regency in 2018. We include it in the graph along with other Langowan data for visual interpretation Adjusted to inflation, 2,500 Indonesian Rupiah (IDR) per kg of wild pig meat in 1993 rose to 25,888 IDR in 2023 (conversion using inflation tool). Based on this, the price increase per kg wild pig is 114.4%, from an average of 20,305 IDR during 1993-1999 (10,997-29,474 IDR) to 43,524 IDR per kg in 2022-2023 (39,740-46,651 IDR). The price before the pandemic had been slightly higher than that in 2022-2023 at an average of 52,206 IDR per kg. In all three time periods, wild pig meat was invariably the most expensive in December. Babirusa has not been sold openly since 2011, except for one occasion in 2018 in the Ibolian market (Fig. 2), when up to three individual babirusas were discovered and priced per kg at 35,000 IDR, or 40,327 IDR in 2023 value. In the earliest data, 1992-1999, the variation in numbers of babirusa on sale was heavily influenced by law enforcement, as explained in (Milner-Gulland and Clayton [2002]).

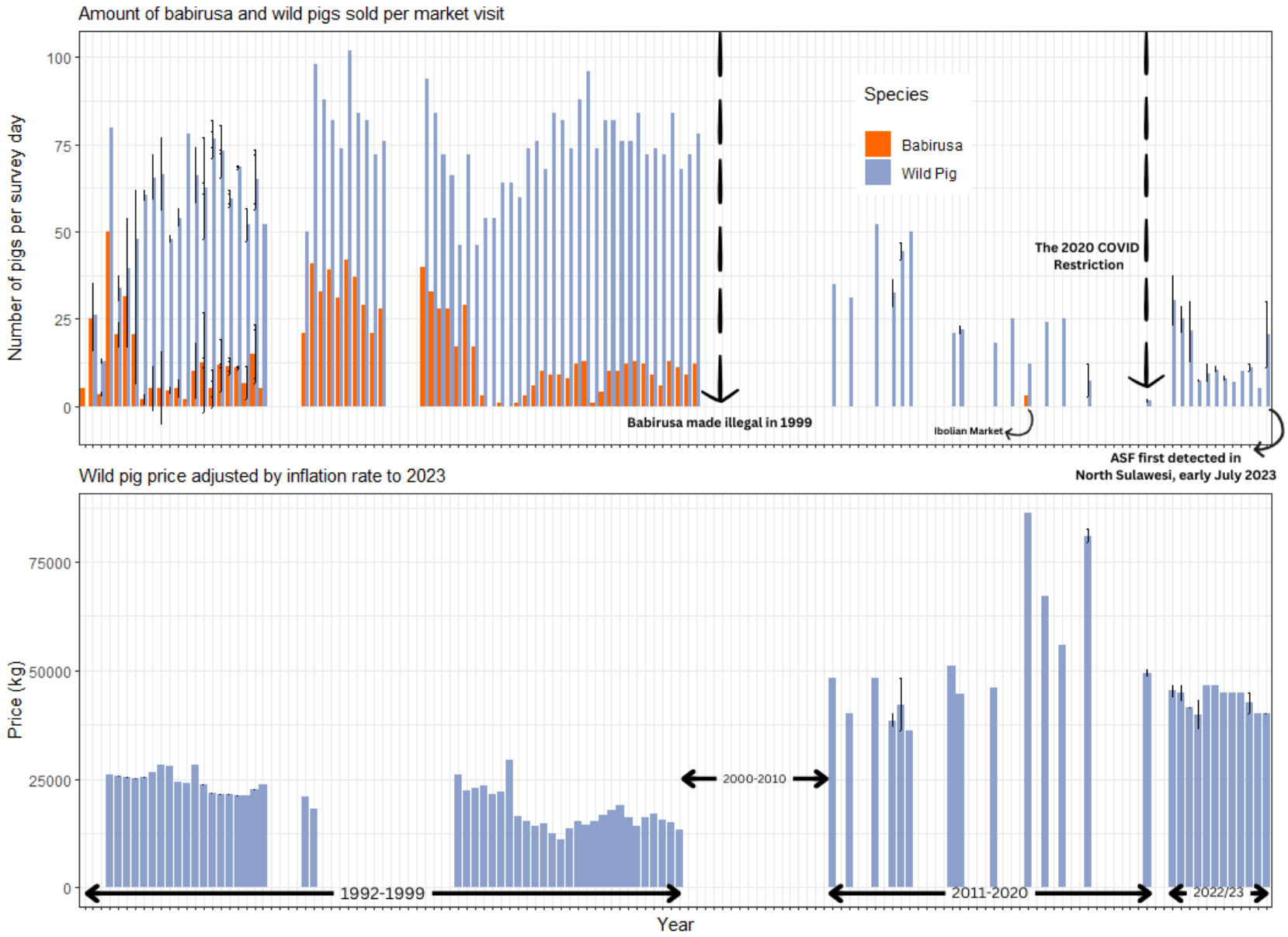


Figure 6.9: A thirty-year trend of two endemic pigs, the babirusa and Sulawesi wild pigs, sold in Langowan market, Minahasa regency, North Sulawesi. Each tick on the x-axis represents the year.

6.5 Discussion

A market is a place where businesses and cultures collide. In the context of a wild meat market, the opportunities for profit from selling what may be perceived as unconventional goods are determined by the community from which supply and demand originate. Our study illustrates the insights gained by using market data to assess sustainability and the risk of over-exploitation and an interpretive framework informed by an exploration of the vendors' characteristics. We demonstrate variation between vendors and markets depending on whether they are rural, urban, or suburban (the three main markets). This level of granularity has not been documented in Sulawesi previously and is an important prerequisite to formulating a strategy to reduce the unsustainable trade of wild meat in Sulawesi. Two decades ago, working in North Sulawesi, (Milner-Gulland and Clayton [2002]) cautioned that market data on the price and quantities of wild meat on sale represent an amalgam of many factors. Heeding this warning, we approached our analyses on two-time scales: short, intensive, and unbiased observations of market dynamics, set against a background of trends over two decades, all framed within an analysis of the vendors's characteristics and perceptions. Entangled with these factors are changes in community perception and behaviour, due to evolving social mores.

We showed that selling wild meat has been a profitable and reliable way to generate income, with an average monthly net profit per vendor 2.5 times more than the region's minimum wage set by the Indonesian government (Annur [2023]). Wages in North Sulawesi are the highest in Sulawesi, and 75% higher than the developed and densely populated province of West Java, where the Indonesian capital, Jakarta, is located. Our estimate of profit to the wild meat vendors is much higher than previous estimates (Kasenda et al. [2019], Masengie et al. [2022]) since we assessed the total monthly net profit from all meat, not just from bats like the one covered in those studies. The vendors in the three main markets we studied reported monthly profits above the average, with Langowan recording almost twice that average. Urban markets recorded profits hovering around the average, whereas rural markets mostly achieved only half of the average monthly profit. The average price of meat is indeed much cheaper in the rural markets, with the three main markets second, and the urban markets most expensive; however, these differences were not significant, in contrast to the findings of (Liana and Witno [2021]). We also discovered that in general there has been an increase in monthly net profit per vendor in almost all markets we observed, and this finding contrasts with the perceived decrease in profit most vendors felt they had experienced due to the last pandemic. It seems that the 'trauma' of economic gain forgone due to COVID-19 restrictions has deeply influenced perceptions, whereas our data on profit reveal a different reality. It is also important to note the considerable variation within markets, as well as between them. Small vendors appear able to generate profits approximating only the regional minimum wage, whereas

large vendors can achieve a large multiple of that profit. These large profits are a hindrance to discouraging the illegal wild meat trade and the temptations of unsustainable harvests of legal quarry.

We show that while hunters are predominantly men, vendors are slightly more likely to be women, and aside from the suppliers we interviewed in the main markets, the suppliers in rural areas are also women. This contrasts with generalisations documented in African countries, where women were primarily vendors, but not necessarily owners, and where the decision-makers were men who also acted as suppliers (Ellis [2000], Lowassa et al. [2012]). In comparison to other regions with long bushmeat traditions, the Minahasan wild meat vendors are more gender equal in terms of representation, role, and bargaining power in the supply chain. This reflects the perception that wild meat vendors are an acceptable occupation in North Sulawesi society. The current high profit from the wild meat trade might seem unlikely to be sustainable as the supply of wildlife dwindles. A decline in the local population of Sulawesi's wild pig population was apparent even almost thirty years ago (Clayton et al. [1997], and was further evidenced with respect not only to wild pigs but also flying foxes, more recently (Latinne et al. [2020]). To meet the demand, these animals must be supplied from other provinces in Sulawesi where a Muslim majority does not consume the meat. This confirms Rejeki's (Rejeki [2018]) finding that hunters are guided by market forces, and not influenced by their ethnic or religious circumstances. Importantly, we document that the rural markets are still heavily dependent on the catchment area of the National Park, specifically for small bats and rodents (see also Latinne et al., 2020). It is also in these rural markets that threatened species such as the Sulawesi civet, black macaques, and bear cuscus are more probably traded. Hunting and trading threatened species are illegal, and the legal trade in small bats and rodents with the high quantity of harvest we found is scarcely less concerning insofar as many are endemic. Most vendors already perceived the supply and demand of wild meat to have decreased. Our data support this perception, revealing a significant decline in the amount of wild meat sold, before, during (2020), and after (2022-2023) the COVID-19 pandemic. Following on the heels of COVID-19, ASF was officially reported in North Sulawesi in July 2023, with foci in the districts of Minahasa and Sangihe (FAO [2024]); this outbreak coincided with the end of our year-long monitoring of local wild meat markets, and it was also reported to have affected the wild pig population in Bogani Nani Wartabone National Park on 29 August 2023 (de Rosary [2021b]).

Direct measures of sustainability are elusive, so market data are frequently used as a proxy(Milner-Gulland and Clayton [2002], Crookes et al. [2005], Allebone-Webb et al. [2011]). Some limitations of market data in this regard are combatted by the size and duration of the sample recommended to capture the variance (Fa et al., 2004; Mayor et al., 2019). Our data gathered on every market day of the week for a full year meet and exceed these recommendations. They revealed peaks of transactions associated with

religious and social celebrations of Christmas and New Year, trends most strongly apparent in the rural markets. The three main markets, which are closer to urban centres, revealed a peak in sales in July-Aug, seemingly associated with the Minahasa Thanksgiving ceremony. By stratifying our sampling according to naturally occurring strata, such as urban vs rural, we avoided biases such as the Simpson paradox. These discrepancies between rural and urban areas in terms of religious and cultural celebrations have never been observed in a previous study (Latinne et al. [2020], Bailey et al. [2021]), where data is normally aggregated for all sorts of markets.

A real, and concerning, decrease in quarry population is exemplified by our analysis of three decades of endemic pigs' trade in the region. These observations are made at a single market, revealing a significant decline in supply (amount of meat sold) and an increase in price for wild pigs, even though the supply is now perforce met from all provinces in Sulawesi and even Kalimantan. The quantities sold are only 20% of those two decades ago, and the price has doubled – strong indicators of unsustainability. As for babirusa, whatever trade remains of their threatened population has been driven underground. Since the early 2000s, babirusa have rarely been found on the market, although wild pigs are still abundant (Babirusa is illegal to hunt/trade since 1999 - Government Regulation No. 7, 1999, Decree No. P.20/MENLHK/SETJEN/KUM.1/6/2018). We found only one instance of babirusa detected in a market. A survey in 2020 of 60 respondents in five markets (Tondano, Remboeken, Kawangkoan, Langowan, and Tanawangko) revealed that when a would-be customer enquiry about illegal wild meat, the vendors will exchange secret signals if they suspect the person is an undercover police officer (Kiroh et al. [2020]). As is typical of illegal wildlife trade more generally (Dutton et al. [2013], 't Sas-Rolfes et al. [2019]), the vendors usually know genuine customers for babirusa. They can source babirusa from Central Sulawesi (58%), Gorontalo (25%), and Bolaang Mongondow (17%) (Kiroh et al. [2020]). Over the three decades of market monitoring, we infer that market dynamics have been noticeably affected by law enforcement, and of course by external shocks such as the COVID-19 pandemic-related restrictions, and most recently by the impact of Asian Swine Fever.

6.6 Conclusions and recommendations

The strategy to reduce the unsustainable wild meat trade in Sulawesi requires a thorough understanding of the vendors and markets, with a focus on the differences between those in rural and urban/suburban areas. We discovered that larger animals were sold mostly in urban and main markets, while smaller animals were marketed in rural areas, largely because of the different ways in which these different categories of animals were obtained. While the diversity of animal species is comparable across the main and rural markets, those in rural regions also secured supplies from local hunters operating in the Bogani Nani Wartabone National Park, where their catch frequently included threatened species.

Regulation is necessary to limit the movement of wild meat from outside the province. Similarly, more stringent law enforcement is required to protect species within Protected Areas, a conclusion that has been reached also in other parts of the world (Macdonald et al. [2012]). Two principal types of meat, the endemic wild pigs and many flying foxes are not protected, which complicates the regulatory challenge: a more informed and rigorous calculation of harvest quotas is needed, and then its implementation is enforced. These steps are unlikely to be effective unless they are supported by changes in the attitudes and behaviour of the wild meat consumers, and the behaviour of individual consumers is likely to be shaped by the norms and mores of their community as in other spheres of wildlife conservation (Veríssimo et al. [2020]).

It is particularly insightful, in the context of social mores, that peak sales of wild meat coincide with religious and social events, particularly in rural areas such as the Bolaang Mongondow districts, whereas the main (suburban) areas show peaks in transactions during the Minahasan Thanksgiving (in the three main markets in the Minahasa District). A key finding, therefore, is that religiosity is interwoven with wild meat consumption in rural Sulawesi, and most educational awareness involving the central Minahasa church in urban areas (Sibarani, 2020; Supit et al., 2021) might be more effective in rural. While for the urban area of Minahasa, an alternative and more progressive Minahasan identity, that does not involve wild meat consumption must be fostered.

7

Urban and Rural Wild Meat Consumption, Food Culture, and Shared Identity in the Biodiversity-Rich Sulawesi within Wallacea Ecoregion

7.1 Abstract

Understanding the origins of wild meat consumption is crucial for driving demand reduction efforts; yet the cultural and social factors that drive consumer behaviour are inadequately known, particularly in Asia. We conducted qualitative interviews with urban and rural wild meat consumers in North Sulawesi, Indonesia, to investigate perceptions of wild meat and the social norms that govern demand for it. We discovered that young rural males consumed wild meat more frequently than other demographics and that people's perceptions of the frequency of wild meat consumption were greater than that stated by consumers. The surveys indicated that the prime motivation for consuming wild meat is its flavour and that it is consumed neither because of a lack of alternatives nor as a delicacy or luxury. However, demand for wild meat is inelastic up to a limit, with rats most preferred (more than 100% rise from the initial price), particularly in rural areas. The consumption of endemic and vulnerable species in North Sulawesi is concerning and given the risk of zoonoses, it is desirable to end this traditional practice. However, the pursuit of this goal requires humility, and acknowledging the importance of food culture to community identity. The development of a better strategy for behavioural change necessitates consumer-focused research. We argue that behaviour change can be more

effectively encouraged at the level of society rather than that of the individual, and by understanding complex contagion, which has been successful in other fields such as public health. We propose an innovative approach, which holds promise for fostering societal behavioural change in North Sulawesi and elsewhere.

7.2 Introduction

While few societies on earth can now be described as pure hunter-gatherers, the consumption of wild meat continues to hold significance for many rural communities, not only nutritionally and economically (e.g., (Kaswamila et al. [2007], Pattiselanno and Nasi [2015], Cawthorn and Hoffman [2015])), but also culturally and spiritually (Drury [2011], Shairp et al. [2016], Supit et al. [2021]). However, while hunting can be sustainable for some fast-reproducing species, and generally in small, remote communities (Alvard [2000], Goguen and Riley [2020]), in many contexts it leads to over-exploitation and biodiversity loss (Tollefson [2019], Rija et al. [2020]).

While much has been published on the use, drivers and impacts of wild meat hunting in Central Africa much less is known of hunting in Asia, potentially due to the generally higher levels of law enforcement in comparison to Africa (Coad et al. [2019b]), which makes hunting and wild meat use information harder to elicit from wary stakeholders (but see (Kusumaningrum et al. [2022], Saba Villarroel et al. [2023])). The focus of this study is to help build the wild meat evidence base for Asia, by forming an understanding of the different drivers of wild meat consumption in a key biodiversity hotspot, in particular how consumption varies between rural and urban settlements and how cultural and social identity might influence consumption (Bourdieu and Nice [1979], Kamphuis et al. [2015], West [2020]).

In North Sulawesi, in the centre of Wallace biodiversity hotspot (Myers et al. [2000], CEPF [2014]) many communities open and proudly practice wild meat consumption (Chapter 3) and almost all local species are available for sale in North Sulawesi markets. Rats (Rodentia), fruit bats, and wild pigs make up the majority of sales (Latinne et al. [2020]). Legally protected species such as macaques (*Macaca nigra* and M. *nigrescens*), babirusas (*Babyrousa celebensis*), anoas (*Bubalus depressicornis*), deer (*Cervus timorensis*), cuscuses (*Ailurops ursinus* and *Strigocuscus celebensis*), and tarsiers (*Tarsius* Sp.) which are also sold, albeit in smaller numbers and often more clandestinely (Clayton et al. [2000], Lee [2000], Milner-Gulland and Clayton [2002]). The signs of biodiversity population decline in Sulawesi are quite apparent (Chapter 6) and especially alarming due to the high number of endemic and/or endangered species on the island (Rowe et al. [2016], Latinne et al. [2020], Martin et al. [2019]). North Sulawesi is one of the most developed provinces with the fifth highest Human Development Index (HDI) in Indonesia at 74.4, marginally higher than the national average of 73.6. Similarly, only 7.34% of citizens in North Sulawesi are classified as poor, compared with a national average of 10.3 (Open

Data Jabar and BPS - Badan Pusat Statistik [2023]). Wild meat consumption in North Sulawesi may not therefore be driven by rural poverty (Maulany [2006])(Maulany, 2006), and nor it is an expensive luxury (Latinne et al. [2020], Bailey et al. [2021]). Rather, it is a staple food and a strong signifier of group identity (Weichart [2004]). Reflecting the close link between wild meat consumption and traditional preference and culture, consumption increases significantly with holidays (Lee et al. [2005]) such as Christmas, New Year, or the Minahasa Thanksgiving (Sheherazade and Tsang [2015], Latinne et al. [2020]) (Chapter 6).

The Minahasan who live in the northern tip of the Indonesian island of Sulawesi, inhabit the area of Indonesia best known for the consumption of wild meat (Chapter 3). While they originally practiced animism, as did most Indonesians before colonialism, the Minahasan were introduced to Christianity by the first colonists, the Portuguese, in 1560 (Lee 2000). The process of adopting Christianity took the Minahasan more than a century and culminated with the arrival of Dutch missionaries in the 18th century (Lee [2000], Weichart [2004]). Christianity does not involve the religious food prohibitions of Islam and so the Minahasan have continued the food culture of their animist ancestors. This lack of religious prohibition is not merely an enabling condition (Lee [2000], Milner-Gulland and Clayton [2002], Lee et al. [2005], Maulany [2006], Latinne et al. [2020], Bailey et al. [2021]), but signals a deep connection to their communal identity. The consumption of wild meat, combined with heavy seasoning with chilli introduced by the 16th-century colonists, became symbolic of the 'toughness' or 'machoism' embraced as a signal of Minahasan identity (Weichart [2004]). While the halal food of the Moslem is labelled as 'national food', the wild meat menus of Minahasan are labelled as 'Minahasan food', which Weichart (Weichart [2004]) interprets as signifying an 'us' and 'them', this is embodied in the colloquial phrase 'us eat pork, and they eat beef'. This distinction is not necessarily antagonistic but does differentiate Minahasan identity. More recently, the Minahasan consumption of wild meat has been highlighted by government authorities as part of the region's attraction for tourists (the 'extreme' food and wild meat market – *Pers. communication with the head of Tomohon market, March 2023*).

Numerous approaches have been applied in the attempt to halt the extinction of Sulawesi's iconic species, including educational awareness campaigns (Melfi [2010], Yayasan Selamatkan Yaki [2018]), including through religious sermons (Sibarani [2020], Supit et al. [2021], Cahyami [2023]) the provision of alternative livelihoods (Indonesia, 2018), law enforcement (Lee et al. [2005]) and habitat protection through ranger based patrol (Kholis et al. [2016]). However, none have yet succeeded in 'bending the curve', changing the downward direction of the extinction trajectory. Changing behaviour that is so intertwined with a population's sense of self is complicated and challenging (Higgs [2015]). Furthermore, wildlife consumers are not homogenous, and there may be variation in many factors, such as the frequency of consumption in rural or urban locations, and a strong

association between geography, demography, and sense of identity (Elmhirst [1999]). In-depth research into the characteristics and motivations of wild meat consumers constitutes an essential first step for planning interventions to reduce unsustainable or otherwise risky consumption. This study aims to provide a baseline for the design and development of evidence-based interventions, under the hypothesis and hopes that such an approach will increase the effectiveness of current approaches. In this study, we first look at the characteristics of wild meat consumers in 11 villages in North Sulawesi province. Using consumer interviews, we then investigate the drivers of this consumption and consumer perceptions regarding wild meat consumption. Finally, considering our findings, we discuss how the Minahasan tradition of wild meat consumption might change under current development trajectories, and what, in practice, might influence people's consumption habits to minimise damage to biodiversity and zoonotic disease transmission risk. We also use this opportunity to consider how our results are shaped by the questions that we ask, comparing the results of questions asked directly about the respondents' consumption patterns with those asked when they are asked about the consumption patterns of the community in general.

7.3 Method

7.3.1 Study area characteristics.

The research was conducted in North Sulawesi Province, an area of 14,500.27 km^2 which consists of the mainland and smaller islands to the north. The mainland part of the North Sulawesi province can be considered as two areas: a larger, eastern, Minahasan area dominated by the predominantly protestant Minahasan ethnicity and accounting for approximately 30% of the total population, and the Bolaang Mongondow to the west, dominated by the predominantly Muslim Bolaang Mongondow (BolmMong) and accounting for 11.3% (BPK RI [b]). Another ethnicity distributed across numerous regencies/municipalities is the Sangir (19.8%), Gorontalo (7.4%) and Indonesian Chinese (3%). Manado, the capital, has the densest human population and is the most economically advanced of the sampling areas, with the highest human development index. The BolMong are the largest in area, and the Minahasa Regency is the most developed insofar as having the most extensive road system (BPS - Statistics of Sulawesi Utara Province, 2024). While the BolMong Regency has the highest proportion of economically active working-age persons, it also has the lowest economic development, the highest number of poor people, and the worst crime rate (BPS - Statistics of Sulawesi Utara Province [2024]).

We conducted interviews in 11 villages, divided into two categories: urban (Villages 1-4) and rural (Villages 5-11) (Figure 7.1). To protect the respondent's identity, village names are hidden. We chose the district to reflect what we define as urban and rural,

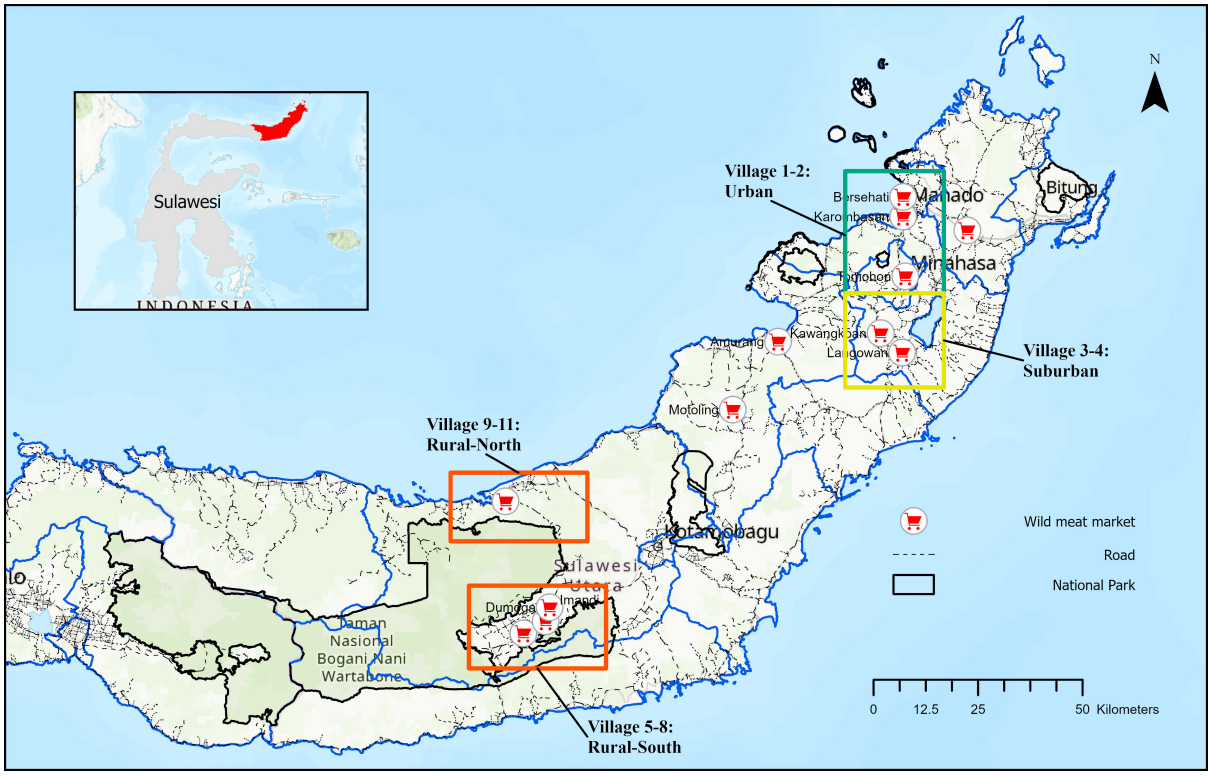


Figure 7.1: Village survey locations surrounding the Bogani Nani Wartabone Landscape and urban-suburban region in Manado-Minahasa, Sulawesi, Indonesia. The wild meat market icon on the Village 9-11 polygon is not a market, but rather an important middleman that supplies wild meat to urban markets.

however, the choice of the villages within those districts was made randomly by listing the village names and using the 'sample' function in R (R Core Team, 2023). Mindful of our aim to understand differences in consumption behaviour between rural and urban areas in North Sulawesi Provinces. We define "rural" as the area right adjacent to the Bogani Nani Wartabone National Park (BNWNP) and therefore closer to the catchment area (forested area), and urban as the more developed area in the Minahasa region. The urban sample, Villages 1-4, was drawn from the municipalities of Manado and Tomohon, and from the two villages in Minahasa closest to the two main markets of Langowan and Kawangkoan. Villages 5-8 provide the rural sample in the BolMong Selatan Regency, Dumoga District (Southeast of the National Park), and are referred to as 'Rural-South'. Villages 9-11 are in the BolMong Regency, Lolak District, along the national park's north-east boundary and the Trans-Sulawesi highway and are designated as 'Rural-North'. The BolMong and BolMong Selatan Regencies contain a substantial amount of their land in BNWNP, with the remaining park in Gorontalo Province (Figure 7.1).

7.3.2 Respondents Interviews

To investigate the characteristics and consumption preferences in each of the study villages, we conducted two surveys: a preliminary village profile survey (herein 'profile

survey') and a follow-up individual consumption survey (herein 'consumption survey'). The goal of the profile survey was to provide an overall picture of wild meat consumption (including prevalence of consumption) in the study villages, whereas the goal of the consumption survey was exclusively to interview individual consumers, going into greater detail on their personal preferences and drivers of consumption.

To select households to interview, we used systematic random sampling of up to 10% of the total households in each village, interviewing any adult ($\geq$ 18 years old) from a selected house before moving on to the next. Despite being undertaken in the same villages, each type of survey had a distinct set of respondents, was completed on a different day at a different location and was managed by a different enumerator. Both interviews began with explaining the research and securing verbal consent (A.5.3). Whenever possible, a consenting participant was audio recorded (n = 16 for the profile survey and 9 for the consumption survey). Because the interviews are usually conducted in Minahasan, a research assistant translated them into Bahasa Indonesia and prepared a transcript of the conversation. Consumption surveys asked questions about both themselves and their families, whereas profile surveys asked questions about the broader community rather than just themselves. The consumption survey's selection criteria required respondents to be consumers, whereas the profile does not.

The profile survey investigated local perceptions of wild meat consumption, hunting practices in the BNWNP catchment area, and trade activities. It was conducted in the study villages from June 24th to December 1st, 2022. We interviewed 155 households in seven villages. Interviews took an average of 37 minutes and consisted of 24 questions (Table 7.1, A.5.2), of which the first eight focused on demographic information. Subsequent questions fell into four categories: wild meat consumption, hunting for consumption, wild meat trade, and change over time. For this study, just the consumption component of the profile survey is used to contrast with the consumption survey data.

The consumption survey was conducted in all study villages between June 28th and November 3rd, 2022, involving 373 households across eleven villages with interviews averaging 36 minutes, and comprised of 30 questions divided into five topic areas (Table 7.1, A.5.1). We modified the questionnaire from (Chausson et al. [2019]), with the first part focussing on respondent demographics, followed by sections on consumption frequency, reasoning about wild meat consumption, a control section, and finally the conditions that may change the consumption habit. To understand more about customers' perception of wild meat, we asked them a series of questions: 1) Which type of meat, wild or otherwise, is most consumed, and which one is your favourite meat? 2) What is your opinion on wild versus domestic meat? 3) What is your opinion on domestic meat? We also ask about the consumers' willingness to pay above the current meat price to make a qualitative exploration of price elasticity.

Table 7.1: The questions from both surveys, including the one used in this study.

Profile Survey (sample size 155 respondents)	**Consumption Survey (sample size 373 respondents)**	**Response Type**
• Perception of how many people in their village consume wild meat* • Perceptions of favourite animals to consume • How often do people eat wild meat?*	Wild Meat Consumption: • How often do you consume meat, both wild and domestic?* • What is your favourite type of meat, both wild and domestic? • Why do you prefer wild meat over domestic meat? • Do your children also consume wild meat? • How does the price of wild meat affect your consumption habits? • What factors could cause a change in the supply of wild meat? • What factors could cause a change in the demand for wild meat?	All open-ended, except the questions with *

Profile Survey (sample size 155 respondents)	**Consumption Survey (sample size 373 respondents)**	**Response Type**
When do people eat it?	The belief structure in wild meat consumption: • What are the primary reasons that people consume wild meat? • Do you believe the younger generation shares the same reasons for consuming wild meat as the older generation? • Compared to wild meat, what is your opinion on domestic meat?	Open-ended
For what reasons?	Reflective questions: • Why did you consume wild meat as often or rarely as you stated? • What reason or event can make you change your consumption habits?	Open-ended
Where do they get the wild meat?		Open-ended

We then utilise the data from the two surveys to answer the following questions:

1. What are the consumer's characteristics?

2. What is the frequency of consumption of wild meat, and what demographic factors

influence it?

3. What is the customer preference for wild versus domestic meat?
4. What drives them to consume wild meat?
5. Is there any ailment or event that might cause them to quit eating?

7.3.3 Data Coding and Analysis

Our profile and consumption survey results were used to understand the characteristics of wild meat consumers in North Sulawesi, applying an Ordinal Logistic Regression (OLR) with the frequency of individual consumption as the response variable. Five demographic variables (Rural/Urban, Sex, Age range, Education Attained, and Occupation) and the type of survey (consumption or profile) were included as predictors. The response variable is a six-point ordinal scale describing the frequency of wild meat consumption: 'Every Day', 'Every Week', 'Every Month', 'Every Few Months', 'Every Year' to 'Every Few Years'. The statistical model and all graphs were generated using R 4.3.1, with the polr and Tidyverse package.

To summarise the information from both surveys, we used a content analysis through NVivo 14 (QSR International Pty Ltd [2023]), wherein responses were explored and synthesized based on a predefined codebook. The coding process followed deductive reasoning from hypotheses derived from prior studies and inductive reasoning to incorporate categories not previously identified (Patton [2015]). For analysis of interview responses, themes were summarised within codes and sub-codes, and cross-tabulated with attributes of interest such as urban vs. rural, sex, or age range. When addressing questions two and three, we compared data from consumption and profile questionnaires whenever feasible. Within the surveys, we also asked questions with numerous variations to confirm or triangulate the result.

7.4 Results

7.4.1 Respondent characteristics

In both surveys, there was a gender balance of respondents: 53% and 51% of the profile survey and consumption survey respondents were men, respectively. The average respondent age category for the profile survey was 45-54 years for women, 55-65 for men, and 45-54 years for both sexes for the consumer survey. In both surveys, respondents' most prevalent jobs were male farmers and female homemakers (Table A.11). The consumer survey's respondents were mostly Minahasan with a variation in the Rural-North villages which are mostly Sangihe (Sangir). Villages in Rural-North are mostly dominated by Sangir people who migrated to the area from the Islands of Sangir-Talaud in the North

of the mainland, near the border with the Philippines, compared to villages in Rural-South which are all dominated by Minahasan. The profile survey respondents were still dominated by Minahasan but had a mix of more various ethnicities with the second rank being the Mongondow, followed by the Gorontalo, Siau, Talaud, Jawa, and other minor ethnicities. The Urban villages sample area represents diverse ethnicities but is still dominated by Minahasan.

The villagers in Rural-South villages hunt wild meat, regardless of their religion and ethnicity. Their primary occupations are farming and small-scale artisanal gold mining. Wild meat markets included the Ibolian, Imandi, and Dumoga markets. In contrast, the Rural-North settlements are primarily Sangihe, with fewer residents pursuing hunting as a main income. There is no artisanal gold mining in the Rural-North village, however many of the young males work as miners for nickel or gold mining corporations in Halmahera and other eastern islands of Maluku. The major livelihoods here are farming, and no wild meat markets are nearby. Our Rural-North sample revealed consumption of the endangered Macaca nigrescens and critically endangered *Macaca nigra*. This is driven by the monkey-human conflict in plantations adjacent to the forest. The respondents in the North villages also reported that they similarly are prompted to consume wild pigs in response to conflict:

"*masyarakat menjadi serba salah. Contohnya babi hutan menyerang tanaman pertanian kalau tidak diburu maka semakin banyak dan merusak tanaman pertanian*" – ENG: because community has gone awry. For example, wild boars raid our crops. If they are not hunted, they will increase in number and damage crops even more (male, 35-44, skilled worker)

The Rural-North is near the Trans-Sulawesi highway, positioning Village 10 as a trade hub to supply urban markets. The urban sample places only have low levels of hunting, mostly for rodents, and diverse range of jobs, greater education levels, and a plethora of local and big wild meat markets, traditional as well as modern.

7.4.2 The frequency of consumption varies with the geography and demography of the respondents

We ran five candidate models and chose the one with the lowest AIC as the top (parsimonious) model (Table 7.2). The top model has age, sex, whether respondents are urban or rural, and survey type as predictors with an AIC weight of 96% compared to the other model candidates. According to our OLR model, respondents who were from rural villages, men, and respondents under the age of 44, were those most likely to consume wild meat frequently (Figure 7.2, Table A.12). The reported frequency of consumption was higher for the profile survey, where respondents were asked to report on the overall consumption habits of the community, as compared to the consumption survey, where respondents were reporting on their consumption habits (Fig. S2).

Table 7.2: Model selection table for candidate models in predicting which factors are associated with wild meat-eating frequency.

Model	Intercept	Survey	Type	Sex	Age	Education	Occupation	AICc	Delta	Weight
4	+	+	+	+	+	NA	NA	1174.19	0	0.96
5	+	+	+	+	+	+	NA	1181.53	7.34	0.02
6	+	+	+	+	+	+	+	1183.04	8.85	0.01
3	+	+	+	+	NA	NA	NA	1188.28	14.09	0.00
2	+	+	+	NA	NA	NA	NA	1190.40	16.21	0.00
1	+	NA	NA	NA	NA	NA	NA	1234.50	60.31	0.00

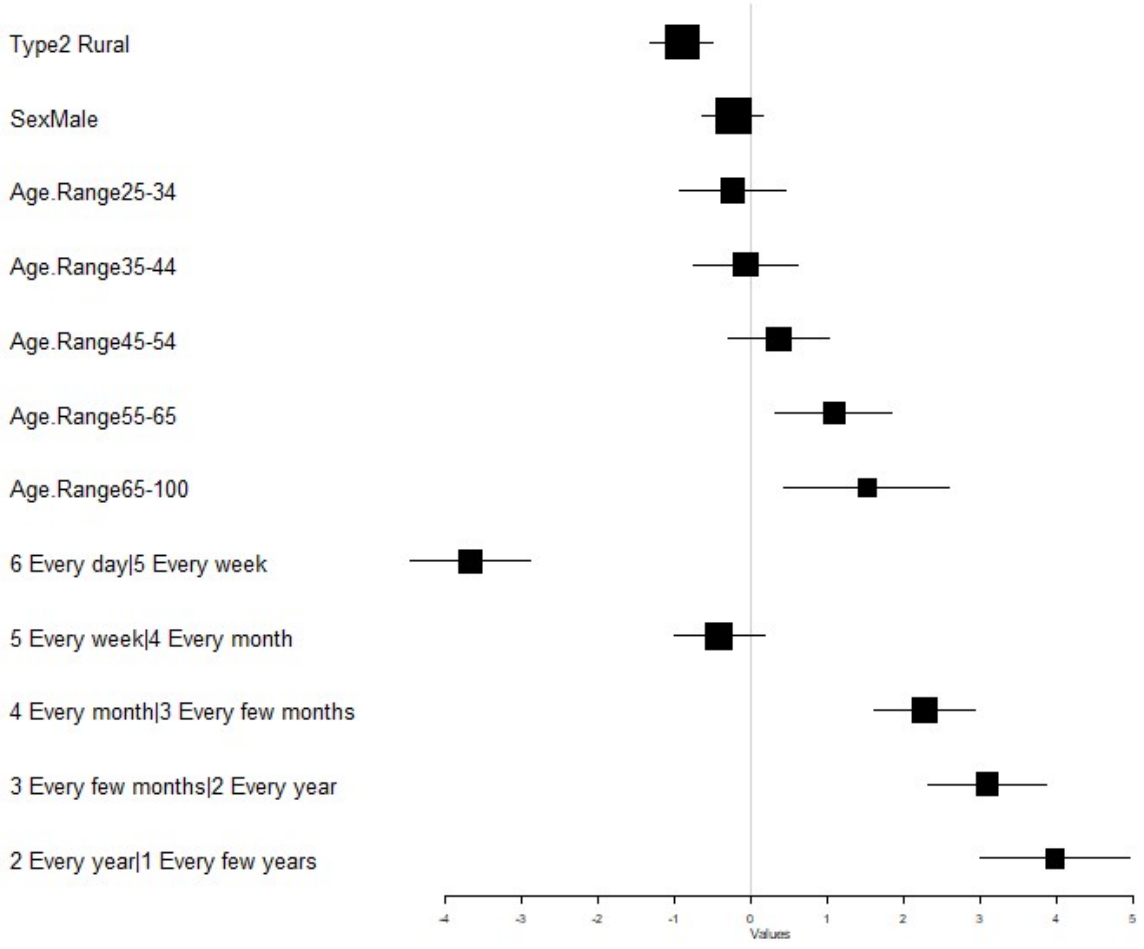


Figure 7.2: The graphic shows the odds ratio of the predictor and responder variables; the black square represents the mean estimate, and the whiskers indicate the 95% confidence interval. The odds of consuming wild meat rarely ($\geq$ once a month) increase as the estimate moves to the right, and vice versa.

7.4.3 Preferences for wild and domestic species.

The consumers mostly mentioned wild pigs when asked about the meat they frequently eat, however fish, even though slightly less mentioned, is the meat they overwhelmingly said consumed every day (Figure 7.3). What ones frequently eat isn't necessarily the most preferred, as wild pigs are still the most favourite, both as meat in general and as wild meat. In both the profile and the consumer survey, wild pig (*Sus celebensis*) was the most preferred species to eat of any wild or domestic species. Both consumers and profile survey respondents have the same perception of the three topmost preferred wild meat: wild pigs, rats, and bats, in that order (Figure 7.4).

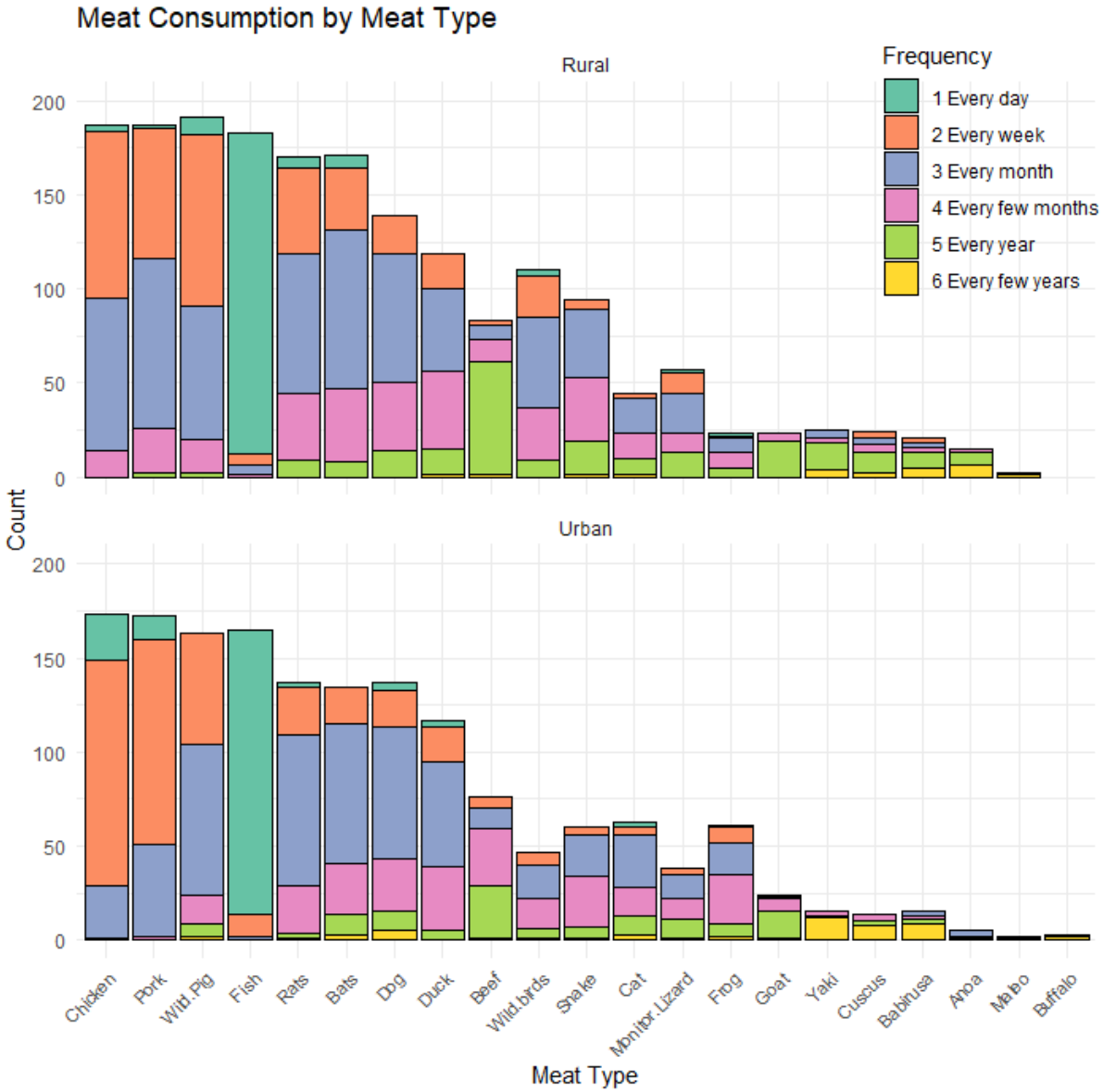


Figure 7.3: The frequency with which respondents consumed meat in the consumption survey. The results from both rural and urban areas appear similar, with chicken, pork, wild pig, and fish being the most often stated. However, most respondents reported eating fish every day.

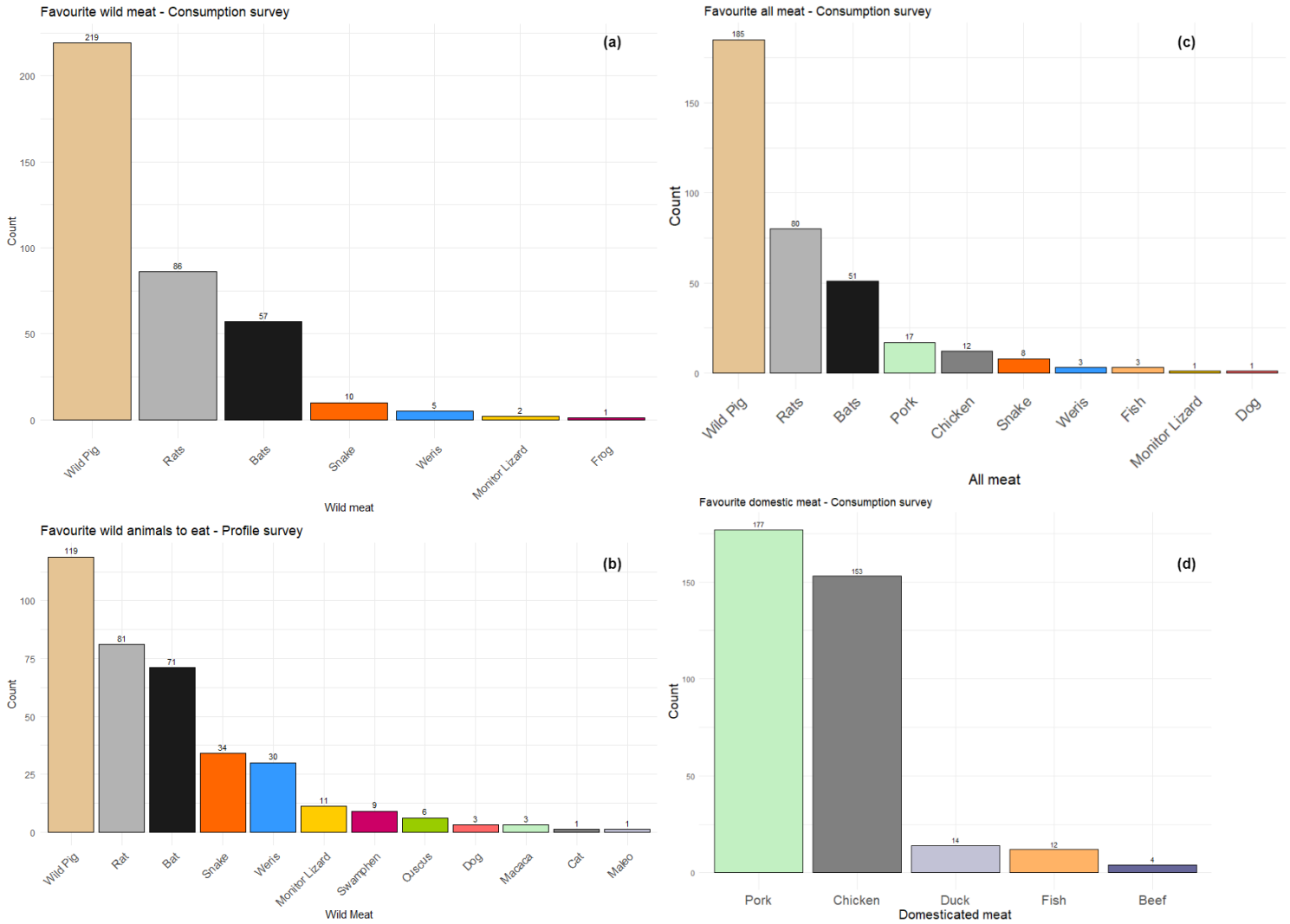


Figure 7.4: The most popular animals to eat, as reported by survey respondents. Graphs a, c, and d are taken from the consumer survey (n = 373 respondents), and b is from the profile survey (n = 155 respondents)

7.4.4 Drivers of consumption

The primary reason given by respondents of the consumer survey for eating wild meat is because it's tasty (Table 7.3), and this is consistent across all respondent types (i.e. rural/urban, age gender). The next most common reason is that eating wild meat is a habit instilled in children by their parents, family, and others. The third reason given by rural respondents is that they know how to prepare it, and by urban respondents because it is uncommon or rare. Respondents generally considered that preparing wild meat is more difficult than cooking domestic meat, and this opinion is reflected in the tendency of urban respondents to favour domestic beef because it is easier to cook. The term "rare" refers not to the animal's population status but rather to the fact that wild meat in urban areas is not often available and is considered a delicacy. Amongst rural villages, affordability ranks in the top three reasons for consuming wild meat, whereas it ranks seventh amongst urban respondents, ranking higher than the skill required to prepare wild meat and its status as a delicacy. Familiarity, expressed as the perception that consuming wild meat is 'nothing special' because they see it as ordinary daily food, is ranked fourth by urban respondents, but was mentioned by only two rural respondents. This appeared to contradict the perception that eating wild meat is a delicacy (27 references for 'nothing special' compared to 25 for 'rare').

Table 7.3: The count of how many times a given topic was referred to in the consumer survey (with the percentage from total).

Reasons to consume wild meat	**Urban (n = 179)**	**Rural (n = 194)**	**Total (373)**
Tasty	119 (40%)	169 (44%)	288 (42%)
Habit	55 (18%)	93 (24%)	148 (22%)
Know how to prepare	16 (5%)	23 (6%)	39 (6%)
Rare	25 (8%)	14 (4%)	39 (6%)
Affordable	11 (4%)	27 (7%)	38 (6%)
Nothing special	27 (9%)	2 (1%)	29 (4%)
Healthy	6 (2%)	17 (4%)	23 (3%)
Medicinal	13 (4%)	8 (2%)	21 (3%)
Natural	9 (3%)	10 (3%)	19 (3%)
Available	8 (3%)	8 (2%)	16 (2%)
Curious	8 (3%)	2 (1%)	10 (1%)
Tradition	2 (1%)	6 (2%)	8 (1%)
Menu Variation	0	4 (1%)	4 (1%)
Other - Prohibition	2 (1%)	1 (0%)	3 (0%)
Not Illegal	0	1 (0%)	1 (0%)
Prestige	0	1 (0%)	1 (0%)
Top Menu	0	1 (0%)	1 (0%)
Total	301	387	688

When asked to compare wild versus domestic meat (Table 7.4), respondents mostly expressed positive sentiments toward wild meat. Aside from taste, urban consumers said wild meat is natural and rare, while rural consumers think wild meat is natural and a

habit. Other reasons given include price (wild meat is inexpensive, particularly in rural areas), tradition (mainly in urban areas), medicinal properties, wild meat providing variation to the menu, and, finally, that people eat it simply because it is edible. Opinions favouring domestic meat focused mainly on its widespread availability and ease of preparation compared to wild meat (Table 7.4). In contrast to wild meat, respondents mostly expressed negative sentiments about domesticated meat. Respondents from both urban and rural villages think that domestic animals are fed chemically and receive chemical products such as vitamins and growth hormones, which they consider as neither healthy nor natural, contributing to their low preference. Rural consumers, more than urban consumers, mostly think domestic meat is not natural and hence less tasty. However, some urban consumer also typically considers that domestic meat is more readily available and easier to find than their rural counterpart believes.

Table 7.4: The consumption survey respondents' opinions on wild vs. domestic meat (with the percentage from total).

Opinion on wild against domestic meat	**Urban (n = 179)**	**Rural (n = 194)**	**Total (373)**
Wild - Tasty	96 (42%)	108 (45%)	204 (44%)
Wild - Natural	31 (14%)	41 (17%)	72 (15%)
Wild - Rare	24 (11%)	15 (6%)	39 (8%)
Wild - Habit	8 (4%)	28 (12%)	36 (8%)
Wild - Healthy	13 (6%)	20 (8%)	33 (7%)
Wild - Available	11 (5%)	11 (5%)	22 (5%)
Wild - Affordable	0	8 (3%)	8 (2%)
Wild - Tradition	5 (2%)	2 (1%)	7 (2%)
Wild - Medicinal	1 (0%)	2 (1%)	3 (1%)
Wild - Menu variation	1 (0%)	0	1 (0%)
Wild - because its food	0	1 (0%)	1 (0%)
Domestic - Available	12 (5%)	2 (1%)	14 (3%)
Domestic - Easy to prep	12 (5%)	1 (0%)	13 (3%)
Domestic - Tasty	6 (3%)	0	6 (1%)
Domestic - Habit	2 (1%)	1 (0%)	3 (1%)
Domestic - Healthy	2 (1%)	0	2 (0%)
Domestic - Safe	1 (0%)	0	1 (0%)
Total	226	240	466

7.4.5 Factors that may incentivise individuals to alter their patterns of consumption

When we asked consumers if there was anything that would cause them to modify their consumption patterns, here are their responses. The more frequently given reason for respondents ceasing to eat wild meat is that it is associated with health concerns (Table 7.5); a view most often expressed by respondents aged between 45 and 65 years (Table A.13). The second was an opinion that there is nothing that can modify their consumption habits (rank second), an opinion held similarly in urban and rural areas and among younger age groups (Table A.13).

Table 7.5: The condition that will urge consumers to change their consumption habits (with the percentage from total).

Situation that drives change	**Urban (179)**	**Rural (194)**	**Total (373)**
(-) Health issue decrease consumption	44 (25%)	61 (32%)	105 (29%)
No Change	36 (20%)	47 (25%)	83 (23%)
(-) Economic ability decreases	25 (14%)	31 (16%)	56 (15%)
(-) Decrease of supply in market	23 (13%)	21 (11%)	44 (12%)
(+) Economic ability increases	7 (4%)	12 (6%)	19 (5%)
(+) Social event frequency	14 (8%)	2 (1%)	16 (4%)
(+) If the wild meat menu is already served	7 (4%)	1 (1%)	8 (2%)
(+) The notion that wild meat is healthy	4 (2%)	2 (1%)	6 (2%)
(-) If the wild meat menu is not available	3 (2%)	3 (2%)	6 (2%)
(-) If it is not a 'hobby'	4 (2%)	2 (1%)	6 (2%)
(-) If the rat meat is a 'contraband'	5 (3%)	0	5 (1%)
(+) Tasty	2 (1%)	1 (1%)	3 (1%)
(+) Family member asked for it	1 (1%)	1 (1%)	2 (1%)
(-) Bored	1 (1%)	1 (1%)	2 (1%)
(+) if the meat fresh	0	1 (1%)	1 (0%)
(+) Back to village	1 (1%)	0	1 (0%)
(-) If the meat old	0	1 (1%)	1 (0%)
(-) If it's illegal	0	1 (1%)	1 (0%)
(-)If they migrate away	0	1 (1%)	1 (0%)
(-) If they are busy	0	1 (1%)	1 (0%)
Total	177	190	367

There is almost no mention of zoonotic disease risk from wild meat consumers. Only one respondent mentioned COVID-19.

"*Karena kesehatan, takut kena covid karena katanya berasal dari paniki*" –ENG 'for health reason, I don't want to get COVID, people said it's from the bat' (male , 55-65, rural farmer).

Cholesterol, gout, and high hypertension were the most frequently mentioned health risks, and similarly so across age groups, sex, urban/rural, employment, and level of education (primary to college). One vendor stated that he believes the reason that members of his community do not get any spillover disease from the animals they eat is because they cook differently to other parts of the world:

"*We used many fresh herbs and spices which killed all the virus, and when we eat dog, we do not eat the head part*" (male, 35-44, wild meat vendor in Langowan market).

Concerns about food safety are mostly focused on 'fraudulent' rats' meat (city sewage rats instead of forest rats) (n=5 respondents, all urban) and old or spoiled meat (n = 1 rural respondent).

At the time of our surveys (2022), the average market price for pork was 60-70,000 IDR per kg, wild pig was 30-50,000 IDR per kg, bats were 60-70,000 IDR per kg, and rats 70,000 IDR per kg. The price variation is because of location, with urban areas having

slightly higher prices compared to rural. Our qualitative questions about price elasticity found that for all respondents combined, rats, followed by wild pigs, are the top two wild meat for which consumers are willing to pay ≥50% of the prevailing cost (Table 7.6).

Table 7.6: Average Price Increase of Meat per Unit Sold

Meat	Price Increase			Price Increase by Gender		
	Rural	Urban	All Respondent	Female	Male	All Respondent
Rats (n = 84)	132%	53%	85%	75%	94%	85%
Wild pig (n = 217)	63%	66%	64%	59%	68%	64%
Bats (n = 50)	43%	54%	48%	47%	50%	48%

When we strata the consumer into rural/urban, rats showed high elasticity in rural areas with consumers willing to pay more than twice the average price per unit for rats (132%). Urban consumers value wild pigs more, which they price slightly higher than the average (66%). Males indicated a greater price elasticity for all three wild meat than females (e.g., rats' elasticity of 94% for males and 75% for females). However, the majority (61%) of those shopping for wild meat are women. This reflects a disparity between the greater willingness to pay expressed by male respondents and the reality that most purchases are made by female respondents.

7.5 Discussion

Our study showed that respondents believe that people who consume wild meat eat it more frequently than the consumers themselves state. This is important as we highlight who has a say on certain issues matters (Hinsley et al. [2022]). This disparity between the perceptions of the wider population and the wild meat consumers may be an example of the distorting influence of social categorization (Stolier and Freeman [2017]), which is well-known to lead to inaccurate stereotyping (Noguchi et al. [2013]).

We also showed an in-depth analysis of consumers in a granularity, urban/rural and demographic factors, which has never been done before in Sulawesi. Elsewhere there is evidence that urban demand drives unsustainable consumption of wild meat (Drury [2011], Morsello et al. [2015], Sandalj et al. [2016], Shairp et al. [2016], Mbete et al. [2019], Luiselli et al. [2020]), but we found no evidence of this; indeed, our rural respondents ate wild meat more frequently than did urban respondents. The North Sulawesi demographic most frequently eating wild meat was young men, although this did not seem to reflect, as it does in Vietnam, a fashion (Drury [2011]). Rather, it seemed to arise from a reticence to eat wild (or any red) meat amongst consumers older than 44 years, based on health concerns including risks from cholesterol or developing gout. Men have also been found to eat more wild meat than women in Cameroon (Brittain et al. [2022]), and six West African metropolitan centres (Luiselli et al. [2020]), although in both cases these were

older men. A study from Congo which informed our own, showed similar results of a lack of significant association between frequency of consumption and education or profession (Chausson et al. [2019]).
Wild meat consumption in our Rural-South sample, drawn from the Dumoga regency, was funded mostly by income from small-scale artisanal gold mining (Meutia et al. [2022]), with an increase in spending associated with finding gold (Head of Village 5 and Vendors of Imandi market – *Pers. Communication*). Insofar as the villagers' cultural roots lie in animism, irrespective of their current religion, hunting has traditionally existed alongside their agriculture practice (Weichart [2004]). Nowadays, while a few specialist hunters make their living principally from hunting (unpublished data), hunting is predominantly a stopgap between employment in mines and waiting for the harvest from agriculture (Hunters of Village 5 — *Pers. Communication*). Our Rural-North samples showed that they consumed wild meat to deal with the human-wildlife conflict.

7.5.1 Reason and preferences in wild meat consumption

We show that taste was a prime factor for wild meat consumption in both rural and urban communities, echoing similar findings in the Republic of Congo (Chausson et al. [2019]) and in rural communities in Cameroon (Brittain et al. [2022]). Reasons linked to respondents' pride in Minahasan culinary traditions, and the role of wild meat consumption in reinforcing the Minahasan's identity as a member of the community were noted as important in our study. Perceptions of taste can be linked to familiarity (Becker et al. [2022]), and this aligns with our second most reported reason for consumption, which was 'habit'. Nonetheless, the Minahasan style of cooking wild meat involves masking its gamey taste of the meat with herbs and chilli, and pride in this culinary style is one of the three main reasons given to explain their consumption of wild meat (a sentiment emphasised particularly by consumers in comparison to domestic meat). Domestic meat is considered bland and is associated with concentrated food, growth hormones and other chemicals. Chausson (Chausson et al. [2019]) note the role of 'nostalgia' for traditional practices is known to be a driver of urban consumption of wild meat in other countries, the continuing links with rural village life in Minahasan likely dilute this effect, although we found some urban dwellers who sought gifts of wild meat from their rural village family. The complexities of reported consumption drivers suggest that interventions to reduce wild meat consumption that are based solely on the impact on biodiversity, or even health disbenefits of eating wild meat, may be unsuccessful unless they incorporate cultural values associated with consumption. Manfredo et al., (Manfredo et al. [2017]) argue for research that takes a multi-layered and dynamic approach, involving creative conservation measures that fit within current value structures. More diverse and inclusive intervention design can be achieved using a co-design approach, to incorporate key stakeholder views and experiences into the design process, and this has been demonstrated

to produce culturally appropriate and innovative interventions in traditional medicine markets in China (Hu et al. [2023]).

Our findings confirm that the drivers, circumstances, and consequences of wild meat consumption vary greatly between locations and have varied relationships to food dependency (Walelign et al. [2019]). Although all consumers in our sample eat wild meat because it is tasty and part of the habit, urban consumers also reported that they ate it because it was rare, while rural consumers reported that it was because it was affordable. Although wealthy overall, wealth is not equally distributed in the province (World Bank [2015]), which could explain both the preference for more affordable meat and higher price elasticity in urban areas. Affordability is important because economic limitations to eating wild meat were reported as the second most important factor for reducing consumption, Similar limitations were reported in the Republic of Congo, where consumption was limited by affordability (price) and availability (Chausson et al. [2019]), and price is known to be an important factor in wildlife consumer decision making more broadly, often overriding other preferences (Hinsley and 't Sas-Rolfes [2020]). Nonetheless, in general customers in North Sulawesi demonstrate inelastic demand, meaning that they aren't particularly responsive to price fluctuations, and a price rise would probably cause a proportionately smaller drop in the amount required (and vice versa). Similar inelastic demand for wild meat has been reported in the Greater Serengeti Ecosystem (Walelign et al. [2019]) and Vietnam (Shairp et al. [2016]). Some consumers in Vietnam attach a higher value to wild meat because it is expensive (Drury [2009a]), a so-called Veblen effect where a high price is a status symbol (Bagwell and Bernheim [1996]).

Despite the focus on price, we conclude that wild meat is generally not a luxury in Sulawesi, being priced similarly to pork, and generally being eaten at home during communal traditional or religious occasions. In Northern Sulawesi, as in Ghana, the inelasticity of wild meat differed between urban and rural samples (McNamara et al. [2019]), and across consumer's sex, and type of animal. Rural customers' strong propensity for paying more for rats much outweighs urban consumers' willingness to spend just 50% more than usual rates for the three most common types of wild meat: wild pigs, bats, and rats. And, while the males in society evidenced a greater willingness to pay, females were the decision-makers. This suggests that a possible policy such as a 'wild meat tax' is unlikely to be effective in reducing wild meat consumption in North Sulawesi. Current health concerns about (wild) meat were dietary rather than epizootiology and restricted to older consumers. This reason seems unlikely to drive behavioural change under current circumstances.

7.5.2 How can we reach the tipping point of changing wild meat consumption habits/culture?

Sulawesi is the area most studied wild meat issue compared to other Indonesia regions (Chapter 5): the study of over-exploitation (Lee [2000]), illicit market dynamic (Milner-Gulland and Clayton [2002]), cause of concern for zoonotic spillover (Kusumaningrum et al. [2022]), or a curious case of food as symbolic for group identity from Anthropological perspective (Weichart [2008]). Many strategies also have been and still conducted to curb the demise of Sulawesi fauna, including educational awareness campaigns done in wild meat markets (Yayasan Selamatkan Yaki [2018]) and the 'green gospels' through the largest church in Minahasa, the Gereja Masehi Injil di Minahasa (GMIM) [Christian Evangelical Church in Minahasa] (Supit et al. [2021], Cahyami [2023]). The first is an attempt to influence the agents directly involved in the supply chain, the vendors, and customers, with a special goal of instilling pride in the local endangered black macaque, while the second is a method of mobilising the support of local actors and institutions (Sibarani [2020]). However, we haven't yet seen that these approaches are effective. It has long been known that improved knowledge does not necessarily lead to behaviour change (Rice et al. [2024]), one of the reasons is confirmation bias, which is the propensity to only accept information that supports our previous beliefs (Kolbert [2017]). Moreover, as with many other conservation initiatives, efforts to reduce wild meat consumption, in Sulawesi and elsewhere, are often lacking in impact evaluation using a robust causal inference, which is particularly hard for behaviour change intervention (Thomas-Walters et al. [2020]).

Food consumption, and thus culture, is a behaviour shaped in the social sphere and involves unconscious dispositions shaped by societal interaction with abiotic circumstances (Maton [2008]). What to consume and what is considered safe foods are regulated by social norms (Higgs [2015]), and more broadly social norms provide tight-knit connections among members as a foundation for norms enforcement and widespread adoption of behaviour within the group (Centola and Macy [2007]). For the Minahasan, hunting and wild meat consumption is more than ingestion of nutrients, but is a social act that contributes to social identity as well as to survival and is part of the fabric of the community (Weichart [2008]).

The power of social norms needs to be considered in the quest for behavioural change. Learning from another field might help us solve this deadlock (Travers et al. [2021]). One of them is the science of complex contagion from computational social science (Centola and Macy [2007], Bamberg et al. [2018]). This is a framework to make behavioural change at the societal level instead of the individual (Centola [2010]), by seeding change into small, committed individuals in a highly knitted community at the periphery of the social network. This will produce an opportunity to reach a critical point of people on

the periphery of a social network, which will further change the wider community into a new equilibrium of behaviour and norms (Centola et al. [2018]), In our case this would be from wild animal consumer to non-wild animal consumer, but the approach has been effective in public health when addressing vaccine hesitancy (Onnela et al. [2016]).
We have seen evidence of this happening organically among the Manado's animal lover group. The cats and dog lovers of Manado are communities of animal lovers with a big presence online. Unlike traditional messages which are expected to spread from central 'influencers', the animal welfare message was first adopted by a strong minority community in the periphery. After the message is adopted by at least 25% of the people at the periphery of the social network, the tipping point to reach a societal behaviour change is met (Centola et al. [2018]). Insofar as many of our respondents mentioned that they had stopped eating cats and dogs, and a well-known wild meat restaurant had taken them off the menu (Unpublished data). Rather than changing their consumption habits due to increased knowledge from education awareness, Minahasa wild meat consumers adopted a new shared identity as animal lovers (Galam and Moscovici [1991], Schulte et al. [2020]). That appears to be the sole shift in North Sulawesi's wild meat consumption habits in the last three decades.
In summary, a principal motivation for continuing the consumption of wild meat appears to be its link to a sense of traditional identity. We found no evidence that this sense had been reduced by two decades of conservation education. We proposed to have a robust impact evaluation of the existing conservation strategies in the area to learn from what we can do better. Furthermore, we need to understand more about how the tipping point in social convention happens in Manado's cats and dog lovers, and how can we replicate this in all the other endemic-endangered wild animals in Sulawesi.

7.6 Study Limitation

Our study is the first to attempt to gain a better understanding of wild meat consumers in North Sulawesi. As a result, many of the study constraints listed here reflect what we would like to achieve if we were to redo this study entirely. A thorough choice experiment on wild meat preferences will strengthen our study's findings, and a quantitative price elasticity study in which supply is evaluated alongside domestic meat as an alternative product will yield a quantification of price elasticity.

Part III

Epilogue

"No single raindrop feels responsible for the flood."

— Douglas Adams

8

Some final brief reflections

Wicked problem needs a 'wicked solution', or so they say (Steinhall et al. [2023], Walls [2018]). I do not want to overstate the achievement of this thesis: I believe these 200 or so pages offer abundant insight, but we are still far from solutions, wicked or otherwise, to all the problems identified herein. However, I can comfortably attest that I, supported by my co-authors, have ventured significantly and originally into the, at least until recently, rather sparingly explored framework of system thinking in conservation biodiversity (Lönngren and van Poeck [2021]).

System thinking, an approach defined by Meadows [2008], is, in my opinion, crucial. This is because it is the bridge for epistemic divides linking the knowledge and disciplines that comprise interdisciplinary conservation science. Its product can be the shared understanding of how to maintain biodiversity (Davila et al. [2021]). By taking this approach, I hope that I have led my collaborators towards solutions that offer the best hope under current circumstances and with current knowledge. Of course, future circumstances, and knowledge will be different, and we can confidently expect a fresh crop of 'unknown unknowns' (the ones we don't know we don't know, after Donald Rumsfield), and future system changes may all redefine the system; but for the time being, we can only try our best.

8.1 Research questions revisited.

In these final reflections, it is not my intention to revisit and repeat conclusions I have already drawn in the papers that comprise this thesis – such repetition would be superfluous as each paper is intended to stand on its own. Rather, my intention here is briefly to make a few higher-level points that I feel need emphasis above and beyond the previous data chapters. Some of these arise from my results, some just from my experience. They

led me to conclude with some practical recommendations and, where appropriate, suggestions for worthwhile next steps that would not have been obvious before my work. The logical final step, the bookend to his thesis, is now to revisit the questions I posed in the section 1.3 and to take stock of the answers. This is my purpose in these next paragraphs.

8.1.1 Protected areas are social-ecological systems entrusted with maintaining biodiversity.

The first question relates to the spatial component of biodiversity protection, specifically the land on which it takes place. The land is not inert; it reacts to human and other species' intrusions and interventions. Returning to system thinking, we must recall that the features of 'the whole' arise from the dynamic interplay of linked pieces ('the parts'), leading systems to develop their behaviour (i.e., as Aristotle first articulated, the whole is larger than the sum of the parts). In the case of Sulawesi, the research in this thesis has led me to consider as particularly relevant two 'active' factors: the present (distribution) of threatened species and the ultramafic soil. The importance of the first factor is self-evident, whereas the second reminds us of the high nickel content in this soil type which, along with gold, is another valuable resource extracted in Sulawesi. Both factors are precariously open to the risks of over-exploitation, as in the case of environmental destruction linked to nickel mining (Jong [2024]) and defaunation from biodiversity loss. In this context, the answer to the question of whether the current protected areas (PA) network has been effective is no; it is not yet effective (Chapter 4). The current protected area network fails to protect the areas that are now used as primary hunting grounds to meet the demands of North Sulawesi's wild meat markets (Chapter 6). Furthermore, the concept of PAs, as implemented in Sulawesi, and Indonesia in general, represents an 'island' approach. That is, a core zone in the middle is surrounded by a buffer zone. This is only the first stage in the evolution of a PA system – the desired destination is a social-ecological approach. Figure 8.1 reproduced from Clements et al. [2024] visualizes this progression. A social-ecological approach culminates in a mosaic of PAs achieving various levels of protected status, with the biodiversity they are entrusted to maintain being inextricably linked to people's needs and values.

8.1.2 Wild meat supply chains in North Sulawesi and their impact on biodiversity

The functional niches of those terrestrial animals in my study that were under constant threats of over-exploitation almost invariably involved areas farther from edges of the forest, in inaccessible places, and in several cases at high elevation (maleo and junglefowl were exceptions). I demonstrated this pattern in Bogani Nani Wartabone National Park. Superimposed on this pattern, I also exposed a causal relationship whereby species

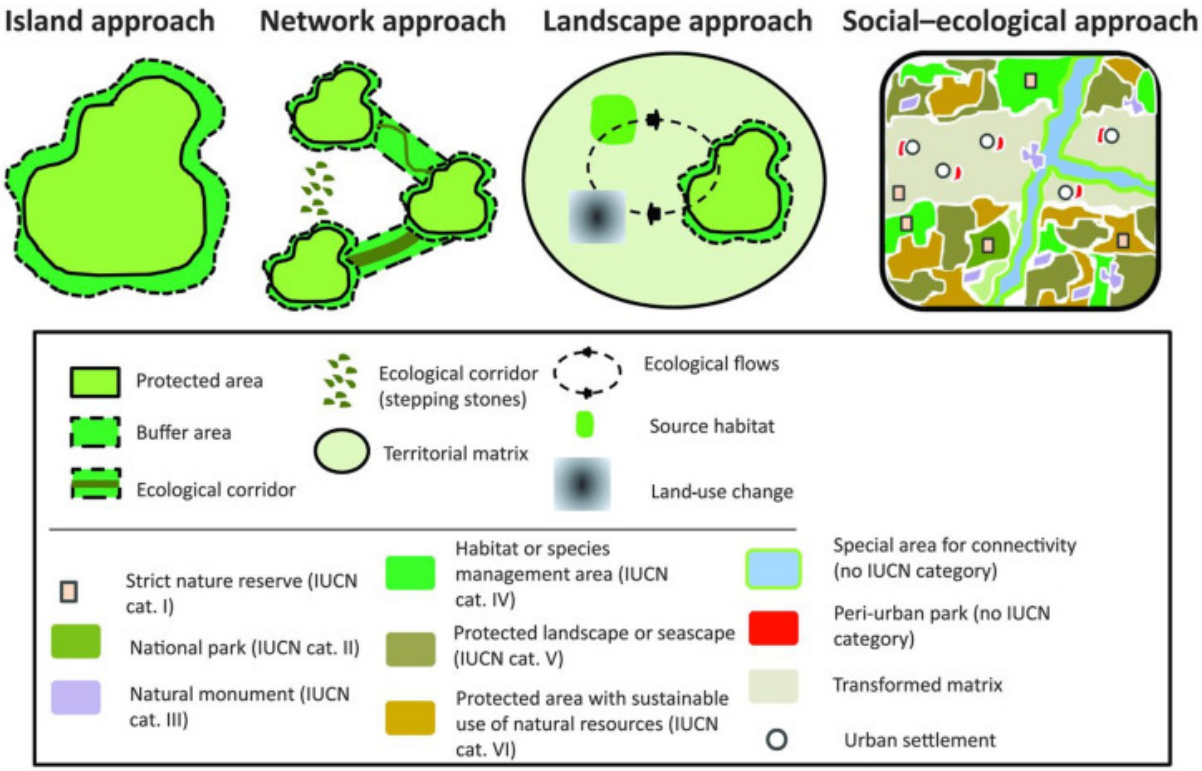


Figure 8.1: Taken from (Clements et al., 2024) on the evolution of the protected area concept.

richness decreases in proximity to a wild meat market, even though hunting takes place throughout the areas surrounding the park (Chapter 6). My findings strongly suggest that the wild meat markets of North Sulawesi are driving the fate of the entire island's terrestrial fauna. As I demonstrate, current demand is met from farther and farther afield as time passes, particularly so for those species that have been experiencing population declines for several decades. From the first principles of life histories, species with low fecundity can withstand a lesser rate of harvest and approach local extirpation sooner, which is the case for threatened species such as anoa and babirusa. Even more resilient species are experiencing hunting at an intensity that pushes them to population decline despite their greater fecundity and more resilient demography; previous studies had mistakenly concluded that their resilience would protect them (Robinson and Bennett [2000]): this is the situation of wild pigs and cuscus, together with the Sulawesi endemic bats (both mega- and micro-chiroptera) (Jones et al. [2009], Mickleburgh et al. [2009], Ransaleleh et al. [2020], Tanalgo et al. [2023]). Rodents present an intriguing case (Amori et al. [2008]); along with smaller bats they are hunted in the forested areas bordering and within Bogani Nani Wartabone National Park. The fecundity of these rodents might be thought to be sufficient (Dwyer [1975]), and as in the case of African's cane rats, to sustain heavy levels of consumption (Kilwanila et al. [2021]). On this basis, rodents have been proposed as a sustainable source of meat for the masses (Gruber [2016]). Thus far,

the dynamics and harvest of rodent populations are insufficiently understood, but once adequate information is available two options will lie ahead: either a) decide that it is necessary to make the selling and consumption of these animals illegal and then enforce the law, or b) establish and enforce a scientifically valid quota to ensure that the harvest is sustainable. The Minahasan, as the primary consumers of wild meat, do not eat it from necessity for their survival, but, as I demonstrate, they nonetheless regard doing so as essential to maintaining their Minahasan identity. In the context of this cultural reality, any attempts at instigating behaviour change necessitate sensitivity.

8.2 Strategy and policy recommendations

1. Increase the protection status of those forests on the island of Sulawesi where hunting is currently occurring by promoting a social-ecology approach to the management of protected areas. This approach should also acknowledge the value of other categories of conservation areas such as the OECM (Other Effective Area-Based Conservation Measures) and indigenous land.

2. The Bogani Nani Wartabone National Park is the only park in Sulawesi in which biodiversity is systematically and regularly monitored (it is undertaken by WCS-Indonesia program in collaboration with the national park). A similar program must be replicated throughout the PA network, attending first to the areas identified as priorities in Chapter 4.

3. Undertake robustly designed impact evaluations of existing conservation strategies, educational awareness campaigns and the green gospels.

4. Develop and implement a holistic approach to wild meat consumption in North Sulawesi, such that the management authority attends respectfully to all elements of the system, including conservation areas, communities engaged in both the hunting and selling of wild meat and the cultural attributes of eating wild meat as an important dimension of Minahasan's shared identity. It is imperative that any and all multi-sectoral and multi-disciplinary activities should be undertaken in a coordinated manner, within an appropriately consultative framework designed to deliver a shared purpose and preferably supervised by a government body.

8.3 Suggestions for future research

As I reach the end of my doctoral research, an obvious question is what next steps I would propose as priority topics for research by my successors. Based on my own experience, I would propose:

1. An empirical investigation to map the social network of one of our sample villages and to test Centola's tipping points theory (Centola et al. [2018]). This is highly

feasible. The ideal village would be highly secluded from other settlements, with a population of 200-300. One of our Rural-North villages may be a contender for this project. Similar work has been done elsewhere to employ social network mapping of the community for conservation objectives (de Lange et al. [2019, 2022]), however, a study using a computational social science approach such as those involving complex contagion has never been attempted. I foresee this work being a conceptually novel and policy-relevant post-doctoral project.

2. Using Chapters 6 and 7 as the baseline, a continuation study using a more rigid social science technique is needed, I propose:

    - A choice experiment to explore the nuances in consumer perception of different species of bats and rodents, exploring the life-history correlates and differing ecological circumstances that affect their potential for sustainable harvest.
    - A detailed price elasticity study, with measurement of both the supply and demand side.
    - A continuation of my market survey, at least in Langowan market where data already span three decades (Chapter 6). A particular focus is on the implications of African Swine Flu, for both species of wild pigs, and the domestic pig, and the consequences of both for peoples' livelihoods and wellbeing.

Bibliography

Anang S. Achmadi, Fahri Fahri, Abigail Gazzard, Heru Handika, Nurul Inayah, Rosalind J. Kennerley, Asnim Alyoihana Lanusi, Meis Nangoy, Muhammad Rizaldi Trias Jaya Putra Nurdin, Kevin C. Rowe, and Sheherazade. Conservation status and priorities for sulawesi's unique small mammal fauna. *Oryx*, 57:690–691, 11 2023. ISSN 0030-6053. doi: 10.1017/S0030605323001059.

Vanessa M Adams, Nadya Dimitrova, Hugh P Possingham, James R Allan, Caitlin D Kuempel, Nate Peterson, Alu Kaiye, Malcolm Keako, and Vivitskaia J.D. Tulloch. Scheduling incremental actions to build a comprehensive national protected area network for Papua New Guinea. *Conservation Science and Practice*, 3(2):1–11, 2 2021. ISSN 2578-4854. doi: 10.1111/csp2.354. URL `https://onlinelibrary.wiley.com/doi/10.1111/csp2.354`.

William M Adams, Ros Aveling, Dan Brockington, Barney Dickson, Jo Elliott, Jon Hutton, Dilys Roe, Bhaskar Vira, and William Wolmer. Biodiversity Conservation and the Eradication of Poverty. *SCIENCE*, 306, 2004.

Alessandro Albani, Maurizio Cutini, Lavinia Germani, Erin P. Riley, Putu Oka Ngakan, and Monica Carosi. Activity budget, home range, and habitat use of moor macaques (Macaca maura) in the karst forest of South Sulawesi, Indonesia. *Primates*, (0123456789), 2020. ISSN 16107365. doi: 10.1007/s10329-020-00811-8. URL `https://doi.org/10.1007/s10329-020-00811-8`.

S M Allebone-Webb, N F Kuempel, J Rist, G Cowlishaw, J M Rowcliffe, and E J Milner-Gulland. Use of Market Data to Assess Bushmeat Hunting Sustainability in Equatorial Guinea. *Conservation Biology*, 25(3):597–606, 2011. ISSN 0888-8892. doi: 10.1111/j.1523-1739.2011.01681.x.

Michael Alvard. The Potential for Sustainable Harvests by Traditional Wana Hunters in Morowali Nature Reserve, Central Sulawesi, Indonesia. *Human Organization*, 59 (4):428–440, 12 2000. ISSN 0018-7259. doi: 10.17730/humo.59.4.k75r633wv3l03537. URL `https://meridian.allenpress.com/human-organization/article/59/4/428/71005/The-Potential-for-Sustainable-Harvests-by`.

Tatsuya Amano, Valeria Ramírez-Castañeda, Violeta Berdejo-Espinola, Israel Borokini, Shawan Chowdhury, Marina Golivets, Juan David González-Trujillo, Flavia Montaño-Centellas, Kumar Paudel, Rachel Louise White, and Diogo Veríssimo. The manifold costs of being a non-native English speaker in science. *PLOS Biology*, 21(7):e3002184, 7 2023. ISSN 1545-7885. doi: 10.1371/JOURNAL.PBIO.3002184. URL `https://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.3002184`.

Giovanni Amori, Spartaco Gippoliti, and Kristofer M. Helgen. Diversity, distribution, and conservation of endemic island rodents. *Quaternary International*, 182(1):6–15, 5 2008. ISSN 1040-6182. doi: 10.1016/J.QUAINT.2007.05.014.

Cindy Mutia Annur. Daftar Lengkap UMP 2024 di 38 Provinsi Indonesia, 2023. URL https://databoks.katadata.co.id/datapublish/2023/11/28/daftar-lengkap-ump-2024-di-38-provinsi-indonesia.

Jeff A Ardron, Hugh P Possingham, and Carissa J Klein. Marxan Good Practices Handbook. Technical Report July 2010, Victoria, BC, Canada, 2010.

Henry Arenas-Castro, Violeta Berdejo-Espinola, Shawan Chowdhury, Argelia Rodríguez-Contreras, Aubrie R M James, Nussaïbah B Raja, Emma M Dunne, Sandro Bertolino, Nayara Braga Emidio, Chantelle M Derez, Szymon M Drobniak, Graham R Fulton, L Francisco Henao-Diaz, Avneet Kaur, Catherine J S Kim, Malgorzata Lagisz, Iliana Medina, Peter Mikula, Vikram P Narayan, Christopher J O'bryan, Rachel Rui, Ying Oh, Ekaterina Ovsyanikova, Katharina-Victoria Pérez-Hämmerle, Patrice Pottier, Jennifer Sarah Powers, Astrid J Rodriguez-Acevedo, Andes Hamuraby Rozak, Pedro H A Sena, Nicola J Sockhill, Anazélia M Tedesco, Francisco Tiapa-Blanco, Jo-Szu Tsai, Jaramar Villarreal-Rosas, Susana M Wadgymar, Masato Yamamichi, and Tatsuya Amano. Academic publishing requires linguistically inclusive policies. *Proceedings of the Royal Society B*, 291(2018), 3 2024. ISSN 0962-8452. doi: 10.1098/RSPB.2023.2840. URL https://royalsocietypublishing.org/doi/10.1098/rspb.2023.2840.

Suchinta Arif. *Implementing Causal Inference in Ecology Through the Structural Causal Model (SCM) Framework*. PhD thesis, Dalhousie University, Halifax, Nova Scotia, 12 2022. URL https://dalspace.library.dal.ca/handle/10222/82190.

Suchinta Arif and M. Aaron MacNeil. Predictive models aren't for causal inference. *Ecology Letters*, 25(8):1741–1745, 2022a. ISSN 14610248. doi: 10.1111/ele.14033.

Suchinta Arif and M. Aaron MacNeil. Utilizing causal diagrams across quasi-experimental approaches. *Ecosphere*, 13(4), 4 2022b. ISSN 2150-8925. doi: 10.1002/ecs2.4009.

Suchinta Arif and M. Aaron MacNeil. Applying the structural causal model framework for observational causal inference in ecology. *Ecological Monographs*, 93(1):1–18, 2 2023. ISSN 0012-9615. doi: 10.1002/ecm.1554. URL https://esajournals.onlinelibrary.wiley.com/doi/10.1002/ecm.1554.

D I D Arini, M Christita, Sheherazade, A Mayasari, R Suryaningsih, and A T A J Simamora. A review of anoa conservation efforts in Sulawesi, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 533(1):012003, 8 2020. ISSN 1755-1307. doi: 10.1088/1755-1315/533/1/012003. URL https://iopscience.iop.org/article/10.1088/1755-1315/533/1/012003.

Agustina Yohana Setyarini Arobaya, Deny A Iyai, Johan F Koibur, Martha Kayadoe, and Freddy Pattiselanno. Indigenous Hunting In Indonesian New Guinea: Cultural Identity, Food Security And Income Opportunities. *Media Konservasi*, 26(3):248–253, 1 2022. ISSN 2502-6313. doi: 10.29244/medkon.26.3.248-253. URL https://journal.ipb.ac.id/index.php/konservasi/article/view/36533.

Laurie Simon Bagwell and B Douglas Bernheim. Veblen Effects in a Theory of Conspicuous Consumption. *The American Economic Review*, 86(3):349–373, 1996. URL https://www.jstor.org/stable/2118201.

C. Bailey, H. Hilser, Y. Siwi, Z. Lawe, J. Waterman, T. A. C. Loffeld, H. Sampson, J. Tasirin, V. Melfi, and A. E. Bowkett. Trends in the bushmeat market trade in North Sulawesi and conservation implications. *Animal Conservation*, 25(1):4–14, 2 2021. ISSN 1367-9430. doi: 10.1111/acv.12723. URL https://zslpublications.onlinelibrary.wiley.com/doi/10.1111/acv.12723.

William Baldwin-Cantello, Michael Clark, Stephen Cornelius, Angela Francis, Jaboury Ghazoul, James Gordon, Sarah Halevy, Nathaniel Matthews, Pete Smith, Dave Tickner, Simon Walmsley, Mark Wright, and Lucy Young. The Triple Challenge : Synergies, trade-offs and integrated responses to meet our climate, food and biodiversity goals. 2020.

Ian R Ball, Hugh P Possingham, and Matthew E Watts. Marxan and relatives: Software for spatial conservation prioritization. In A Moilanen, K A Wilson, and Hugh P. Possingham, editors, *Spatial conservation prioritization: Quantitative methods and computational tools.*, number January, chapter 14, pages 185–195. Oxford University Press, Oxford, UK, 2009. URL www.ecology.uq.edu.au/marxan.

Philip Ball. Nobel-winning 'natural experiments' approach made economics more robust. *Nature*, 10 2021. ISSN 0028-0836. doi: 10.1038/d41586-021-02799-7.

Sebastian Bamberg, Jonas H. Rees, and Maxie Schulte. Environmental protection through societal change. In *Psychology and Climate Change*, pages 185–213. Elsevier, 2018. doi: 10.1016/B978-0-12-813130-5.00008-4. URL https://linkinghub.elsevier.com/retrieve/pii/B9780128131305000084.

Cristina Banks-Leite, Cecilia Larrosa, Luis R. Carrasco, Leandro R. Tambosi, and E. J. Milner-Gulland. The suggestion that landscapes should contain 40% of forest cover lacks evidence and is problematic. *Ecology Letters*, pages 1–2, 2021. ISSN 14610248. doi: 10.1111/ele.13668.

Jan Beck and Wolfgang Schwanghart. Comparing measures of species diversity from incomplete inventories: an update. *Methods in Ecology and Evolution*, 1(1):38–44, 3 2010. ISSN 2041210X. doi: 10.1111/j.2041-210X.2009.00003.x. URL https://onlinelibrary.wiley.com/doi/10.1111/j.2041-210X.2009.00003.x.

Elisa Becker, Stella Kozmér, Matthias B. Aulbach, and Natalia S. Lawrence. The relationship between meat disgust and meat avoidance—A chicken-and-egg problem. *Frontiers in Nutrition*, 9, 9 2022. ISSN 2296-861X. doi: 10.3389/fnut.2022.958248.

Ana Benítez-López, Luca Santini, Aafke M. Schipper, Michela Busana, and Mark A. J. Huijbregts. Intact but empty forests? Patterns of hunting-induced mammal defaunation in the tropics. *PLOS Biology*, 17(5):e3000247, 2019. ISSN 1545-7885. doi: 10.1371/journal.pbio.3000247. URL http://dx.plos.org/10.1371/journal.pbio.3000247.

Heather C. Bingham, Marine Deguignet, Edward Lewis, Jessica Stewart, Diego Juffe-Bignoli, Brian MacSharry, Amy Milam, and Naomi Kingston. User Manual for the

World Database on Protected Areas and world database on other effective area- based conservation measures : 1 . 6 User Manual for the World Database on Protected Areas and world database on other effective area-. Technical report, UNEP-WCMC, Cambridge, UK, 2019. URL http://wcmc.io/WDPA_Manual.

M E Blair, M D Le, and E J Sterling. Special Issue: Multidisciplinary studies on wildlife trade in primates. *Special Issue: Multidisciplinary studies on wildlife trade in primates.*, 79(11):e22710–e22715, 2017. ISSN 0275-2565. doi: http://dx.doi.org/10.1002/ajp.22710. URL http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)1098-2345PT-Journalissue.

Jesse Bonwitt, Michael Dawson, Martin Kandeh, Rashid Ansumana, Foday Sahr, Hannah Brown, and Ann H Kelly. Unintended consequences of the 'bushmeat ban' in West Africa during the 2013–2016 Ebola virus disease epidemic. *Social Science & Medicine*, 200(December 2017):166–173, 2018. ISSN 0277-9536. doi: https://doi.org/10.1016/j.socscimed.2017.12.028. URL http://www.sciencedirect.com/science/article/pii/S027795361730758X.

Hollie Booth, Melissa Arias, Stephanie Brittain, Daniel W. S. Challender, Munib Khanyari, Timothy Kuiper, Yuhan Li, Alegria Olmedo, Rodrigo Oyanedel, Thomas Pienkowski, and E. J. Milner-Gulland. "Saving Lives, Protecting Livelihoods, and Safeguarding Nature": Risk-Based Wildlife Trade Policy for Sustainable Development Outcomes Post-COVID-19. *Frontiers in Ecology and Evolution*, 9(February), 2 2021a. ISSN 2296-701X. doi: 10.3389/fevo.2021.639216. URL https://www.frontiersin.org/articles/10.3389/fevo.2021.639216/full.

Hollie Booth, Michael Clark, E.J. Milner-Gulland, Kofi Amponsah-Mensah, André Pinassi Antunes, Stephanie Brittain, Luciana C. Castilho, João Vitor Campos-Silva, Pedro de Araujo Lima Constantino, Yuhan Li, Lessah Mandoloma, Lotanna Micah Nneji, Donald Midoko Iponga, Boyson Moyo, James McNamara, O. Sarobidy Rakotonarivo, Jianbin Shi, Cédric Thibaut Kamogne Tagne, Julia van Velden, and David R. Williams. Investigating the risks of removing wild meat from global food systems. *Current Biology*, 31(8):1788–1797, 4 2021b. ISSN 09609822. doi: 10.1016/j.cub.2021.01.079. URL https://linkinghub.elsevier.com/retrieve/pii/S0960982221001445.

Pierre Bourdieu and Richard Nice. Distinction: A social critique of the judgement of taste. In Carole Couinahan and Penny van Esterik, editors, *Food and Culture: A Reader*, chapter 1, pages 31–39. Taylor and Francis, New York, 3rd edition, 11 1979. ISBN 9781136162039. doi: https://doi.org/10.4324/9780203079751. URL https://www.taylorfrancis.com/chapters/edit/10.4324/9780203079751-11/distinction-social-critique-judgement-taste-pierre-bourdieu-tr-richard-nice.

BPK RI. Pemerintah Provinsi Sulawesi Utara, a. URL https://sulut.bpk.go.id/pemerintah-provinsi-sulawesi-utara/.

BPK RI. Pemerintah Provinsi Sulawesi Utara, b. URL https://sulut.bpk.go.id/pemerintah-provinsi-sulawesi-utara/.

BPS. *Data dan Informasi Kemiskinan Kabupaten/Kota Tahun 2020*, volume 3205014. Badan Pusat Statistik, Jakarta, 2020. ISBN 2087-2216 Katalog. URL

https://www.bps.go.id/publication/2020/11/30/337a88d303fca9911cb7b0a8/data-dan-informasi-kemiskinan-kabupaten-kota-tahun-2020.html.

BPS. Hasil Sensus Penduduk 2020, 2021. ISSN 1098-6596. URL https://www.bps.go.id/website/materi_ind/materiBrsInd-20210121151046.pdf.

BPS - Statistics of Sulawesi Utara Province. Provinsi Sulawesi Utara Dalam Angka 2023 - Sulawesi Utara Province in Figures 2023. Technical report, BPS Provinsi Sulawesi Utara, 2024. URL https://sulut.bps.go.id/publication/2023/02/28/1408088e65af83090874e529/provinsi-sulawesi-utara-dalam-angka-2023.html.

Gorontalo Province BPS-Statistic. *Gorontalo Province in Figures 2021*. 2022. ISBN 75000.2201. URL https://gorontalo.bps.go.id/publication/2022/02/25/7606b1472cae1e4ee194d43f/provinsi-gorontalo-dalam-angka-2022.html.

Sulawesi Utara Province BPS-Statistic. *Sulawesi Utara Province in Figures 2021*. 2021. ISBN 715602102. URL https://ppid.bps.go.id/?mfd=7100.

Justin S Brashares, Peter Arcese, Moses K Sam, Peter B Coppolillo, A R E Sinclair, and Andrew Balmford. Bushmeat Hunting, Wildlife Declines, and Fish Supply in West Africa. *SCIENCE*, 306, 2004.

Stephanie Brittain, Cedric Thibaut Kamogne Tagne, Dilys Roe, Francesca Booker, Mama Mouamfon, Neil Maddison, Soreya Djibrila Ngomna Tsabong, Salihou Mfone Nteroupe, and E. J. Milner-Gulland. The drivers of wild meat consumption in rural Cameroon: Insights for wild meat alternative project design. *Conservation Science and Practice*, 4 (6):e12700, 6 2022. ISSN 2578-4854. doi: 10.1111/csp2.12700. URL https://conbio.onlinelibrary.wiley.com/doi/10.1111/csp2.12700.

Bayu Broto and Alessio Mortelliti. The status of research on the mammals of Sulawesi, Indonesia. *Mammal Review*, 49(1):78–93, 2019. ISSN 13652907. doi: 10.1111/mam.12141.

BRWA. GIS - BRWA: Peta Wilayah Adat, 2022a. URL https://www.brwa.or.id/sig/.

BRWA. Infografis Status Pengakuan Wilayah Adat di Indonesia, 2022b. URL https://www.brwa.or.id/assets/image/rujukan/1660033570.pdf.

BTNBNW. Taman Nasional Bogani Nani Wartabone. URL https://boganinaniwartabone.org/welcome.

J. A. Burton, S. Hedges, and A. H. Mustari. The taxonomic status, distribution and conservation of the lowland anoa Bubalus depressicornis and mountain anoa Bubalus quarlesi. *Mammal Review*, 35(1):25–50, 1 2005. ISSN 0305-1838. doi: 10.1111/j.1365-2907.2005.00048.x. URL http://doi.wiley.com/10.1111/j.1365-2907.2005.00048.x.

Declan Butler. Free journal-ranking tool enters citation market. *Nature*, 451(7174):6, 1 2008. ISSN 14764687. doi: 10.1038/451006A.

Restifani Cahyami. Manfaat Studi Biblika Kontekstual dalam Membangun Ajaran Ekoteologis di Masa Pasca Pandemi Covid-19. *Jurnal Apokalupsis*, 14(1):40–60, 6 2023. ISSN 2747-285X. doi: 10.52849/apokalupsis.v14i1.74. URL https://ojs.hits.ac.id/index.php/OJS/workflow/index/74https://ojs.hits.ac.id/index.php/OJS/article/view/74.

Charles H. Cannon, Marcy Summers, John R. Harting, and Paul J.A. Kessler. Developing conservation priorities based on forest type, condition, and threats in a poorly known ecoregion: Sulawesi, Indonesia. *Biotropica*, 39(6):747–759, 2007. ISSN 00063606. doi: 10.1111/j.1744-7429.2007.00323.x.

Damian Carrington. Humanity has wiped out 60% of animal populations since 1970, report finds — Wildlife — The Guardian, 2018. URL https://www.theguardian.com/environment/2018/oct/30/humanity-wiped-out-animals-since-1970-major-report-finds.

Steve Carver, Ian Convery, Sally Hawkins, Rene Beyers, Adam Eagle, Zoltan Kun, Erwin Van Maanen, Yue Cao, Mark Fisher, Stephen R. Edwards, Cara Nelson, George D. Gann, Steve Shurter, Karina Aguilar, Angela Andrade, William J. Ripple, John Davis, Anthony Sinclair, Marc Bekoff, Reed Noss, Dave Foreman, Hanna Pettersson, Meredith Root-Bernstein, Jens-Christian Svenning, Peter Taylor, Sophie Wynne-Jones, Alan Watson Featherstone, Camilla Fløjgaard, Mark Stanley-Price, Laetitia M. Navarro, Toby Aykroyd, Alison Parfitt, and Michael Soulé. Guiding principles for rewilding. *Conservation Biology*, 35(6):1882–1893, 12 2021. ISSN 0888-8892. doi: 10.1111/cobi.13730. URL https://onlinelibrary.wiley.com/doi/10.1111/cobi.13730.

Donna-Mareè Cawthorn and Louwrens C. Hoffman. The bushmeat and food security nexus: A global account of the contributions, conundrums and ethical collisions. *Food Research International*, 76(P4):906–925, 10 2015. ISSN 09639969. doi: 10.1016/j.foodres.2015.03.025. URL https://linkinghub.elsevier.com/retrieve/pii/S0963996915001301.

Donna-Mareè Cawthorn and Louwrens C. Hoffman. Controversial cuisine: A global account of the demand, supply and acceptance of "unconventional" and "exotic" meats. *Meat Science*, 120:19–36, 10 2016. ISSN 03091740. doi: 10.1016/j.meatsci.2016.04.017. URL https://linkinghub.elsevier.com/retrieve/pii/S0309174016301061.

CBD. Key Elements of the Strategic Plan 2011-2020, including Aichi Biodiversity Targets, 2011. URL https://www.cbd.int/sp/elements/default.shtml.

CBD. First Draft of the Post-2020 Global Biodiversity Framework, 2021. URL https://www.cbd.int/article/draft-1-global-biodiversity-framework.

Damon Centola. The Spread of Behavior in an Online Social Network Experiment. *Science*, 329(5996):1194–1197, 9 2010. ISSN 0036-8075. doi: 10.1126/science.1185231. URL https://www.science.org/doi/10.1126/science.1185231.

Damon Centola and Michael Macy. Complex Contagions and the Weakness of Long Ties. *American Journal of Sociology*, 113(3):702–734, 11 2007. ISSN 0002-9602. doi: 10.1086/521848. URL http://www.journals.uchicago.edu/doi/10.1086/521848.

Damon Centola, Joshua Becker, Devon Brackbill, and Andrea Baronchelli. Experimental evidence for tipping points in social convention. *Science*, 360(6393):1116–1119, 6 2018. ISSN 0036-8075. doi: 10.1126/science.aas8827. URL https://www.science.org/doi/10.1126/science.aas8827.

CEPF. Wallacea Biodiversity Hotspot-Ecosystem profile. Technical report, CEPF, 2014.

Anne-Lise Chaber, Kyle N. Amstrong, Sigit Wiantoro, Vanessa Xerri, Charles Caraguel, Wayne S. J. Boardman, and Torben D. Nielsen. Bat E-Commerce: Insights Into the Extent and Potential Implications of This Dark Trade. *Frontiers in Veterinary Science*, 8, 6 2021. ISSN 2297-1769. doi: 10.3389/fvets.2021.651304. URL https://www.frontiersin.org/articles/10.3389/fvets.2021.651304/full.

Anne Chao. Nonparametric Estimation of the Number of Classes in a Population. Technical Report 4, 1984.

Jonathan M. Chase, Alienor Jeliazkov, Emma Ladouceur, and Duarte S. Viana. Biodiversity conservation through the lens of metacommunity ecology. *Annals of the New York Academy of Sciences*, 1469(1):86–104, 6 2020. ISSN 0077-8923. doi: 10.1111/nyas.14378.

Alexandre M. Chausson, J. Marcus Rowcliffe, Lucie Escouflaire, Michelle Wieland, and Juliet H. Wright. Understanding the Sociocultural Drivers of Urban Bushmeat Consumption for Behavior Change Interventions in Pointe Noire, Republic of Congo. *Human Ecology*, 47(2):179–191, 4 2019. ISSN 0300-7839. doi: 10.1007/s10745-019-0061-z. URL http://link.springer.com/10.1007/s10745-019-0061-z.

Shunyang Chen, Bin Chen, Pramudji Sastrosuwondo, I Wayan Eka Dharmawan, Danyun Ou, Xijie Yin, Weiwei Yu, and Guangcheng Chen. Ecosystem carbon stock of a tropical mangrove forest in North Sulawesi, Indonesia. *Acta Oceanologica Sinica*, 37(12):85–91, 12 2018. ISSN 0253-505X. doi: 10.1007/s13131-018-1290-5. URL http://link.springer.com/10.1007/s13131-018-1290-5.

L. M. Clayton, E. J. Milner-Gulland, D W Sinaga, and A H Mustari. Effects of a Proposed Ex Situ Conservation Program on In Situ Conservation of the Babirusa, an Endangered Suid. *Conservation Biology*, 14(2):382–385, 4 2000. ISSN 0888-8892. doi: 10.1046/j.1523-1739.2000.99123.x. URL https://onlinelibrary.wiley.com/doi/abs/10.1046/j.1523-1739.2000.99123.x.

Lynn Clayton, Matthew Keeling, and E J Milner-Gulland. Bringing Home the Bacon: A Spatial Model of Wild Pig Hunting in Sulawesi, Indonesia. *Ecological Applications*, 7 (2):642–652, 1997. doi: 10.1890/1051-0761(1997)007.

Hayley S. Clements, Reinette (Oonsie) Biggs, Maike Hamann, Odirilwe Selomane, and Nadia Sitas. Social-Ecological Systems Thinking and Biodiversity. In *Encyclopedia of Biodiversity*, pages 50–63. Elsevier, 1 2024. doi: 10.1016/B978-0-12-822562-2.00126-2. URL https://linkinghub.elsevier.com/retrieve/pii/B9780128225622001262.

Reuben Clements, Navjot S. Sodhi, Menno Schilthuizen, and Peter K.L. Ng. Limestone karsts of southeast Asia: Imperiled arks of biodiversity. *BioScience*, 56(9):733–742, 2006. ISSN 00063568. doi: 10.1641/0006-3568(2006)56[733:LKOSAI]2.0.CO;2.

Lauren Coad, Julia E Fa, Katharine Abernethy, Nathalie van Vliet, Catalina Santamaria, David Wilkie, Hani R El Bizri, Daniel J Ingram, Donna-Maree Cawthron, and Robert Nasi. *Towards a sustainable, participatory and inclusive wild meat sector*. Center for International Forestry Research (CIFOR), Bogor, Indonesia, 3 2019a. ISBN 978-602-387-083-7. doi: 10.17528/cifor/0070. URL https://www.cifor.org/online-library/browse/view-publication/publication/7046.htmlhttps://www.cifor.org/publications/pdf_files/Books/BCoad1901.pdf.

Lauren Coad, Sotheary Lim, and Lim Nuon. Wildlife and livelihoods in the cardamom mountains, Cambodia. *Frontiers in Ecology and Evolution*, 7(AUG), 2019b. ISSN 2296701X. doi: 10.3389/fevo.2019.00296.

J.L. Coleman, J.S. Ascher, D. Bickford, D. Buchori, A. Cabanban, R.A. Chisholm, K.Y. Chong, P. Christie, G.R. Clements, T.E.E. dela Cruz, W. Dressler, D.P. Edwards, C.M. Francis, D.A. Friess, X. Giam, L. Gibson, D. Huang, A.C. Hughes, Z. Jaafar, A. Jain, L.P. Koh, E.P. Kudavidanage, B.P.Y.-H. Lee, J. Lee, T.M. Lee, M. Leggett, B. Leimona, M. Linkie, M. Luskin, A. Lynam, E. Meijaard, V. Nijman, A. Olsson, S. Page, P. Parolin, K.S.-H. Peh, M.R. Posa, G.W. Prescott, S.A. Rahman, S.J. Ramchunder, M. Rao, J. Reed, D.R. Richards, E.M. Slade, R. Steinmetz, P.Y. Tan, D. Taylor, P.A. Todd, S.T. Vo, E.L. Webb, A.D. Ziegler, and L.R. Carrasco. Top 100 research questions for biodiversity conservation in Southeast Asia. *Biological Conservation*, 234 (October 2018):211–220, 2019. ISSN 00063207. doi: 10.1016/j.biocon.2019.03.028. URL https://linkinghub.elsevier.com/retrieve/pii/S0006320718315751.

Jeff Conklin. Social Complexity Wicked Problems. *Wicked Problems & Social Complexity in Dialogue Mapping: Building Shared Understanding of Wicked Problems*, pages 1–20, 2005. URL https://www.wiley.com/en-us/Dialogue+Mapping%3A+Building+Shared+Understanding+of+Wicked+Problems-p-9780470017685.

Richard T. Corlett. The Impact of Hunting on the Mammalian Fauna of Tropical Asian Forests. *Biotropica*, 39(3):292–303, 5 2007. ISSN 0006-3606. doi: 10.1111/j.1744-7429.2007.00271.x. URL https://onlinelibrary.wiley.com/doi/10.1111/j.1744-7429.2007.00271.x.

D.J. Crookes, N. Ankudey, and E.J. Milner-Gulland. The value of a long-term bushmeat market dataset as an indicator of system dynamics. *Environmental Conservation*, 32(4):333–339, 12 2005. ISSN 0376-8929. doi: 10.1017/S037689290500250X. URL https://www.cambridge.org/core/product/identifier/S037689290500250X/type/journal_article.

Heike Culmsee, Christoph Leuschner, Gerald Moser, and Ramadhanil Pitopang. Forest aboveground biomass along an elevational transect in Sulawesi, Indonesia, and the role of Fagaceae in tropical montane rain forests. *Journal of Biogeography*, 37(5):960–974, 2010. ISSN 03050270. doi: 10.1111/j.1365-2699.2009.02269.x.

Daemen Library. Research Impact and Scholarly Metrics - SCImago Journal Rank (SJR), 2023. URL https://libguides.daemen.edu/c.php?g=1239513&p=9072137.

Mark R.T. Dale. *Applying Graph Theory in Ecological Research*. Cambridge University Press, 11 2017. ISBN 9781316105450. doi: 10.1017/9781316105450.

Iain Darbyshire, Seona Anderson, Anna Asatryan, Andrew Byfield, Martin Cheek, Colin Clubbe, Zeineb Ghrabi, Timothy Harris, Charlie D. Heatubun, James Kalema, Sékou Magassouba, Ben McCarthy, William Milliken, Bertrand de Montmollin, Eimear Nic Lughadha, Jean Michel Onana, Doumbouya Saïdou, Anca Sârbu, Krishna Shrestha, and Elizabeth A. Radford. Important Plant Areas: revised selection criteria for a global approach to plant conservation. *Biodiversity and Conservation*, 26(8):1767–1800, 7 2017. ISSN 15729710. doi: 10.1007/S10531-017-1336-6/TABLES/2. URL https://link.springer.com/article/10.1007/s10531-017-1336-6.

Glyn Davies. Bushmeat and International Development. *Conservation Biology*, 16(3): 587–589, 6 2002. URL https://www.jstor.org/stable/3061204.

Federico Davila, Roel Plant, and Brent Jacobs. Biodiversity revisited through systems thinking. *Environmental Conservation*, 48(1):16–24, 3 2021. ISSN 0376-8929. doi: 10.1017/S0376892920000508. URL https://www.cambridge.org/core/product/identifier/S0376892920000508/type/journal_article.

Emiel de Lange, E. J. Milner-Gulland, and Aidan Keane. Improving Environmental Interventions by Understanding Information Flows. *Trends in Ecology and Evolution*, 34(11):1034–1047, 11 2019. ISSN 01695347. doi: 10.1016/J.TREE.2019.06.007.

Emiel de Lange, E. J. Milner-Gulland, and Aidan Keane. Effects of social networks on interventions to change conservation behavior. *Conservation Biology*, 36(3):e13833, 6 2022. ISSN 1523-1739. doi: 10.1111/COBI.13833. URL https://onlinelibrary.wiley.com/doi/full/10.1111/cobi.13833https://onlinelibrary.wiley.com/doi/abs/10.1111/cobi.13833https://conbio.onlinelibrary.wiley.com/doi/10.1111/cobi.13833.

Ebed de Rosary. African swine fever rips through parts of southern indonesia. *Mongabay*, 2021a. URL https://news.mongabay.com/2021/03/african-swine-fever-rips-through-parts-of-southern-indonesia/.

Ebed de Rosary. African swine fever rips through parts of southern Indonesia. *Mongabay*, 2021b. URL https://news.mongabay.com/2021/03/african-swine-fever-rips-through-parts-of-southern-indonesia/.

Mairin C M Deith and Jedediah F Brodie. Predicting defaunation: accurately mapping bushmeat hunting pressure over large areas. *Proceedings of the Royal Society. B, Biological sciences*, 287(1922):20192677, 2020. ISSN 1471-2954. doi: 10.1098/rspb.2019.2677.

Jared M Diamond. *Guns, germs, and steel : the fates of human societies*. Norton, New York, 2005. ISBN 9780393609295 0393609294.

Eric Dinerstein, David Olson, Anup Joshi, Carly Vynne, Neil D. Burgess, Eric Wikramanayake, Nathan Hahn, Suzanne Palminteri, Prashant Hedao, Reed Noss, Matt Hansen, Harvey Locke, Erle C. Ellis, Benjamin Jones, Charles Victor Barber, Randy Hayes, Cyril Kormos, Vance Martin, Eileen Crist, Wes Sechrest, Lori Price, Jonathan E.M. Baillie, Don Weeden, Kierán Suckling, Crystal Davis, Nigel Sizer, Rebecca Moore, David Thau, Tanya Birch, Peter Potapov, Svetlana Turubanova, Alexandra Tyukavina, Nadia De Souza, Lilian Pintea, Joscrossed C. Brito, Othman A.

Llewellyn, Anthony G. Miller, Annette Patzelt, Shahina A. Ghazanfar, Jonathan Timberlake, Heinz Klöser, Yara Shennan-Farpón, Roeland Kindt, Jens Peter Barnekow Lillesø, Paulo Van Breugel, Lars Graudal, Maianna Voge, Khalaf F. Al-Shammari, and Muhammad Saleem. An Ecoregion-Based Approach to Protecting Half the Terrestrial Realm. *BioScience*, 67(6):534–545, 2017. ISSN 15253244. doi: 10.1093/biosci/bix014.

Robert M Dorazio and J. Andrew Royle. Estimating Size and Composition of Biological Communities by Modeling the Occurrence of Species. *Journal of the American Statistical Association*, 100(470):389–398, 6 2005. ISSN 0162-1459. doi: 10.1198/016214505000000015. URL http://www.tandfonline.com/doi/abs/10.1198/016214505000000015.

Rebecca Drury. Reducing urban demand for wild animals in Vietnam: examining the potential of wildlife farming as a conservation tool. *Conservation Letters*, 2(6):263–270, 2009a. ISSN 1755263X. doi: 10.1111/j.1755-263X.2009.00078.x. URL http://doi.wiley.com/10.1111/j.1755-263X.2009.00078.x.

Rebecca Drury. Hungry for success: Urban consumer demand for wild animal products in Vietnam. *Conservation and Society*, 9(3):247, 2011. ISSN 0972-4923. doi: 10.4103/0972-4923.86995.

Rebecca Catherine Drury. *Identifying and understanding consumers of wild animal products in Hanoi, Vietnam: Implications for conservation management.* PhD thesis, University College London, 2009b.

Adam J. Dutton, Brian Gratwicke, Cameron Hepburn, Emilio A. Herrera, and David W. Macdonald. Tackling unsustainable wildlife trade. In *Key Topics in Conservation Biology 2*, pages 74–91. Wiley, 4 2013. doi: 10.1002/9781118520178.ch5. URL https://onlinelibrary.wiley.com/doi/10.1002/9781118520178.ch5.

Asri A. Dwiyahreni, Habiburrachman A.H. Fuad, Sunaryo Muhtar, T. E.Budhi Soesilo, Chris Margules, and Jatna Supriatna. Changes in the human footprint in and around Indonesia's terrestrial national parks between 2012 and 2017. *Scientific Reports*, 11(1):1–14, 2021. ISSN 20452322. doi: 10.1038/s41598-021-83586-2. URL https://doi.org/10.1038/s41598-021-83586-2.

PD Dwyer. Observations on Breeding Biologyof some New Guinea Murid Rodents. *Wildlife Research*, 2(1):33, 1975. ISSN 1035-3712. doi: 10.1071/WR9750033. URL https://www.publish.csiro.au/wr/wr9750033http://www.publish.csiro.au/?paper=WR9750033.

Christna M Ellis. *An Integrated Model for Conservation: Case Study on The Role of Women in The Commercial Bushmeat Trade in Cameroon.* PhD thesis, York University, North York, Ontario, 5 2000.

Rebecca Elmhirst. Space, identity politics and resource control in Indonesia's transmigration programme. *Political Geography*, 18:813–835, 1999.

Jacob A. Esselstyn, Anang S. Achmadi, Heru Handika, and Kevin C. Rowe. A Hog-Nosed Shrew Rat (Rodentia: Muridae) from Sulawesi Island, Indonesia. *Journal of Mammalogy*, 96(5):895–907, 2015. ISSN 15451542. doi: 10.1093/jmammal/gyv093.

J. E. Fa, L Albrechtsen, P. J. Johnson, and D. W. Macdonald. Linkages between household wealth, bushmeat and other animal protein consumption are not invariant: evidence from Rio Muni, Equatorial Guinea. *Animal Conservation*, 12(6): 599–610, 12 2009. ISSN 13679430. doi: 10.1111/j.1469-1795.2009.00289.x. URL http://doi.wiley.com/10.1111/j.1469-1795.2009.00289.x.

John E. Fa, Paul J. Johnson, Jef Dupain, Juan Lapuente, Pamela Köster, and David W. Macdonald. Sampling effort and dynamics of bushmeat markets. *Animal Conservation*, 7(4):409–416, 11 2004. ISSN 1367-9430. doi: 10.1017/S136794300400160X. URL https://zslpublications.onlinelibrary.wiley.com/doi/10.1017/S136794300400160X.

Julia E. Fa, Sarah Seymour, Jef Dupain, Rajan Amin, Lise Albrechtsen, and David Macdonald. Getting to grips with the magnitude of exploitation: Bushmeat in the Cross–Sanaga rivers region, Nigeria and Cameroon. *Biological Conservation*, 129(4): 497–510, 5 2006. ISSN 00063207. doi: 10.1016/j.biocon.2005.11.031. URL https://linkinghub.elsevier.com/retrieve/pii/S0006320705005045.

Julia E. Fa, Miguel Angel Farfan, Ana Luz Marquez, Jesus Duarte, Janet Nackoney, Amy Hall, Jef Dupain, Sarah Seymour, Paul J. Johnson, David W. Macdonald, and J. Mario Vargas. Mapping Hotspots of Threatened Species Traded in Bushmeat Markets in the Cross–Sanaga Rivers Region. *Conservation Biology*, 28(1):224–233, 2 2014. ISSN 0888-8892. doi: 10.1111/cobi.12151. URL https://conbio.onlinelibrary.wiley.com/doi/10.1111/cobi.12151.

FAO. African swine fever (ASF) situation update in Asia and Pacific, 2024. URL https://www.fao.org/animal-health/situation-updates/asf-in-asia-pacific.

FAO, CIFOR, CIRAD, and WCS. Policy Brief - Build Back Better in a post-COVID world – Reducing future wildlife-borne spillover of disease to humans. 2020.

Tim F. (Tim Fridtjof) Flannery and Peter. Schouten. *Possums of the world : a monograph of the Phalangeroidea*. GEO Productions in association with the Australian Museum, Chatswood N.S.W, 1994. ISBN 9780646143897. URL https://search.worldcat.org/title/926053019.

Serge Galam and Serge Moscovici. Towards a theory of collective phenomena: Consensus and attitude changes in groups. *European Journal of Social Psychology*, 21(1):49–74, 1 1991. ISSN 0046-2772. doi: 10.1002/ejsp.2420210105. URL https://onlinelibrary.wiley.com/doi/10.1002/ejsp.2420210105.

M. L. Galey, A. van der Ent, M. C.M. Iqbal, and N. Rajakaruna. Ultramafic geoecology of South and Southeast Asia. *Botanical Studies 2017 58:1*, 58(1):1–28, 4 2017. ISSN 1999-3110. doi: 10.1186/S40529-017-0167-9. URL https://as-botanicalstudies.springeropen.com/articles/10.1186/s40529-017-0167-9.

Edward T Game and Hedley S Grantham. Marxan User Manual: For Marxan version 1.8.10, 2008.

David L A Gaveau, Serge Wich, Justin Epting, Daniel Juhn, Markku Kanninen, and Nigel Leader-Williams. The future of forests and orangutans (Pongo abelii) in Sumatra:

predicting impacts of oil palm plantations, road construction, and mechanisms for reducing carbon emissions from deforestation. *Environmental Research Letters*, 4(3): 34013, 2009. ISSN 1748-9326. URL internal-pdf://139.101.170.110/Gaveauetal_2009b.pdf.

Andrew Gelman. Prior distributions for variance parameters in hierarchical models (comment on article by Browne and Draper). *Bayesian Analysis*, 1(3):515–534, 9 2006. ISSN 1936-0975. doi: 10.1214/06-BA117A.

Amber D. Goguen and Shawn J. Riley. Consumption of Wild-Harvested Meat in Society. *Wildlife Society Bulletin*, 44(3):553–563, 9 2020. ISSN 2328-5540. doi: 10.1002/WSB.1108. URL https://onlinelibrary.wiley.com/doi/full/10.1002/wsb.1108https://onlinelibrary.wiley.com/doi/abs/10.1002/wsb.1108https://wildlife.onlinelibrary.wiley.com/doi/10.1002/wsb.1108.

Maria J. Grant and Andrew Booth. A typology of reviews: an analysis of 14 review types and associated methodologies. *Health Information & Libraries Journal*, 26(2): 91–108, 6 2009. ISSN 1471-1834. doi: 10.1111/j.1471-1842.2009.00848.x. URL https://onlinelibrary.wiley.com/doi/10.1111/j.1471-1842.2009.00848.x.

Hedley S Grantham, A Shapiro, Djoan Bonfils, Valery Gond, Elizabeth Goldman, Fiona Maisels, A J Plumptre, Tim Rayden, J G Robinson, Samantha Strindberg, Emma Stokes, A I T T Tulloch, J E M Watson, Lauren Williams, and Olivia Rickenbach. Spatial priorities for conserving the most intact biodiverse forests within Central Africa. *Environmental Research Letters*, 15(9):0940b5, 9 2020. ISSN 1748-9326. doi: 10.1088/1748-9326/ab9fae. URL https://iopscience.iop.org/article/10.1088/1748-9326/ab9fae.

Thomas N. E. Gray, Alice C. Hughes, William F. Laurance, Barney Long, Anthony J. Lynam, Hannah O'Kelly, William J. Ripple, Teak Seng, Lorraine Scotson, and Nicholas M. Wilkinson. The wildlife snaring crisis: an insidious and pervasive threat to biodiversity in Southeast Asia. *Biodiversity and Conservation*, 2017. ISSN 0960-3115. doi: 10.1007/s10531-017-1450-5. URL http://link.springer.com/10.1007/s10531-017-1450-5.

Sylvia Grewatsch, Steve Kennedy, and Pratima (Tima) Bansal. Tackling wicked problems in strategic management with systems thinking. *Strategic Organization*, 21(3):721–732, 8 2023. ISSN 1476-1270. doi: 10.1177/14761270211038635. URL http://journals.sagepub.com/doi/10.1177/14761270211038635.

Karl Gruber. Rodent meat – a sustainable way to feed the world? *EMBO reports*, 17 (5):630–633, 5 2016. ISSN 1469-221X. doi: 10.15252/embr.201642306. URL https://onlinelibrary.wiley.com/doi/10.15252/embr.201642306.

Gurutzeta Guillera-Arroita, Marc Kéry, and José J. Lahoz-Monfort. Inferring species richness using multispecies occupancy modeling: Estimation performance and interpretation. *Ecology and Evolution*, 9(2):780–792, 2019. ISSN 2045-7758. doi: 10.1002/ece3.4821. URL https://onlinelibrary.wiley.com/doi/abs/10.1002/ece3.4821.

Hendra Gunawan and Sugiarti. *Mekongga: Hidden Paradise of Sulawesi's Biodiversity*. LIPI Press, Jakarta, 2014. ISBN 978.979.799.795.3.

Hendra Gunawan and Sugiarti. Perlunya Penunjukan Kawasan Konservasi Baru Untuk Mengantisipasi Degradasi Keanekaragaman Hayati Akibat Perubahan RTWT dKawasan Wallacea (Lesson Learnt Inisiasi Pengusulan Taman Nasional Mekongga, Sulawesi Tenggara). *BioWallacea Jurnal Ilmiah Ilmu Biologi*, 1(3):122–133, 2015. ISSN 2442-2622.

Lee Hannah, Patrick R. Roehrdanz, Pablo A. Marquet, Brian J. Enquist, Guy Midgley, Wendy Foden, Jon C. Lovett, Richard T. Corlett, Derek Corcoran, Stuart H. M. Butchart, Brad Boyle, Xiao Feng, Brian Maitner, Javier Fajardo, Brian J. McGill, Cory Merow, Naia Morueta-Holme, Erica A. Newman, Daniel S. Park, Niels Raes, and Jens-Christian Svenning. 30% land conservation and climate action reduces tropical extinction risk by more than 50%. *Ecography*, 43(7):943–953, 7 2020. ISSN 0906-7590. doi: 10.1111/ecog.05166. URL https://onlinelibrary.wiley.com/doi/abs/10.1111/ecog.05166.

Richaldo Hariandja. Pemetaan Wilayah Adat Lebih 20 Juta Hektar tetapi Pengakuan Minim, Mengapa?, 9 2022. URL https://shorturl.at/GINT9.

Rhett D. Harrison. Emptying the Forest: Hunting and the Extirpation of Wildlife from Tropical Nature Reserves. *BioScience*, 61(11):919–924, 11 2011. ISSN 1525-3244. doi: 10.1525/bio.2011.61.11.11. URL https://academic.oup.com/bioscience/article-lookup/doi/10.1525/bio.2011.61.11.11.

Medi Hendra, Dijan Sunar Rukmi, Surianto Effendi, Freminci Freminci, and Auliana Auliana. Ethnobiology Study: Game in Dayak Lun Dayeh Community at Watershed of Mentarang in Malinau. *Jurnal Manajemen Hutan Tropika*, 29(1):68–78, 2023. ISSN 2087-0469. doi: 10.7226/jtfm.29.1.68.

David. Henley. *Nationalism and regionalism in a colonial context : Minahasa in the Dutch East Indies*. KITLV Press, 1996. ISBN 9789004486928.

Suzanne Higgs. Social norms and their influence on eating behaviours. *Appetite*, 86: 38–44, 3 2015. ISSN 1095-8304. doi: 10.1016/J.APPET.2014.10.021. URL https://pubmed.ncbi.nlm.nih.gov/25451578/.

Harry Hilser. *Collective stewardship and pathways to change: understanding pro-social values, connectedness to nature and empathic capacity to cultivate ecocentrism in rural communities of North Sulawesi, Indonesia Harry Hilser, PhD Human Geography.* PhD thesis, University of Exeter, 2021.

Amy Hinsley and Michael 't Sas-Rolfes. Wild assumptions? Questioning simplistic narratives about consumer preferences for wildlife products. *People and Nature*, 2(4): 972–979, 12 2020. ISSN 25758314. doi: 10.1002/PAN3.10099/SUPPINFO. URL https://besjournals.onlinelibrary.wiley.com/doi/10.1002/pan3.10099.

Amy Hinsley, Anita Kar Yan Wan, David Garshelis, Michael Hoffmann, Sifan Hu, Tien Ming Lee, Keila Meginnis, Brendan Moyle, Yingjie Qiu, Xiangdong Ruan, and E. J. Milner-Gulland. Understanding why consumers in China switch between wild, farmed, and synthetic bear bile products. *Conservation Biology*, 36(3), 6 2022. ISSN 0888-8892. doi: 10.1111/cobi.13895. URL https://conbio.onlinelibrary.wiley.com/doi/10.1111/cobi.13895.

Robert D. Holt. Bringing the Hutchinsonian niche into the 21st century: Ecological and evolutionary perspectives. *Proceedings of the National Academy of Sciences of the United States of America*, 106(SUPPL. 2):19659–19665, 11 2009. ISSN 10916490. doi: 10.1073/PNAS.0905137106/ASSET/4E855142-8A6D-4984-9AD7-AEFF46A23730/ASSETS/GRAPHIC/ZPQ9990902880002.JPEG. URL https://www.pnas.org/doi/abs/10.1073/pnas.0905137106.

Sifan Hu, Zhijian Liang, Kaiwen Zhou, Diogo Veríssimo, Tien Ming Lee, Xiangdong Ruan, and Amy Hinsley. Applying a co-design approach with key stakeholders to design interventions to reduce illegal wildlife consumption. *People and Nature*, 5(4):1234–1244, 8 2023. ISSN 2575-8314. doi: 10.1002/pan3.10492. URL https://besjournals.onlinelibrary.wiley.com/doi/10.1002/pan3.10492.

Iwan Hunowu, Alfons Patandung, Wulan Pusparini, Isabel Danismend, Andi Cahyana, Syahril Abdullah, Caspian L Johnson, Harry Hilser, Rivo Rahasia, Jenly Gawina, and Matthew Linkie. New insights into Sulawesi's apex predator: the Sulawesi civet Macrogalidia musschenbroekii. *Oryx*, 54(6):878–881, 11 2019. ISSN 0030-6053. doi: 10.1017/S0030605319000723. URL https://www.cambridge.org/core/product/identifier/S0030605319000723/type/journal_article.

George Evelyn Hutchinson. *An Introduction to Population Ecology*. Yale University Press, 4 edition, 1978.

Kelly J. Iknayan, Morgan W. Tingley, Brett J. Furnas, and Steven R. Beissinger. Detecting diversity: Emerging methods to estimate species diversity. *Trends in Ecology and Evolution*, 29(2):97–106, 2014. ISSN 01695347. doi: 10.1016/j.tree.2013.10.012.

Karlina Indraswari, Rachel S Friedman, Richard Noske, Chris R Shepherd, Duan Biggs, Connie Susilawati, and Clevo Wilson. It's in the news: Characterising Indonesia's wild bird trade network from media-reported seizure incidents. *Biological Conservation*, 243:108431, 3 2020. ISSN 00063207. doi: 10.1016/j.biocon.2020.108431. URL https://doi.org/10.1016/j.biocon.2020.108431https://linkinghub.elsevier.com/retrieve/pii/S0006320719310742.

Daniel J. Ingram. Wild Meat in Changing Times. *Journal of Ethnobiology*, 40(2):117, 7 2020. ISSN 0278-0771. doi: 10.2993/0278-0771-40.2.117. URL https://bioone.org/journals/journal-of-ethnobiology/volume-40/issue-2/0278-0771-40.2.117/Wild-Meat-in-Changing-Times/10.2993/0278-0771-40.2.117.fullhttps://bioone.org/journals/journal-of-ethnobiology/volume-40/issue-2/0278-0771-40.2.117/Wild-Meat-in-Chan.

Daniel J. Ingram, Lauren Coad, E.J. Milner-Gulland, Luke Parry, David Wilkie, Mohamed I. Bakarr, Ana Benítez-López, Elizabeth L. Bennett, Richard Bodmer, Guy Cowlishaw, Hani R. El Bizri, Heather E. Eves, Julia E. Fa, Christopher D. Golden, Donald Midoko Iponga, Nguyn Văn Minh, Thais Q. Morcatty, Robert Mwinyihali, Robert Nasi, Vincent Nijman, Yaa Ntiamoa-Baidu, Freddy Pattiselanno, Carlos A. Peres, Madhu Rao, John G. Robinson, J. Marcus Rowcliffe, Ciara Stafford, Miriam Supuma, Francis Nchembi Tarla, Nathalie van Vliet, Michelle Wieland, and Katharine Abernethy. Wild Meat Is Still on the Menu: Progress in Wild Meat Research, Policy, and Practice from 2002 to 2020. *Annual Review of Environment and Resources*, 46(1):221–254, 10 2021. ISSN

1543-5938. doi: 10.1146/annurev-environ-041020-063132. URL https://www.annualreviews.org/doi/abs/10.1146/annurev-environ-041020-063132https://www.annualreviews.org/doi/10.1146/annurev-environ-041020-063132.

IPBES. Scientific Outcome of the IPBES-IPCC co-sponsored workshop on biodiversity and climate change. Technical report, 2021.

IUCN-WCPA. *Recognising and reporting other effective area-based conservation measures*. IUCN World Commission on Protected Areas Task Force on OECMs, Gland, Switzerland, 2019. ISBN 978-2-8317-2025-8. URL https://portals.iucn.org/library/node/48773.

Michael Jacobsen. On the question of contemporary identity in minahasa, north sulawesi province, indonesia. *Asian Anthropology*, 1:31–58, 1 2002. ISSN 1683-478X. doi: 10.1080/1683478X.2002.10552520. URL http://www.tandfonline.com/doi/abs/10.1080/1683478X.2002.10552520.

Katy L. James, Nicola P. Randall, and Neal R. Haddaway. A methodology for systematic mapping in environmental sciences. *Environmental Evidence*, 5(1):1–13, 2016. ISSN 20472382. doi: 10.1186/s13750-016-0059-6.

Andrew P Jennings and Geraldine Veron. Predicted distributions and ecological niches of 8 civet and mongoose species in Southeast Asia. *Journal of Mammalogy*, 92(2):316–327, 4 2011. ISSN 0022-2372. doi: 10.1644/10-MAMM-A-155.1. URL http://dx.doi.org/10.1644/10-MAMM-A-155.1internal-pdf://72.96.68.88/Jennings&Veron2011(J.Mamm.)(niches8mongoosesandcivets)-1.pdf.

Paul Jepson and Cain Blythe. *Rewilding [electronic resource] / the radical new science of ecological recovery*. Hot science. London, 2020. ISBN 9781785786280.

Paul Jepson and Robert J Whittaker. Histories of Protected Areas: Internationalisation of Conservationist Values and their Adoption in the Netherlands Indies (Indonesia). *Environment and History*, 8:129–72, 2002.

Paul R. Jepson, Ben Caldecott, Suzanne F. Schmitt, Sergio H.C. Carvalho, Ricardo A. Correia, Norah Gamarra, Chiara Bragagnolo, Ana C.M. Malhado, and Richard J. Ladle. Protected area asset stewardship. *Biological Conservation*, 212(September 2016):183–190, 8 2017. ISSN 00063207. doi: 10.1016/j.biocon.2017.03.032. URL http://dx.doi.org/10.1016/j.biocon.2017.03.032https://linkinghub.elsevier.com/retrieve/pii/S0006320716304979.

Caspian L. Johnson, Harry Hilser, Noviar Andayani, Iwan Hunowu, Matthew Linkie, Alfons Patandung, Wulan Pusparini, Rivo Rahasia, and Andrew E. Bowkett. Camera Traps Clarify the Distribution Boundary between the Crested Black Macaque (Macaca nigra) and Gorontalo Macaque (Macaca nigrescens) in North Sulawesi. *International Journal of Primatology*, 2019. ISSN 01640291. doi: 10.1007/s10764-019-00082-1.

Caspian L. Johnson, Harry Hilser, Matthew Linkie, Rivo Rahasia, Francesco Rovero, Wulan Pusparini, Iwan Hunowu, Alfons Patandung, Noviar Andayani, John Tasirin, Lukita A. Nistyantara, and Andrew E. Bowkett. Using occupancy-based camera-trap surveys to assess the Critically Endangered primate Macaca nigra across its

range in North Sulawesi, Indonesia. *Oryx*, 54(6):784–793, 11 2020. ISSN 0030-6053. doi: 10.1017/S0030605319000851. URL https://www.cambridge.org/core/product/identifier/S0030605319000851/type/journal_article.

Kate E. Jones, Simon P. Mickleburgh, Wes Sechrest, and Allyson L. Walsh. Global Overview of the Conservation of Island Bats: Importance, Challenges, and Opportunities. In Theodore H. Fleming and Paul A. Racey, editors, *Island Bats. Evolution, ecology, and conservation.*, chapter 16, pages 496–530. University Chicago Press, Chicago, 2009. ISBN 978-0-226-25330-5. URL https://www.degruyter.com/document/doi/10.7208/9780226253312-016/html.

Hans Nicholas Jong. Indonesian nickel project harms environment and human rights, report says, 2 2024. URL https://news.mongabay.com/2024/02/indonesian-nickel-project-harms-environment-and-human-rights-report-says/.

Lucas N. Joppa, Scott R. Loarie, and Stuart L. Pimm. On the protection of "protected areas". *Proceedings of the National Academy of Sciences of the United States of America*, 105(18):6673–6678, 2008. ISSN 00278424. doi: 10.1073/pnas.0802471105.

Elizabeth Joyce, Kevin Thiele, Ferry Slik, and Darren Crayn. Checklist of the vascular flora of the Sunda-Sahul Convergence Zone. *Biodiversity Data Journal*, 8:e51094–, 5 2020. ISSN 1314-2828. doi: 10.3897/BDJ.8.e51094. URL https://bdj.pensoft.net/article/51094/.

Achmad R. Junaid, Jihad, and Ferry Hasudungan. *Burung-burung di Indonesia: Daftar dan Status 2021*. Burung Indonesia, Bogor, 2021. URL https://www.burung.org/2021/12/28/burung-burung-di-indonesia-daftar-dan-status-2021.

Abdul Kadir, Eka Suaib, and La Husen Zuada. Mining in Southeast Sulawesi and Central Sulawesi: Shadow Economy and Environmental Damage Regional Autonomy Era in Indonesia. In *Proceedings of the International Conference on Social Studies and Environmental Issues (ICOSSEI 2019)*, volume 404, pages 20–27, Paris, France, 2020. Atlantis Press. ISBN 978-94-6252-907-6. doi: 10.2991/assehr.k.200214.004. URL https://www.atlantis-press.com/article/125934660.

Carlijn B.M. Kamphuis, Tessa Jansen, Johan P. Mackenbach, and Frank J. Van Lenthe. Bourdieu's Cultural Capital in Relation to Food Choices: A Systematic Review of Cultural Capital Indicators and an Empirical Proof of Concept. *PLoS ONE*, 10(8), 8 2015. ISSN 19326203. doi: 10.1371/JOURNAL.PONE.0130695. URL /pmc/articles/PMC4526463//pmc/articles/PMC4526463/?report=abstracthttps://www.ncbi.nlm.nih.gov/pmc/articles/PMC4526463/.

Defren Ch Kasenda, R E.M.F Osak, T F.D Lumy, and F N.S Oroh. Analisis Keuntungan Pedagang Daging Kelelawar di Pasar Tradisional Kecamatan Amurang dan Kecamatan Modoinding Kabupaten Minahasa Selatan. *ZOOTEC*, 40(1):94, 12 2019. ISSN 2615-8698. doi: 10.35792/zot.40.1.2020.26818. URL https://ejournal.unsrat.ac.id/index.php/zootek/article/view/26818.

Abiud Kaswamila, Shaun Russell, and Mike McGibbon. Impacts of Wildlife on Household Food Security and Income in Northeastern Tanzania. *Human Dimensions of Wildlife*, 12(6):391–404, 12 2007. ISSN 1087-1209. doi: 10.1080/10871200701670003. URL http://www.tandfonline.com/doi/abs/10.1080/10871200701670003.

Lisa C Kelley and Agung Prabowo. Flooding and Land Use Change in Southeast Sulawesi, Indonesia. *Land*, 8(139):1–19, 2019.

Lisa C. Kelley, Samuel G. Evans, and Matthew D. Potts. Richer histories for more relevant policies: 42 years of tree cover loss and gain in Southeast Sulawesi, Indonesia. *Global Change Biology*, 23(2):830–839, 2017. ISSN 13652486. doi: 10.1111/gcb.13434.

Marc Kery. Estimating Abundance From Bird Counts: Binomial Mixture Models Uncover Complex Covariate Relationships. *The Auk*, 125(2):336–345, 2008. ISSN 0004-8038. doi: 10.1525/auk.2008.06185. URL http://www.bioone.org/doi/abs/10.1525/auk.2008.06185.

Marc Kery and J Andrew Royle. Inference About Species Richness and Community Structure Using Species-Specific Occupancy Models in the National Swiss Breeding Bird Survey MHB. In D. L. Thomson, editor, *Modeling demographic processes in marked populations*, volume 3, pages 639–656. Springer Science+Business Media, 3 edition, 2009. ISBN 978-0-387-78150-1. doi: 10.1007/978-0-387-78151-8. URL http://link.springer.com/content/pdf/10.1007/978-0-387-78151-8.pdf%5Cnhttp://link.springer.com/10.1007/978-0-387-78151-8%5Cnhttp://link.springer.com/content/pdf/10.1007/978-0-387-78151-8.pdf%5Cnhttp://link.springer.com/10.1007/978-0-387-78151-8.

Marc Kéry and J. Andrew Royle. *Applied Hierarchical Modeling in Ecology. Analysis of distribution, abundance and species richness in R and BUGS.*, volume 1. Elsevier, London, volume 1 edition, 2016. ISBN 9780128014868. doi: 10.1016/B978-0-12-801378-6.01001-8. URL http://linkinghub.elsevier.com/retrieve/pii/B9780128013786010018.

Munawar Kholis, Oktafa Rini Puspita, Donny Gunaryadi, and Lili Aries Sadikin. Pedoman Implementasi SMART di Kawasan Konservasi. Technical report, Kementrian Lingkungan Hidup dan Kehutanan, Jakarta, 2016.

Gerold Kier, Holger Kreft, Tien Ming Lee, Walter Jetz, Pierre L. Ibisch, Christoph Nowicki, Jens Mutke, and Wilhelm Barthlott. A global assessment of endemism and species richness across island and mainland regions. *Proceedings of the National Academy of Sciences*, 106(23):9322–9327, 6 2009. ISSN 0027-8424. doi: 10.1073/pnas.0810306106. URL https://www.pnas.org/content/106/23/9322https://www.pnas.org/content/106/23/9322.abstracthttps://pnas.org/doi/full/10.1073/pnas.0810306106.

Shadia I. Kilwanila, George M. Msalya, Charles M. Lyimo, and Alfan A. Rija. Geographic biases in cane rat (Thryonomyds) research may impede broader wildlife utilization and conservation in Africa: A systematic review. *Scientific African*, 12:e00785, 7 2021. ISSN 24682276. doi: 10.1016/j.sciaf.2021.e00785. URL https://linkinghub.elsevier.com/retrieve/pii/S2468227621000892.

H.J Kiroh, F.S. Ratulangi, S.C. Rimbing, and I Wahyuni. Kajian Pemotongan Babirusa (Babyrousa babirussa celebensis Deniger) Sebagai Satwa Endemik Sulawesi Utara Pada Beberapa Pasar Tradisional di Kabupaten Minahasa. *ZOOTEC*, 40(2):689, 7 2020. ISSN 2615-8698. doi: 10.35792/zot.40.2.2020.30095. URL https://ejournal.unsrat.ac.id/index.php/zootek/article/view/30095.

KLHK. *Deforestasi Indonesia Tahun 2017-2018*, volume 64. Direktorat Inventarisasi dan Pemantauan Sumber Daya Hutan, Direktorat Jenderal Planologi Kehutanan dan Tata Lingkungan, Kementerian Lingkungan Hidup dan Kehutanan, Jakarta, 2019.

Elizabeth Kolbert. Why Facts Don't Change Our Minds — The New Yorker. *The New Yorker*, 2 2017. URL https://www.newyorker.com/magazine/2017/02/27/why-facts-dont-change-our-minds.

MoEF Ditjen KSDAE. Statistik Direktorat Jenderal KSDAE 2017. Technical report, Jakarta, 2018.

Mirza D Kusrini and Ross A Alford. Indonesia's Exports of Frogs' Legs. *TRAFFIC Bulletin*, 21(1):13–24, 2006. URL https://researchonline.jcu.edu.au/4216/1/4216_Kusrini_%26_Alford_2006.pdf.

Mirza Dikari Kusrini. *Edible frog harvesting in Indonesia: evaluating its impact and ecological context*. PhD thesis, James Cook University, 2005. URL https://researchonline.jcu.edu.au/1118/2/02whole.pdf.

Tina Kusumaningrum, Alice Latinne, Stephanie Martinez, Jusuf Kalengkongan, Ageng Wiyatno, Aghnianditya Kresno Dewantari, Novie Kasenda, Janno B. B. Bernadus, Ungke Anton Jaya, Chairin Nisa Ma'roef, Leilani Francisco, Emily Hagan, Maureen Miller, Khin Saw Aye Myint, Peter Daszak, Kevin J. Olival, Suryo Saputro, Joko Pamungkas, and Dodi Safari. Knowledge, attitudes, and practices associated with zoonotic disease transmission risk in North Sulawesi, Indonesia. *One Health Outlook*, 4(1):11, 12 2022. ISSN 2524-4655. doi: 10.1186/s42522-022-00067-w. URL https://onehealthoutlook.biomedcentral.com/articles/10.1186/s42522-022-00067-w.

S Laatung, A M Fuah, B Masy'ud, C Sumantri, and S Dohong. The Hunting of White-tailed rat by Minahasa Tribe, North Sulawesi, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 399(1):012032, 12 2019. ISSN 1755-1307. doi: 10.1088/1755-1315/399/1/012032. URL https://iopscience.iop.org/article/10.1088/1755-1315/399/1/012032.

Sylvia Laatung, Asnath Maria Fuah, Burhanuddin Masy'ud, Cece Sumantri, and Salundik Dohong. Species of white-tailed forest rats hunted and traded, their conservation status and habitat characteristics, in North Sulawesi, Indonesia. *Biodiversitas Journal of Biological Diversity*, 22(7):2778–2784, 6 2021. ISSN 2085-4722. doi: 10.13057/biodiv/d220727. URL https://smujo.id/biodiv/article/view/8122/4947https://smujo.id/biodiv/article/view/8122.

Ashley E. Larsen, Kyle Meng, and Bruce E. Kendall. Causal analysis in control–impact ecological studies with observational data. *Methods in Ecology and Evolution*, 10(7):924–934, 7 2019. ISSN 2041-210X. doi: 10.1111/2041-210X.13190. URL https://besjournals.onlinelibrary.wiley.com/doi/10.1111/2041-210X.13190.

Clark Spencer Larsen. Animal Source Foods and Human Health during Evolution. *The Journal of Nutrition*, 133(11):3893S–3897S, 11 2003. ISSN 0022-3166. doi: 10.1093/JN/133.11.3893S.

Alice Latinne, Suryo Saputro, Jusuf Kalengkongan, Citra Livi Kowel, Lidia Gaghiwu, Tiltje Andretha Ransaleleh, Meis Jacinta Nangoy, Indyah Wahyuni, Tina Kusumaningrum, Dodi Safari, Yasha Feferholtz, Hongying Li, Emily Hagan, Maureen Miller, Leilani Francisco, Peter Daszak, Kevin J. Olival, and Joko Pamungkas. Characterizing and quantifying the wildlife trade network in Sulawesi, Indonesia. *Global Ecology and Conservation*, 21:e00887, 2020. ISSN 23519894. doi: 10.1016/j.gecco.2019.e00887. URL https://doi.org/10.1016/j.gecco.2019.e00887.

Zachary M. Laubach, Eleanor J. Murray, Kim L. Hoke, Rebecca J. Safran, and Wei Perng. A biologist's guide to model selection and causal inference. *Proceedings of the Royal Society B: Biological Sciences*, 288(1943):20202815, 1 2021. ISSN 0962-8452. doi: 10.1098/rspb.2020.2815. URL https://royalsocietypublishing.org/doi/10.1098/rspb.2020.2815.

Yves Laumonier. *The Vegetation and Physiography of Sumatra*. Kluwer Academic Pub, Dordrecht, The Netherlands, 1997. ISBN 07923-3761-1. URL http://books.google.com/books?hl=en&lr=&id=lOclIZ9hyCYC&oi=fnd&pg=PR7&ots=-lZR3E-sGZ&sig=saLhWrJgGsbgitzA0sPYsXnROrM#v=onepage&q&f=false.

Rob J. Lee. Impact of subsistence hunting in North Sulawesi, Indonesia, and Conservation Options. In John G. Robinson and Elizabeth L. Bennett, editors, *Hunting for sustainability in tropical forests*, chapter 23, pages 455–472. Columbia University Press, New York, 2000. ISBN 0231109768.

Robert J. Lee, Jonathan Riley, Iwan Hunowu, and Edison Maneasa. The Sulawesi palm civet: expanded distribution of s little known endemic viverrid. *Oryx*, 37(3):1–4, 2003. ISSN 0030-6053. doi: 10.1017/S0030605302000000.

Robert J. Lee, Antonia J. Gorog, Asri Dwiyahreni, Stephan Siwu, Jon Riley, Harry Alexander, Gary D. Paoli, and Widodo Ramono. Wildlife trade and implications for law enforcement in Indonesia: A case study from North Sulawesi. *Biological Conservation*, 123(4):477–488, 2005. ISSN 00063207. doi: 10.1016/j.biocon.2005.01.009.

Tien Ming Lee, Navjot S. Sodhi, and Dewi M. Prawiradilaga. The importance of protected areas for the forest and endemic avifauna of sulawesi (indonesia). *Ecological Applications*, 17:1727–1741, 9 2007. ISSN 1051-0761. doi: 10.1890/06-1256.1. URL https://esajournals.onlinelibrary.wiley.com/doi/10.1890/06-1256.1.

Tien Ming Lee, Amanda Sigouin, Miguel Pinedo-Vasquez, and Robert Nasi. The harvest of wildlife for bushmeat and traditional medicine in East, South and Southeast Asia. Current knowledge base, challenges, opportunities and areas for future research. Technical report, CIFOR, Bogor, Indonesia, 2014.

Tien Ming Lee, Amanda Sigouin, Miguel Pinedo-Vasquez, and Robert Nasi. The Harvest of Tropical Wildlife for Bushmeat and Traditional Medicine. *Annual Review of Environment and Resources*, 45:145–170, 10 2020. ISSN 15435938. doi: 10.1146/ANNUREV-ENVIRON-102016-060827. URL https://www.annualreviews.org/doi/abs/10.1146/annurev-environ-102016-060827.

K. Leus, A. Macdonald, J. Burton, and I Rejeki. Babyrousa celebensis. The IUCN Red List of Threatened Species 2016: e.T136446A44142964, 2016. URL http://www.iucnredlist.org/details/136446/0.

Liana Liana and Witno Witno. Perdagangan satwa liar di pasar tradisional dan pasar modern di Sulawesi Utara. *Jurnal Penelitian Kehutanan BONITA*, 3(1):28, 7 2021. ISSN 2685-6506. doi: 10.55285/bonita.v3i1.767. URL http://ojs.unanda.ac.id/index.php/bonita/article/view/767.

Matthew Linkie, Jasline Ng, Zhi Qi Lim, Muhammad I. Lubis, Mark Rademaker, and Erik Meijaard. The IUCN Wild Pig Challenge 2015. *Oryx*, pages 1–5, 2016. ISSN 0030-6053. doi: 10.1017/S0030605316000557. URL http://www.journals.cambridge.org/abstract_S0030605316000557.

Johanna Lönngren and Katrien van Poeck. Wicked problems: a mapping review of the literature. *International Journal of Sustainable Development & World Ecology*, 28(6):481–502, 8 2021. ISSN 1350-4509. doi: 10.1080/13504509.2020.1859415. URL https://www.tandfonline.com/doi/full/10.1080/13504509.2020.1859415.

Sarah Amber Loos. *Exploration of MARXAN for Utility in Marine Protected Area Zoning.* PhD thesis, University of Victoria,, 2001.

Julien Louys, Michael Herrera, Stuart Hawkins, Ken Aplin, Christian Reepmeyer, Felicitas Hopf, Stephen C Donnellan, Sue O'connor, and Daud A Tanudirjo. Neolithic dispersal implications of murids from late Holocene archaeological and modern natural deposits in the Talaud Islands, northern Sulawesi. In Sue O'Connor, David Bulbeck, and Juliet Meyer, editors, *The Archaeology of Sulawesi: Current research on the Pleistocene to the Historic Period*, chapter 14, pages 223–242. ANU Press, Canberra, Australia, 2018.

Asanterabi Lowassa, Degu Tadie, and Anke Fischer. On the role of women in bushmeat hunting – Insights from Tanzania and Ethiopia. *Journal of Rural Studies*, 28(4):622–630, 10 2012. ISSN 07430167. doi: 10.1016/j.jrurstud.2012.06.002.

Luca Luiselli, Emmanuel M. Hema, Gabriel Hoinsoudé Segniagbeto, Valy Ouattara, Edem A. Eniang, Gnoumou Parfait, Godfrey C. Akani, Djidama Sirima, Barineme B. Fakae, Daniele Dendi, and Julia E. Fa. Bushmeat consumption in large urban centres in West Africa. *Oryx*, 54(5):731–734, 9 2020. ISSN 0030-6053. doi: 10.1017/S0030605318000893. URL https://www.cambridge.org/core/product/identifier/S0030605318000893/type/journal_article.

Matthew Scott Luskin, Erik Meijaard, Selly Surya, Sheherazade, Chris Walzer, and Matthew Linkie. African Swine Fever threatens Southeast Asia's 11 endemic wild pig species. *Conservation Letters*, 14(3):e12784, 5 2021. ISSN 1755-263X. doi: 10.1111/conl.12784. URL https://onlinelibrary.wiley.com/doi/full/10.1111/conl.12784https://onlinelibrary.wiley.com/doi/abs/10.1111/conl.12784https://conbio.onlinelibrary.wiley.com/doi/10.1111/conl.12784https://onlinelibrary.wiley.com/doi/10.1111/conl.12784.

Robert H. MacArthur and Edward O. Wilson. *The theory of island biogeography.* Princeton University Press, Princeton, N.J, 1967. ISBN 069108050X.

David W. Macdonald and M. Karen Laurenson. Infectious disease: Inextricable linkages between human and ecosystem health. *Biological Conservation*, 131(2):143–150, 8 2006. ISSN 00063207. doi: 10.1016/j.biocon.2006.05.007. URL https://linkinghub.elsevier.com/retrieve/pii/S0006320706002059.

David W. Macdonald, Paul J. Johnson, Lise Albrechtsen, Sarah Seymour, Jef Dupain, Amy Hall, and John E. Fa. Bushmeat trade in the Cross–Sanaga rivers region: Evidence for the importance of protected areas. *Biological Conservation*, 147(1):107–114, 3 2012. ISSN 0006-3207. doi: 10.1016/J.BIOCON.2011.12.018.

David W. Macdonald, Helen M. Bothwell, Żaneta Kaszta, Eric Ash, Gilmoore Bolongon, Dawn Burnham, Özgün Emre Can, Ahimsa Campos-Arceiz, Phan Channa, Gopalasamy Reuben Clements, Andrew J. Hearn, Laurie Hedges, Saw Htun, Jan F. Kamler, Kae Kawanishi, Ewan A. Macdonald, Shariff Wan Mohamad, Jonathan Moore, Hla Naing, Manabu Onuma, Ugyen Penjor, Akchousanh Rasphone, Darmaraj Mark Rayan, Joanna Ross, Priya Singh, Cedric Kai Wei Tan, Jamie Wadey, Bhupendra P. Yadav, and Samuel A. Cushman. Multi-scale habitat modelling identifies spatial conservation priorities for mainland clouded leopards (Neofelis nebulosa). *Diversity and Distributions*, (March):1–16, 2019. ISSN 1366-9516. doi: 10.1111/ddi.12967. URL `https://onlinelibrary.wiley.com/doi/abs/10.1111/ddi.12967`.

Georgina M Mace. Whose conservation? *Science*, 345(6204), 2014.

Darryl I MacKenzie and William L Kendall. How Should Detection Probability Be Incorporated Into. *Ecology*, 83(9):2387–2393, 2002. URL `http://www.jstor.org/stable/3071800?origin=crossref`.

Darryl I Mackenzie, James D Nichols, Gideon B Lachman, Sam Droege, J Andrew Royle, and Catherine A Langtimm. Estimating site occupancy rates when detection probabilities are less than one. *Ecology*, 83(8):2248–2255, 2002. URL `internal-pdf://5924_mackenzieecology-1271008769/5924_MacKenzieECOLOGY.pdf`.

Darryl I. MacKenzie, James D. Nichols, J. Andrew Royle, Kenneth H. Pollock, Larissa L. Bailey, and James E. Hines. Introduction. *Occupancy Estimation and Modeling*, pages 3–26, 2018. doi: 10.1016/b978-0-12-407197-1.00002-8.

John Mackinnon. Species richness and adaptive capacity in animal communities: lessons from China. *Integrative Zoology*, 3(2):95–100, 6 2008. ISSN 1749-4877. doi: 10.1111/J.1749-4877.2008.00081.X. URL `https://onlinelibrary.wiley.com/doi/full/10.1111/j.1749-4877.2008.00081.xhttps://onlinelibrary.wiley.com/doi/abs/10.1111/j.1749-4877.2008.00081.xhttps://onlinelibrary.wiley.com/doi/10.1111/j.1749-4877.2008.00081.x`.

John Ramsay MacKinnon and Kathy MacKinnon. *Review of the protected areas system in the Indo-Malayan Realm*. International Union for Conservation of Nature and Natural Resources (IUCN), Gland, Switzerland and Cambridge, UK, 1986.

Meine M Mambeya, Francesca Baker, Brice R Momboua, Aurélie Flore Koumba Pambo, Martin Hega, Vivien Joseph Okouyi Okouyi, Martial Onanga, Daniel W S Challender, Daniel J Ingram, Hongyan Wang, and Katharine Abernethy. The emergence of a commercial trade in pangolins from Gabon. *African journal of ecology*, 56(3):601–609, 2018. ISSN 0141-6707. doi: 10.1111/aje.12507.

Stella Manes, Mark J. Costello, Heath Beckett, Anindita Debnath, Eleanor Devenish-Nelson, Kerry-Anne Grey, Rhosanna Jenkins, Tasnuva Ming Khan, Wolfgang Kiessling, Cristina Krause, Shobha S. Maharaj, Guy F. Midgley, Jeff Price, Gautam Talukdar,

and Mariana M. Vale. Endemism increases species' climate change risk in areas of global biodiversity importance. *Biological Conservation*, 257:109070, 5 2021. ISSN 00063207. doi: 10.1016/j.biocon.2021.109070. URL https://linkinghub.elsevier.com/retrieve/pii/S0006320721001221.

Michael J. Manfredo, Jeremy T. Bruskotter, Tara L. Teel, David Fulton, Shalom H. Schwartz, Robert Arlinghaus, Shigehiro Oishi, Ayse K. Uskul, Kent Redford, Shinobu Kitayama, and Leeann Sullivan. Why social values cannot be changed for the sake of conservation. *Conservation Biology*, 31(4):772–780, 8 2017. ISSN 0888-8892. doi: 10.1111/cobi.12855. URL https://conbio.onlinelibrary.wiley.com/doi/10.1111/cobi.12855.

Ramon Margalef. Information Theory in Ecology (translation of Margalef 1957). *Gen. Syst.*, 3(36):71, 1958. ISSN 9789896540821.

Geoffrey Marshall, J. W. S. Blacklock, C. Cameron, N. B. Capon, R. Cruickshank, J. H. Gaddum, F. R. G. Heaf, A. Bradford Hill, L. E. Houghton, J. Clifford Hoyle, H Raistrick, J. G. Scadding, W. H. Tytler, G. S. Wilson, and P. D'Arcy Hart. Streptomycin Treatment of Pulmonary Tuberculosis: A Medical Research Council Investigation. *BMJ*, 2(4582):769–782, 10 1948. ISSN 0959-8138. doi: 10.1136/bmj.2.4582.769. URL https://www.bmj.com/lookup/doi/10.1136/bmj.2.4582.769.

Thomas E. Martin, Joseph Monkhouse, Darren P. O'Connell, Kangkuso Analuddin, Adi Karya, Nancy E. C. Priston, Charlotte A. Palmer, Barnabas Harrison, Jack Baddams, Abdul H. Mustari, Philip M. Wheeler, and David G. Tosh. Distribution and status of threatened and endemic marsupials on the offshore islands of south-east Sulawesi, Indonesia. *Australian Mammalogy*, 41(1):76, 3 2019. ISSN 0310-0049. doi: 10.1071/AM17052. URL http://www.publish.csiro.au/?paper=AM17052.

Ibnu Maryanto, Datun Maharadatunkamsi, Anang Setiawan Achmadi, Sigit Wiantoro, Eko Sulistyadi, Masaaki Yoneda, Agustinus Suyanto, and Jito Sugardjito. *Checklist of The Mammals of Indonesia*, volume 3rd Edition. 2019. ISBN 978-979-579-108-9. URL https://www.researchgate.net/publication/338687953_CHECKLIST_OF_THE_MAMMALS_OF_INDONESIA_Scientific_English_Indonesia_Name_and_Distribution_Area_Table_in_Indonesia_Including_CITES_IUCN_and_Indonesian_Category_for_Conservation.

C. J. Masengie, T. F. D Lumy, and I. D. R. Lumenta. Analisis keuntungan pedagang Kelelawar di Pasar Tradisional
}Beriman Kota Tomohon. *Zootec*, 42(1):59–67, 12 2022. URL https://ejournal.unsrat.ac.id/index.php/zootek/article/view/26818.

Duncan M. Matheka, Joseph Nderitu, Daniel Mutonga, Mary I. Otiti, Karen Siegel, and Alessandro R. Demaio. Open access: Academic publishing and its implications for knowledge equity in Kenya. *Globalization and Health*, 10 (1):1–5, 4 2014. ISSN 17448603. doi: 10.1186/1744-8603-10-26/METRICS. URL https://globalizationandhealth.biomedcentral.com/articles/10.1186/1744-8603-10-26.

Karl Maton. Habitus. *Pierre Bourdieu: Key Concepts*, pages 49–66, 1 2008. doi: 10.1017/UPO9781844654031.006. URL https://www.cambridge.org/core/books/pierre-bourdieu/habitus/5FA4EF3F00B10A8D420BFDC4F959B52C.

Risma Illa Maulany. Challenges for Conservation of Sulawesi Crested Black Macaque (Macaca nigra). *PERENNIAL*, 2(2):26, 7 2006. ISSN 1412-7784. doi: 10.24259/perennial.v2i2.158. URL http://journal.unhas.ac.id/index.php/perennial/article/view/158.

Pedro Mayor, Hani R. El Bizri, Thais Q. Morcatty, Kelly Moya, Samantha Solis, and Richard E. Bodmer. Assessing the Minimum Sampling Effort Required to Reliably Monitor Wild Meat Trade in Urban Markets. *Frontiers in Ecology and Evolution*, 0: 180, 5 2019. ISSN 2296-701X. doi: 10.3389/FEVO.2019.00180.

R.A. Mbete, H. Banga-Mboko, P. ., C. Vermeulen, Jean-Louis Doucet, P.L. Leroy, and J.L. Hornick. Evaluation of the Daily Bush Meat Intake in Urban Household Consumption in Brazzaville, the Capital City of the Republic of Congo. *Journal of Animal and Veterinary Advances*, 18(1):18–23, 10 2019. ISSN 16805593. doi: 10.36478/javaa.2019.18.23. URL http://www.medwelljournals.com/abstract/?doi=javaa.2019.18.23.

Richard McElreath. *Statistical Rethinking*. Chapman and Hall/CRC, 3 2020. ISBN 9780429029608. doi: 10.1201/9780429029608.

Mary L McHugh. Interrater reliability: the kappa statistic. *Biochem Med*, 22(3):276–282, 2012.

James McNamara, Julia E. Fa, and Yaa Ntiamoa-Baidu. Understanding drivers of urban bushmeat demand in a Ghanaian market. *Biological Conservation*, 239:108291, 11 2019. ISSN 00063207. doi: 10.1016/j.biocon.2019.108291. URL https://linkinghub.elsevier.com/retrieve/pii/S0006320719307384.

Donella H. Meadows. *Thinking in Systems: A Primer*. Chelsea Green Publishing, White River Junction, VT, 3rd edition, 2008.

Erik Meijaard, Andi Erman, Marc Ancrenaz, and Benoit Goossens. Pig virus imperils food security in Borneo. *Science (New York, N.Y.)*, 383(6680):267, 1 2024. ISSN 1095-9203. doi: 10.1126/science.adn3857. URL http://www.ncbi.nlm.nih.gov/pubmed/38236988.

M. Junus Melalatoa. *Ensiklopedi suku bangsa di Indonesia*. Departemen Pendidikan dan Kebudayaan, 1995. URL https://cir.nii.ac.jp/crid/1130282269765514240.bib?lang=en.

Vicky Melfi. Selamatkan Yaki! Conservation of Sulawesi Crested Black Macaques Macaca nigra. In Sharon Gursky-Doyen and Jatna Supriatna, editors, *Indonesian Primates*, chapter 19, pages 343–356. Springer, 2010. ISBN 9781441915597. doi: 10.1007/978-1-4419-1560-3{_}18. URL https://link-springer-com.ezproxy-prd.bodleian.ox.ac.uk/chapter/10.1007/978-1-4419-1560-3_19.

Ami A. Meutia, Royke Lumowa, and Masayuki Sakakibara. Indonesian Artisanal and Small-Scale Gold Mining—A Narrative Literature Review. *International Journal of Environmental Research and Public Health*, 19(7):3955, 3 2022. ISSN 1660-4601. doi: 10.3390/ijerph19073955. URL https://www.mdpi.com/1660-4601/19/7/3955/htmhttps://www.mdpi.com/1660-4601/19/7/3955.

Simon Mickleburgh, Kerry Waylen, and Paul Racey. Bats as bushmeat: a global review. *Oryx*, 43(02):217, 4 2009. ISSN 0030-6053. doi: 10.1017/S0030605308000938. URL http://www.journals.cambridge.org/abstract_S0030605308000938.

D.J. Middleton, K Armstrong, Y Baba, H Balslev, K Chayamarit, R.C.K. Chung, B.J. Conn, E.S. Fernando, K Fujikawa, R Kiew, H.T. Luu, Mu Mu Aung, M.F. Newman, S Tagane, N Tanaka, D.C. Thomas, T.B. Tran, T.M.A. Utteridge, P.C. van Welzen, D Widyatmoko, T Yahara, and K.M. Wong. Progress on Southeast Asia's Flora projects. *Gardens' Bulletin Singapore*, 71(2):267–319, 12 2019. ISSN 03747859. doi: 10.26492/gbs71(2).2019-02. URL https://www.nparks.gov.sg/sbg/research/publications/gardens-bulletin-singapore/-/media/sbg/gardens-bulletin/gbs_71_02_y2019/71_02_01_y2019_v71p2_gbs_pg267.pdf.

Tammy Mildenstein, Iroro Tanshi, and Paul A. Racey. Exploitation of Bats for Bushmeat and Medicine. In *Bats in the Anthropocene: Conservation of Bats in a Changing World*, pages 325–375. Springer International Publishing, Cham, 2016. doi: 10.1007/978-3-319-25220-9{_}12. URL http://link.springer.com/10.1007/978-3-319-25220-9_12.

E. J. Milner-Gulland, Elizabeth L. Bennett, Kate Abernethy, Mohamed Bakarr, Elizabeth Bennett, Richard Bodmer, Justin Brashares, Guy Cowlishaw, Paul Elkan, Heather Eves, John Fa, E. J. Milner-Gulland, Carlos Peres, Callum Roberts, John Robinson, Marcus Rowcliffe, and David Wilkie. Wild meat: The bigger picture. *Trends in Ecology and Evolution*, 18(7):351–357, 2003. ISSN 01695347. doi: 10.1016/S0169-5347(03)00123-X.

E.J Milner-Gulland and Lynn Clayton. The trade in babirusas and wild pigs in North Sulawesi, Indonesia. *Ecological Economics*, 42(1-2):165–183, 8 2002. ISSN 09218009. doi: 10.1016/S0921-8009(02)00047-2. URL https://linkinghub.elsevier.com/retrieve/pii/S0921800902000472.

E.J. Milner-Gulland, Prue Addison, William Arlidge, Julia Baker, Hollie Booth, Thomas Brooks, Joseph Bull, Michael Burgass, Jonathan Ekstrom, Sophus Zu Ermgassen, Vin Fleming, Henry Grub, Amrei von Hase, Mike Hoffmann, Jon Hutton, Diego Juffe-Bignoli, Kerry ten Kate, Joe Kiesecker, Noelle Kumpel, Martine Maron, Helen Newing, Katrina Ole Moiyoi, Cheli Sinclair, Sam Sinclair, Malcolm Starkey, Simon Stuart, Cath Tayleur, and James Watson. Four Steps for the Earth: mainstreaming the post-2020 Global Biodiversity Framework. *One Earth*, 2050:75–87, 2021. doi: 10.31235/osf.io/gjps6.

MoEF Ditjen KSDAE. Statistik Direktorat Jenderal KSDAE 2017. Technical report, Kementerian Lingkungan Hidup dan Kehutanan Direktorat Jenderal Konservasi Sumber Daya Alam dan Ekosistem, Jakarta, 2018.

MoEF (Ministry of Environment and Forestry of Indonesia). Rekalkulasi Penutupan Lahan (Land Cover Recalculation) Indonesia Tahun 2018, 2019.

David Moher, Alessandro Liberati, Jennifer Tetzlaff, and Douglas G. Altman. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *BMJ (Online)*, 339(7716):332–336, 2009. ISSN 17561833. doi: 10.1136/bmj.b2535. URL http://dx.doi.org/doi:10.1136/bmj.b2535.

Robert A. Montgomery and David W. Macdonald. COVID-19, Health, Conservation, and Shared Wellbeing: Details Matter. *Trends in Ecology & Evolution*, 35(9):748–750, 9 2020. ISSN 01695347. doi: 10.1016/j.tree.2020.06.001. URL https://linkinghub.elsevier.com/retrieve/pii/S0169534720301476.

Carla Morsello, Blanca Yagüe, Letícia Beltreschi, Nathalie van Vliet, Cristina Adams, Tatiana Schor, Maria Paula Quiceno-Mesa, and Daniel Cruz. Cultural attitudes are stronger predictors of bushmeat consumption and preference than economic factors among urban amazonians from brazil and colombia. *Ecology and Society*, 20(4), 2015. ISSN 17083087. doi: 10.5751/ES-07771-200421.

A. Mortelliti, R. Castiglia, G. Amori, I. Maryanto, and G. G. Musser. A new species of ¡i¿Margaretamys¡/i¿ (Rodentia: Muridae: Murinae: Rattini) from Pegunungan Mekongga, southeastern Sulawesi, Indonesia. *Tropical Zoology*, 25(2):74–107, 6 2012. ISSN 0394-6975. doi: 10.1080/03946975.2012.696439. URL http://www.tandfonline.com/doi/abs/10.1080/03946975.2012.696439.

Guy G. Musser. Notes on systematics of Indo-Malayan murid rodents, and descriptions of new genera and species from Ceylon, Sulawesi, and the Philippines. Bulletin of the AMNH ; v. 168, article 3. 1981. URL https://digitallibrary.amnh.org/handle/2246/1053.

Guy G. Musser. A Systematic Review of Sulawesi Bunomys (Muridae, Murinae) with the Description of Two New Species. *Bulletin of the American Museum of Natural History*, 392:1–313, 12 2014. ISSN 0003-0090. doi: 10.1206/863.1. URL http://www.bioone.org/doi/abs/10.1206/863.1.

Norman Myers, Russell A Mittermeier, Cristina G Mittermeier, Gustavo A B da Fonseca, and Jennifer Kent. Biodiversity hotspots for conservation priorities. *Nature*, 403:853–858, 2000. URL internal-pdf://120.239.247.27/Myers_et_al_2000.pdf.

R. Naidoo, D. Gerkey, D. Hole, A. Pfaff, A. M. Ellis, C. D. Golden, D. Herrera, K. Johnson, M. Mulligan, T. H. Ricketts, and B. Fisher. Evaluating the impacts of protected areas on human well-being across the developing world. *Science Advances*, 5(4):1–8, 4 2019. ISSN 2375-2548. doi: 10.1126/sciadv.aav3006. URL https://www.science.org/doi/10.1126/sciadv.aav3006.

Robin Naidoo, Daniel Bergin, and Jan Vertefeuille. Socio-demographic correlates of wildlife consumption during early stages of the COVID-19 pandemic. *Nature Ecology & Evolution*, 9 2021. ISSN 2397-334X. doi: 10.1038/s41559-021-01546-5. URL https://www.nature.com/articles/s41559-021-01546-5.

Robert Nasi, Julia E. Fa, Nathalie van Vliet, Lauren Coad, Miguel Pinedo-Vasquez, Varun Swamy, and Tien Ming Lee. *Wild Meat. FTA Highlights of a Decade 2011–2021 series*. Center for International Forestry Research (CIFOR), 2021a. URL https://www.foreststreesagroforestry.org/publications/research-publication/?title=fta-highlight-no-6-wild-meat&id=11463_22931.

Robert Nasi, Julia E. Fa, Nathalie van Vliet, Lauren Coad, Miguel Pinedo-Vasquez, Varun Swamy, and Tien Ming Lee. Wild Meat. FTA Highlights of a Decade 2011-2021. Technical report, CGIAR, CIFOR, Bogor, 2021b. URL https:

//www.foreststreesagroforestry.org/publications/research-publication/?title=fta-highlight-no-6-wild-meat&id=11463_22931.

K.A.I. Nekaris, C.R. Shepherd, C.R. Starr, and V. Nijman. Exploring cultural drivers for wildlife trade via an ethnoprimatological approach: a case study of slender and slow lorises (¡i¿Loris¡/i¿ and ¡i¿Nycticebus¡/i¿) in South and Southeast Asia. *American Journal of Primatology*, 72(10):877–886, 10 2010. ISSN 0275-2565. doi: 10.1002/ajp.20842. URL https://onlinelibrary.wiley.com/doi/10.1002/ajp.20842.

Thanh Trung Nguyen, Thi Ngan Mai, Sinh Dang-Xuan, Hung Nguyen-Viet, Fred Unger, and Hu Suk Lee. Emerging zoonotic diseases in Southeast Asia in the period 2011-2022: a systematic literature review. *The veterinary quarterly*, 44(1):1–15, 2024. ISSN 1875-5941. doi: 10.1080/01652176.2023.2300965. URL https://pubmed.ncbi.nlm.nih.gov/38229485/.

Vincent Nijman. An overview of international wildlife trade from Southeast Asia. *Biodiversity and Conservation*, 19(4):1101–1114, 4 2010. ISSN 0960-3115. doi: 10.1007/s10531-009-9758-4. URL http://link.springer.com/10.1007/s10531-009-9758-4.

Vincent Nijman, Chris R Shepherd, Mumpuni, Mumpuni, and Kate L Sanders. Over-exploitation and illegal trade of reptiles in Indonesia. *Herpetological Journal*, 22:83–89, 2012.

Kenji Noguchi, Akiko Kamada, and Ilan Shrira. Cultural differences in the primacy effect for person perception. *International Journal of Psychology*, pages n/a–n/a, 11 2013. ISSN 00207594. doi: 10.1002/ijop.12019. URL https://onlinelibrary.wiley.com/doi/10.1002/ijop.12019.

Reed F Noss, Andrew P Dobson, Robert Baldwin, Paul Beier, Cory R Davis, Dominick A Dellasala, John Francis, Harvey Locke, Katarzyna Nowak, Roel Lopez, Conrad Reining, Stephen C Trombulak, and Gary Tabor. Bolder Thinking for Conservation. *Conservation Biology*, 26(1):1–4, 2012. ISSN 08888892. doi: 10.1111/j.1523-1739.2011.01738.x. URL http://doi.wiley.com/10.1111/j.1523-1739.2011.01738.x.

Rose E. O'Dea, Malgorzata Lagisz, Michael D. Jennions, Julia Koricheva, Daniel W.A. Noble, Timothy H. Parker, Jessica Gurevitch, Matthew J. Page, Gavin Stewart, David Moher, and Shinichi Nakagawa. Preferred reporting items for systematic reviews and meta-analyses in ecology and evolutionary biology: a ¡scp¿PRISMA¡/scp¿ extension. *Biological Reviews*, 96(5):1695–1722, 10 2021. ISSN 1464-7931. doi: 10.1111/brv.12721. URL https://onlinelibrary.wiley.com/doi/10.1111/brv.12721.

David M Olson and Eric Dinerstein. The Global 200: Priority Ecoregions for Global Conservation. *Ann. Missouri Bot. Gard.*, 89:199–224, 2002. doi: 10.1109/VPPC.2008.4677498.

Jukka-Pekka Onnela, Bruce E. Landon, Anna-Lea Kahn, Danish Ahmed, Harish Verma, A. James O'Malley, Sunil Bahl, Roland W. Sutter, and Nicholas A. Christakis. Polio vaccine hesitancy in the networks and neighborhoods of Malegaon, India. *Social Science & Medicine*, 153:99–106, 3 2016. ISSN 02779536. doi: 10.1016/j.socscimed.2016.01.024. URL https://linkinghub.elsevier.com/retrieve/pii/S0277953616300247.

Open Data Jabar and BPS - Badan Pusat Statistik. Persentase Penduduk Miskin Berdasarkan Provinsi di Indonesia, 2023. URL https://opendata.jabarprov.go.id/id/dataset/persentase-penduduk-miskin-berdasarkan-provinsi-di-indonesia.

Timothy G O'Brien, Margaret F Kinnaird, Hariyo T Wibisono, Timothy G O'Brien, Margaret F Kinnaird, and Hariyo T Wibisono. Crouching tigers, hidden prey: Sumatran tiger and prey populations in a tropical forest landscape. *Animal Conservation*, 6(2):131–139, 2003. ISSN 1367-9430. doi: 10.1017/S1367943003003172.

Andante Hadi Pandyaswargo, Alan Dwi Wibowo, Meilinda Fitriani Nur Maghfiroh, Arlavinda Rezqita, and Hiroshi Onoda. The Emerging Electric Vehicle and Battery Industry in Indonesia: Actions around the Nickel Ore Export Ban and a SWOT Analysis. *Batteries 2021, Vol. 7, Page 80*, 7(4):80, 11 2021. ISSN 2313-0105. doi: 10.3390/BATTERIES7040080. URL https://www.mdpi.com/2313-0105/7/4/80/htmhttps://www.mdpi.com/2313-0105/7/4/80.

Margaretha Pangau-Adam, Marlina Flassy, Jan-Niklas Trei, Matthias Waltert, and Mahmood Soofi. The role of the introduced rusa deer ¡i¿Cervus timorensis¡/i¿ for wildlife hunting in West Papua, Indonesia. *Ecological Solutions and Evidence*, 3 (1):1–11, 1 2022. ISSN 2688-8319. doi: 10.1002/2688-8319.12118. URL https://besjournals.onlinelibrary.wiley.com/doi/10.1002/2688-8319.12118.

Freddy Pattiselanno and Agustina Y S Arobaya. Subsistence Indigenous Hunting in Papua: Does It Sustainable? (Perburuan Subsistens di Papua: Apakah Lestari?). *Media Konservasi*, 16(2):95–100, 2011. URL https://journal.ipb.ac.id/index.php/konservasi/article/download/13001/9801.

Freddy Pattiselanno and Muhammad Irfansyah Lubis. Hunting at the Abun Regional Marine Protected Areas: A Link Between Wildmeat and Food Security. *HAYATI Journal of Biosciences*, 21(4):180–186, 12 2014. ISSN 19783019. doi: 10.4308/hjb.21.4.180. URL https://linkinghub.elsevier.com/retrieve/pii/S1978301916300936.

Freddy Pattiselanno and Robert Nasi. Importance of bushmeat hunting and trade in Papua. In *XIV WORLD FORESTRY CONGRESS*, 2015.

Freddy Pattiselanno, Janice K. F. Lloyd, Jeffrey Sayer, Agni Klintuni Boedhihartono, and Agustina Y.S. Arobaya. Wild Meat Trade Chain on the Bird's Head Peninsula of West Papua Province, Indonesia. *Journal of Ethnobiology*, 40(2):202–217, 7 2020. ISSN 0278-0771. doi: 10.2993/0278-0771-40.2.202. URL http://journals.sagepub.com/doi/10.2993/0278-0771-40.2.202.

Freddy Pattiselanno, MaxJ. Tokede, Agustina Y. S. Arobaya, Gun Mardiatmoko, and August E. Patiselanno. Hunting introduced species in Indonesia New Guinea. *Biodiversitas Journal of Biological Diversity*, 24(5):3045–3050, 6 2023. ISSN 2085-4722. doi: 10.13057/biodiv/d240560. URL https://smujo.id/biodiv/article/view/13770.

Michael Quinn Patton. *Qualitative Research & Evaluation Methods: Integrating Theory and Practice*. SAGE Publications, Thousand Oaks, California, 4th edition, 12 2015. ISBN 9781412972123.

J M Payne, R D Brown, and F S Guthery. Wild game in Texas. *Rangelands*, 9(5): 207–211, 1987. ISSN 0190-0528.

Judea Pearl. *Causality*. Cambridge University Press, Cambridge, 2 edition, 9 2009. ISBN 9780511803161. doi: 10.1017/CBO9780511803161. URL https://www.cambridge.org/core/books/causality/B0046844FAE10CBF274D4ACBDAEB5F5Bhttps://www.cambridge.org/core/product/identifier/9780511803161/type/book.

Judea Pearl. The International Journal of Biostatistics An Introduction to Causal Inference An Introduction to Causal Inference . *The international journal of biostatistics*, 6(2):Article 7, 2010. ISSN 1557-4679. URL http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2836213&tool=pmcentrez&rendertype=abstract.

Judea Pearl. The causal foundations of structural equation modeling. *Handbook of Structural Equation Modeling*, (June):68–91, 2012.

Judea Pearl. *5.Causality and Structural Models in.* Number 2009. 2016. ISBN 9780511803161.

Judea Pearl, Madelyn Glymour, and Nicholas P Jewell. *Causal inference in statistics : a primer*. John Wiley & Sons Ltd Chichester, West Sussex, UK, Chichester, West Sussex, UK, nv - edition, 2016. ISBN 9781119186854; 1119186854; 9781119186861; 1119186862; 1119186846; 9781119186847. doi: LK-https://worldcat.org/title/922799570.

Ugyen Penjor, Sonam Wangdi, Tandin Tandin, and David W. Macdonald. Vulnerability of mammal communities to the combined impacts of anthropic land-use and climate change in the Himalayan conservation landscape of Bhutan. *Ecological Indicators*, 121(May):107085, 2 2021. ISSN 1470160X. doi: 10.1016/j.ecolind.2020.107085. URL https://doi.org/10.1016/j.ecolind.2020.107085https://linkinghub.elsevier.com/retrieve/pii/S1470160X20310244.

Phoebe Weston. 'The pigs have disappeared': swine fever threatens food source for millions as disease hits wild herds — African swine fever — The Guardian, 2024. URL https://www.theguardian.com/environment/2024/jan/19/african-swine-fever-asian-wild-pigs-borneo-aoe.

S. Pooley, M. Barua, W. Beinart, A. Dickman, G. Holmes, J. Lorimer, A. J. Loveridge, D. W. Macdonald, G. Marvin, S. Redpath, C. Sillero-Zubiri, A. Zimmermann, and E. J. Milner-Gulland. An interdisciplinary review of current and future approaches to improving human–predator relations. *Conservation Biology*, 31(3):513–523, 2017. ISSN 15231739. doi: 10.1111/cobi.12859.

Mathieu Pruvot, Kongsy Khammavong, Phonesavanh Milavong, Chanfong Philavong, Daniel Reinharz, Mayfong Mayxay, Sayapeth Rattanavong, Paul Horwood, Philippe Dussart, Bounlom Douangngeun, Watthana Theppangna, Amanda E. Fine, Sarah H. Olson, Matthew Robinson, and Paul Newton. Toward a quantification of risks at the nexus of conservation and health: The case of bushmeat markets in Lao PDR. *Science of The Total Environment*, 676(April):732–745, 2019. ISSN 00489697. doi: 10.1016/j.scitotenv.2019.04.266. URL https://linkinghub.elsevier.com/retrieve/pii/S0048969719318017.

Wulan Pusparini, Andi Cahyana, Hedley S. Grantham, Sean Maxwell, Carolina Soto-Navarro, and David W. Macdonald. A bolder conservation future for Indonesia by prioritising biodiversity, carbon and unique ecosystems in Sulawesi. *Scientific Reports*, 13(1):842, 1 2023. ISSN 2045-2322. doi: 10.1038/s41598-022-21536-2. URL https://www.nature.com/articles/s41598-022-21536-2.

QSR International Pty Ltd. NVivo 14, 2023. URL https://lumivero.com/product/nvivo-14/.

R Core Team. R: A Language and Environment for Statistical Computing, 2 2023. URL https://www.R-project.org/.

Carsten Rahbek, Michael K. Borregaard, Alexandre Antonelli, Robert K. Colwell, Ben G. Holt, David Nogues-Bravo, Christian M.Ø. Rasmussen, Katherine Richardson, Minik T. Rosing, Robert J. Whittaker, and Jon Fjeldså. Building mountain biodiversity: Geological and evolutionary processes. *Science*, 365(6458): 1114–1119, 9 2019. ISSN 10959203. doi: 10.1126/SCIENCE.AAX0151/ASSET/AC77674F-E295-4BAE-8F2B-48C431B3E9AB/ASSETS/GRAPHIC/365{_}1114{_}F3.JPEG. URL https://www.science.org/doi/abs/10.1126/science.aax0151.

Ramsar Convention Secretariat. Designating Ramsar Sites Ramsar Handbooks 4th edition Handbook 17. Technical report, Ramsar Convention Secretariat, Gland, Switzerland, 2010. URL https://www.ramsar.org/sites/default/files/documents/pdf/lib/hbk4-17.pdf.

TA Ransaleleh, MJ Nangoy, I Wahyuni, A Lomboan, R Koneri, S Saputro, J. Pamungkas, and A Latinne. Identification of bats on traditional market in dumoga district, North Sulawesi. *IOP Conference Series: Earth and Environmental Science*, 473(1):012067, 3 2020. ISSN 1755-1307. doi: 10.1088/1755-1315/473/1/012067. URL https://iopscience.iop.org/article/10.1088/1755-1315/473/1/012067.

Kent H Redford. The empty forest. *BioScience*, pages 412–422, 1992. ISSN 0006-3568. URL internal-pdf://169.35.224.205/Redford_1992.pdf.

Ikeu Sri Rejeki. *Wildlife conservation strategy: an assessment of wildlife hunting activities in Sulawesi*. PhD thesis, Bogor Agricultural University, 2018. URL https://repository.ipb.ac.id/handle/123456789/95984.

Romy Rice, Momna Hejmadi, Herval Silva, Robert N. Kelsh, Janete Agues, Noémie Engel, and Tamás Székely. Environmental education in the classroom: pilot study in Cabo Verde suggests differing impacts on local knowledge and environmental attitudes. *Oryx*, 58(2):210–217, 3 2024. ISSN 0030-6053. doi: 10.1017/S0030605323000303. URL https://www.cambridge.org/core/product/identifier/S0030605323000303/type/journal_article.

Lindsey N. Rich, David A.W. Miller, Hugh S. Robinson, J. Weldon McNutt, and Marcella J. Kelly. Using camera trapping and hierarchical occupancy modelling to evaluate the spatial ecology of an African mammal community. *Journal of Applied Ecology*, 53(4):1225–1235, 8 2016. ISSN 00218901. doi: 10.1111/1365-2664.12650. URL https://onlinelibrary.wiley.com/doi/10.1111/1365-2664.12650.

Alfan Abeid Rija, Rob Critchlow, Chris D. Thomas, and Colin M. Beale. Global extent and drivers of mammal population declines in protected areas under illegal hunting pressure. *PLOS ONE*, 15(8):e0227163, 8 2020. ISSN 1932-6203. doi: 10.1371/journal.pone.0227163. URL https://dx.plos.org/10.1371/journal.pone.0227163.

Erin P. Riley. The endemic seven: Four decades of research on the: Sulawesi macaques. *Evolutionary Anthropology*, 19(1):22–36, 2010. ISSN 10601538. doi: 10.1002/evan.20246.

Jon Riley. Mammals on the Sangihe and Talaud Islands, Indonesia, and the impact of hunting and habitat loss. *Oryx*, 36(3):288–296, 7 2002. ISSN 0030-6053. doi: 10.1017/S0030605302000510. URL https://www.cambridge.org/core/product/identifier/S0030605302000510/type/journal_article.

Horst W.J. Rittel and Melvin M. Webber. Dilemmas in a general theory of planning. *Policy Sciences*, 4(2):155–169, 6 1973. ISSN 00322687. doi: 10.1007/BF01405730/METRICS. URL https://link.springer.com/article/10.1007/BF01405730.

John G Robinson and Elizabeth L Bennett. *Hunting for Sustainability in Tropical Forests*. Columbia University Press, New York, 2000. ISBN 9780231109765.

Gail Emilia Rosen and Katherine F. Smith. Summarizing the Evidence on the International Trade in Illegal Wildlife. *EcoHealth*, 7(1):24–32, 8 2010. ISSN 1612-9202. doi: 10.1007/s10393-010-0317-y. URL https://pubmed.ncbi.nlm.nih.gov/20524140/http://link.springer.com/10.1007/s10393-010-0317-y.

Kevin C. Rowe, Anang S. Achmadi, and Jacob A. Esselstyn. A new genus and species of omnivorous rodent (Muridae: Murinae) from Sulawesi, nested within a clade of endemic carnivores. *Journal of Mammalogy*, 97(3):978–991, 6 2016. ISSN 0022-2372. doi: 10.1093/JMAMMAL/GYW029. URL https://academic.oup.com/jmammal/article/97/3/978/2459835.

Himmah Rustiami and Andrew Henderson. A Synopsis of Calamus (Arecaceae) in Sulawesi. *REINWARDTIA*, 16(2):49–63, 12 2017. ISSN 2337-8824. doi: 10.14203/REINWARDTIA.V16I2.3232. URL https://e-journal.biologi.lipi.go.id/index.php/reinwardtia/article/view/3232.

Paola Mariela Saba Villarroel, Nuttamonpat Gumpangseth, Thanaphon Songhong, Sakda Yainoy, Arnaud Monteil, Pornsawan Leaungwutiwong, Dorothée Missé, and Sineewanlaya Wichit. Emerging and re-emerging zoonotic viral diseases in Southeast Asia: One Health challenge. *Frontiers in Public Health*, 11, 2023. ISSN 22962565. doi: 10.3389/FPUBH.2023.1141483. URL /pmc/articles/PMC10298164//pmc/articles/PMC10298164/?report=abstracthttps://www.ncbi.nlm.nih.gov/pmc/articles/PMC10298164/.

Milica Sandalj, Anna C. Treydte, and Stefan Ziegler. Is wild meat luxury? Quantifying wild meat demand and availability in Hue, Vietnam. *Biological Conservation*, 194:105–112, 2016. ISSN 00063207. doi: 10.1016/j.biocon.2015.12.018. URL http://dx.doi.org/10.1016/j.biocon.2015.12.018.

Karen Saylors, David J Wolking, Emily Hagan, Stephanie Martinez, Leilani Francisco, Jason Euren, Sarah H Olson, Maureen Miller, Amanda E Fine, Nga Nguyen Thi Thanh, Phuc Tran Minh, Jusuf D Kalengkongan, Tina Kusumaningrum, Alice Latinne, Joko Pamungkas, Dodi Safari, Suryo Saputro, Djeneba Bamba, Kalpy Julien Coulibaly, Mireille Dosso, Anne Laudisoit, Kouassi Manzan N'guettia Jean, Shusmita Dutta, Ariful Islam, Shahanaj Shano, Mwokozi I Mwanzalila, Ian P Trupin, Aiah Gbakima, James Bangura, Sylvester T Yondah, Dibesh Karmacharya, Rima D Shrestha, Marcelle Annie Matsida Kamta, Mohamed Moctar Mouliom Mouiche, Hilarion Moukala Ndolo, Fabien Roch Niama, Dionne Onikrotin, Peter Daszak, Christine K Johnson, and Jonna A K Mazet. Socializing One Health: an innovative strategy to investigate social and behavioral risks of emerging viral threats. *One Health Outlook*, 3 (1):11, 12 2021. ISSN 2524-4655. doi: 10.1186/s42522-021-00036-9. URL `https://onehealthoutlook.biomedcentral.com/articles/10.1186/s42522-021-00036-9`.

Carina M. Schlebusch, Helena Malmström, Torsten Günther, Per Sjödin, Alexandra Coutinho, Hanna Edlund, Arielle R. Munters, Mário Vicente, Maryna Steyn, Himla Soodyall, Marlize Lombard, and Mattias Jakobsson. Southern African ancient genomes estimate modern human divergence to 350,000 to 260,000 years ago. *Science*, 358(6363): 652–655, 11 2017. ISSN 10959203. doi: 10.1126/SCIENCE.AAO6266/SUPPL{_}FILE/AAO6266{_}SCHLEBUSCH{_}SM.PDF. URL `https://www.science.org/doi/10.1126/science.aao6266`.

Donald R. Schoolmaster, Chad R. Zirbel, and James Patrick Cronin. A graphical causal model for resolving species identity effects and biodiversity–ecosystem function correlations. *Ecology*, 101(8), 8 2020. ISSN 0012-9658. doi: 10.1002/ecy.3070.

Sabine Schoppe. Status, trade dynamics and management of the Southeast Asian Box Turtle Cuora amboinensis in Indonesia. Technical report, TRAFFIC Southeast Asia, Petaling Jaya, Selangor, Malaysia, 2009. URL `https://www.traffic.org/site/assets/files/5542/southeast-asian-box-turtle-indonesia.pdf`.

Marcin J. Schroeder. Multidisciplinarity, Interdisciplinarity, and Transdisciplinarity: The Tower of Babel in the Age of Two Cultures. *Philosophies*, 7(2):26, 3 2022. ISSN 2409-9287. doi: 10.3390/philosophies7020026. URL `https://www.mdpi.com/2409-9287/7/2/26`.

Maxie Schulte, Sebastian Bamberg, Jonas Rees, and Philipp Rollin. Social identity as a key concept for connecting transformative societal change with individual environmental activism. *Journal of Environmental Psychology*, 72:101525, 12 2020. ISSN 02724944. doi: 10.1016/j.jenvp.2020.101525. URL `https://linkinghub.elsevier.com/retrieve/pii/S0272494420306903`.

SCImago. SCImago Journal & Country Rank. URL `http://www.scimagojr.com`.

T. Setyawati, S. Nando, W. Marthy, N. Andayani, Sheherazade, and M. Linkie. Planning to remove UNESCO World Heritage Sites in Sumatra from being 'In Danger'. *Animal conservation*, 24(2):149–152, 2020. ISSN 1367-9430. doi: 10.1111/acv.12626.

Rachel Shairp, Diogo Veríssimo, Iain Fraser, Daniel Challender, and Douglas Macmillan. Understanding urban demand for wild meat in Vietnam: Implications for conservation

actions. *PLoS ONE*, 11(1):1–14, 2016. ISSN 19326203. doi: 10.1371/journal.pone.0134787.

Claude E. Shannon and Warren Weaver. *The Mathematical Theory of Communication*. University of Illinois Press, Urbana, 1949.

Sheherazade and Susan M. Tsang. Quantifying the bat bushmeat trade in North Sulawesi, Indonesia, with suggestions for conservation action. *Global Ecology and Conservation*, 3:324–330, 2015. ISSN 23519894. doi: 10.1016/j.gecco.2015.01.003. URL http://dx.doi.org/10.1016/j.gecco.2015.01.003.

Sheherazade, Holly K. Ober, and Susan M. Tsang. Contributions of bats to the local economy through durian pollination in Sulawesi, Indonesia. *Biotropica*, (September): 1–10, 2019. ISSN 17447429. doi: 10.1111/btp.12712.

Chris R Shepherd. Civets in trade in Medan, North Sumatra, Indonesia (1997–2001) with notes on legal protection. *Small Carnivore Conservation*, 38:34–36, 2008. URL http://smallcarnivoreconservation.org/sccwiki/images/4/47/SCC38_Shepherd.pdfinternal-pdf://179.160.233.140/SCC38_Shepherd.pdf.

Apriani Magdalena Sibarani. Berteologi dalam konteks pandemi covid 19 - upaya mengembangkan etika teologis dalam relasi keadilan dan keharmonisan dengan alam. *Majalah Ilmiah METHODA*, 10(2):67–73, 8 2020. ISSN 20889534. doi: 10.46880/methoda.Vol10No2.pp67-73. URL https://ejurnal.methodist.ac.id/index.php/methoda/article/view/106.

Vaclav Smil. Eating Meat: Evolution, Patterns, and Consequences. *Population and Development Review*, 28(4):599–639, 12 2002. ISSN 0098-7921. doi: 10.1111/j.1728-4457.2002.00599.x. URL https://onlinelibrary.wiley.com/doi/10.1111/j.1728-4457.2002.00599.x.

Robert J. Smith, Leon Bennun, Thomas M. Brooks, Stuart H.M. Butchart, Annabelle Cuttelod, Moreno Di Marco, Simon Ferrier, Lincoln D.C. Fishpool, Lucas Joppa, Diego Juffe-Bignoli, Andrew T. Knight, John F. Lamoreux, Penny Langhammer, Hugh P. Possingham, Carlo Rondinini, Piero Visconti, James E.M. Watson, Stephen Woodley, Luigi Boitani, Neil D. Burgess, Naamal De Silva, Nigel Dudley, Fabien Fivaz, Edward T. Game, Craig Groves, Mervyn Lötter, Jennifer McGowan, Andrew J. Plumptre, Anthony G. Rebelo, Jon Paul Rodriguez, and Carlos A.de M. Scaramuzza. Synergies between the key biodiversity area and systematic conservation planning approaches. *Conservation Letters*, 12(1):1–10, 2018. ISSN 1755263X. doi: 10.1111/conl.12625.

C. P. Snow. *The two cultures and the scientific revolution. The Rede Lecture.* The Syndics of The Cambridge University Press, New York, 7th printing edition, 1959. URL https://sciencepolicy.colorado.edu/students/envs_5110/snow_1959.pdf.

C. Soto-Navarro, C Ravilious, A Arnell, X. de Lamo, M Harfoot, S L L Hill, O R Wearn, M Santoro, A Bouvet, S Mermoz, T. Le Toan, J Xia, S Liu, W Yuan, S A Spawn, H K Gibbs, S Ferrier, T Harwood, R. Alkemade, A M Schipper, G Schmidt-Traub, B Strassburg, L Miles, N D Burgess, and V Kapos. Mapping co-benefits for carbon storage and biodiversity to inform conservation policy and action. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 375(1794):20190128, 3 2020. ISSN 0962-8436.

doi: 10.1098/rstb.2019.0128. URL https://royalsocietypublishing.org/doi/10.1098/rstb.2019.0128.

Michael E Soulé. What Is Conservation Biology? *BioScience*, 35(11):727–734, 1985. URL https://www.jstor.org/stable/1310054.

Ian F. Spellerberg and Peter J. Fedor. A tribute to Claude Shannon (1916–2001) and a plea for more rigorous use of species richness, species diversity and the 'Shannon–Wiener' Index. *Global Ecology and Biogeography*, 12(3):177–179, 5 2003. ISSN 1466-822X. doi: 10.1046/j.1466-822X.2003.00015.x. URL https://onlinelibrary.wiley.com/doi/10.1046/j.1466-822X.2003.00015.x.

Steven Staal, Lian Thomas, Bernard Bett, Ekta Patel, and Delia Randolph. Wild meat value chains and zoonotic risks in Africa Wild meat value chains and zoonotic risks in Africa. *Physiology or Medicine*, 1996.

A. J. Stattersfield, M. J. Crosby, A. J. Long, and D. C. Wege. *Endemic Bird Areas of the World. Priorities for biodiversity conservation. BirdLife Conservation Series 7.* Cambridge, 1998. URL https://datazone.birdlife.org/info/pubEBAs.

Natasha Steinhall, Rebecca Mcpettit, James Bond, Michelle Parks, Mahwish Khan, Daniel Sharfarz, Laura Cabrera, and Derek Cabrera. Wicked Solutions for Wicked Problems Wicked Solutions for Wicked Problems: Misalignment in Public Policy Wicked Solutions for Wicked Problems. *Journal of System Thinking*, 4(3):1–68, 2023. doi: 10.54120/jost.000053.

Harald O. Stolberg, Geoffrey Norman, Isabelle Trop, Harald O. Stolberg, Geoffrey Norman, and Isabelle Trop. Randomized Controlled Trials. *https://doi.org/10.2214/ajr.183.6.01831539*, 183(6):1539–1544, 11 2012. ISSN 0361803X. doi: 10.2214/AJR.183.6.01831539. URL https://www.ajronline.org/doi/10.2214/ajr.183.6.01831539.

Ryan M. Stolier and Jonathan B. Freeman. A Neural Mechanism of Social Categorization. *The Journal of Neuroscience*, 37(23):5711–5721, 6 2017. ISSN 0270-6474. doi: 10.1523/JNEUROSCI.3334-16.2017. URL https://www.jneurosci.org/lookup/doi/10.1523/JNEUROSCI.3334-16.2017.

Matthew J. Struebig, Sabhrina G. Aninta, Maria Beger, Alessia Bani, Henry Barus, Selina Brace, Zoe G. Davies, Maarten De Brauwer, Karen Diele, Cilun Djakiman, Rignolda Djamaluddin, Rosie Drinkwater, Alex Dumbrell, Darren Evans, Marco Fusi, Leonel Herrera-Alsina, Djoko T. Iskandar, Jamaluddin Jompa, Berry Juliandi, Lesley T. Lancaster, Gino Limmon, Lindawati, Michaela G.Y. Lo, Pungki Lupiyaningdyah, Molly Mccannon, Erik Meijaard, Simon L. Mitchell, Sonny Mumbunan, Darren O'connell, Owen G. Osborne, Alex S.T. Papadopulos, Joeni S. Rahajoe, Rosaria, Stephen J. Rossiter, Rugayah, Himmah Rustiami, Ulrich Salzmann, Sheherazade, I. Made Sudiana, Endang Sukara, Johny S. Tasirin, Aiyen Tjoa, Justin M.J. Travis, Liam Trethowan, Agus Trianto, Tim Utteridge, Maria Voigt, Nurul Winarni, Zulianto Zakaria, David P. Edwards, Laurent Frantz, and Jatna Supriatna. Safeguarding imperiled biodiversity and evolutionary processes in the wallacea center of endemism, 11 2022. ISSN 15253244.

Marcy Summers, Roma Bunsung, and Warman Manasai. "Someday we will all learn anew through hands that love us": Protecting a key insular population of the Sulawesi Fruit Bat ¡i¿Acerodon celebensis¡/i¿. *Conservation Science and Practice*, 3(12):e559, 12 2021. ISSN 2578-4854. doi: 10.1111/csp2.559. URL https://conbio.onlinelibrary.wiley.com/doi/10.1111/csp2.559.

Alva Supit, Agusteivie Telew, and Nancy Bawiling. The Church, Food Culture, and Ecotheology: An Ongoing Church Effort to Reduce Bushmeat Eating in Minahasa, Indonesia. *Christian Journal for Global Health*, 8(1):64–68, 7 2021. ISSN 2167-2415. doi: 10.15566/cjgh.v8i1.537. URL https://journal.cjgh.org/index.php/cjgh/article/view/537.

Jatna Supriatna, Myron Shekelle, Habiburrahman A.H. Fuad, Nurul L Winarni, Asri A Dwiyahreni, Muhammad Farid, Sri Mariati, Chris Margules, Bimo Prakoso, and Zuliyanto Zakaria. Deforestation on the Indonesian island of Sulawesi and the loss of primate habitat. *Global Ecology and Conservation*, 24:e01205, 12 2020. ISSN 23519894. doi: 10.1016/j.gecco.2020.e01205. URL https://doi.org/10.1016/j.gecco.2020.e01205https://linkinghub.elsevier.com/retrieve/pii/S2351989420307460.

Sybille de La Hamaide. Indonesia confirms outbreak of African swine fever, WOAH says, 2023. URL https://www.reuters.com/world/asia-pacific/indonesia-confirms-outbreak-african-swine-fever-woah-says-2023-05-09/.

Krizler Cejuela Tanalgo, Tuanjit Sritongchuay, Angelo Rellama Agduma, Kier Celestial Dela Cruz, and Alice C. Hughes. Are we hunting bats to extinction? Worldwide patterns of hunting risk in bats are driven by species ecology and regional economics. *Biological Conservation*, 279:109944, 3 2023. ISSN 00063207. doi: 10.1016/j.biocon.2023.109944. URL https://linkinghub.elsevier.com/retrieve/pii/S0006320723000447.

Fabrice Teletchea. Animal Domestication: A Brief Overview. *Animal Domestication*, pages 1–20, 2019. doi: 10.5772/intechopen.86783.

Johannes Textor, Benito van der Zander, Mark S. Gilthorpe, Maciej Liśkiewicz, and George TH Ellison. Robust causal inference using directed acyclic graphs: The R package 'dagitty'. *International Journal of Epidemiology*, 45(6):1887–1894, 2016. ISSN 14643685. doi: 10.1093/ije/dyw341.

D.C. Thomas, A. Bour, and W.H. Ardi. Begonia of the Matarombeo karst, Southeast Sulawesi, Indonesia, including two new species. *Gardens' Bulletin Singapore*, 70(1): 163–176, 2018. ISSN 03747859. doi: 10.26492/gbs70(1).2018-15.

Laura Thomas-Walters, Sara Vieira, Victor Jiménez, Domingas Monteiro, Betânia Ferreira, Robert J. Smith, and Diogo Veríssimo. Challenges in the impact evaluation of behaviour change interventions: The case of sea turtle meat and eggs in São Tomé. *People and Nature*, 2(4):913–922, 12 2020. ISSN 2575-8314. doi: 10.1002/pan3.10162.

Morgan W. Tingley, Christopher P. Nadeau, and Manette E. Sandor. Multi-species occupancy models as robust estimators of community richness. *Methods in Ecology and Evolution*, 11(5):633–642, 5 2020. ISSN 2041-210X. doi: 10.1111/2041-210X.13378. URL https://besjournals.onlinelibrary.wiley.com/doi/10.1111/2041-210X.13378.

Jeff Tollefson. Humans are driving one million species to extinction. *Nature*, 569:171–171, 5 2019.

Henry Travers, James Walsh, Sonja Vogt, Tom Clements, and E.J. Milner-Gulland. Delivering behavioural change at scale: What conservation can learn from other fields. *Biological Conservation*, 257:109092, 5 2021. ISSN 00063207. doi: 10.1016/j.biocon.2021.109092. URL https://linkinghub.elsevier.com/retrieve/pii/S0006320721001440.

Liam A. Trethowan, Asrianti Arif, Ruth P. Clark, Deden Girmansyah, Endang Kintamani, Chrissie J. Prychid, Niken Pujirahayu, Rosmarlinasiah, Francis Q. Brearley, Timothy M. A. Utteridge, and Gwilym P. Lewis. An enigmatic genus on an enigmatic island: the re-discovery of Kalappia on Sulawesi. *Ecology*, 100(11):e02793, 11 2019. ISSN 0012-9658. doi: 10.1002/ecy.2793. URL https://esajournals.onlinelibrary.wiley.com/doi/10.1002/ecy.2793.

Liam A. Trethowan, Wolf L. Eiserhardt, Deden Girmansyah, Endang Kintamani, Timothy M.A. Utteridge, and Francis Q. Brearley. Floristics of forests across low nutrient soils in Sulawesi, Indonesia. *Biotropica*, 52(6):1309–1318, 11 2020. ISSN 0006-3606. doi: 10.1111/btp.12838. URL https://onlinelibrary.wiley.com/doi/full/10.1111/btp.12838https://onlinelibrary.wiley.com/doi/abs/10.1111/btp.12838https://onlinelibrary.wiley.com/doi/10.1111/btp.12838.

Liam A. Trethowan, Benjamin Blonder, Endang Kintamani, Deden Girmansyah, Timothy M.A. Utteridge, and Francis Q. Brearley. Metal-rich soils increase tropical tree stoichiometric distinctiveness. *Plant and Soil*, 461(1-2):579–589, 4 2021. ISSN 15735036. doi: 10.1007/S11104-021-04839-7/FIGURES/3. URL https://ezproxy-prd.bodleian.ox.ac.uk:2120/article/10.1007/s11104-021-04839-7.

Peter Tyrrell, Johan T. du Toit, and David W. Macdonald. Conservation beyond protected areas: Using vertebrate species ranges and biodiversity importance scores to inform policy for an East African country in transition. *Conservation Science and Practice*, (December 2018):1–13, 2019. doi: 10.1111/csp2.136.

University of South Florida Libraries. Impact and Metrics: Library Tools and Services - SCIMago Journal Rank (SJR), 2024. URL https://guides.lib.usf.edu/c.php?g=5862&p=7636942.

A. van der Ent, A.J.M. Baker, M.M.J. van Balgooy, and A. Tjoa. Ultramafic nickel laterites in Indonesia (Sulawesi, Halmahera): Mining, nickel hyperaccumulators and opportunities for phytomining. *Journal of Geochemical Exploration*, 128:72–79, 5 2013. ISSN 03756742. doi: 10.1016/j.gexplo.2013.01.009. URL https://linkinghub.elsevier.com/retrieve/pii/S037567421300023X.

Nathalie Van Vliet, Jonas Muhindo, Jonas K. Nyumu, and Robert Nasi. From the forest to the dish: A comprehensive study of the wildmeat value chain in Yangambi, Democratic Republic of Congo. *Frontiers in Ecology and Evolution*, 7(APR):448292, 4 2019. ISSN 2296701X. doi: 10.3389/FEVO.2019.00132/BIBTEX.

Diogo Veríssimo, Michael 't Sas-Rolfes, and Jenny A. Glikman. Influencing consumer demand is vital for tackling the illegal wildlife trade. *People and Nature*, 2(4):872–876,

12 2020. ISSN 2575-8314. doi: 10.1002/pan3.10171. URL https://besjournals.onlinelibrary.wiley.com/doi/10.1002/pan3.10171.

G Veron. The palm civets of Sulawesi. *Small Carnivore Conservation*, 24(May):13–14, 2001.

Geraldine Veron, Maraike Willsch, Victor Dacosta, Marie Lilith Patou, Adrian Seymour, Celine Bonillo, Arnaud Couloux, Siew Te Wong, Andrew P. Jennings, Jörns Fickel, and Andreas Wilting. The distribution of the Malay civet Viverra tangalunga (Carnivora: Viverridae) across Southeast Asia: Natural or human-mediated dispersal? *Zoological Journal of the Linnean Society*, 170(4):917–932, 2014. ISSN 10963642. doi: 10.1111/zoj.12110.

Maria Voigt, Jatna Supriatna, Nicolas J Deere, Agustinus Kastanya, Simon L Mitchell, Isabel M D Rosa, Truly Santika, Rondang Siregar, Johny S Tasirin, Adi Widyanto, Nurul L Winarni, Zuliyanto Zakaria, Sonny Mumbunan, Zoe G Davies, and Matthew J Struebig. Emerging threats from deforestation and forest fragmentation in the Wallacea centre of endemism. *Environmental Research Letters*, 16(9):094048, 9 2021. ISSN 1748-9326. doi: 10.1088/1748-9326/ac15cd. URL https://doi.org/10.1088/1748-9326/ac15cdhttps://iopscience.iop.org/article/10.1088/1748-9326/ac15cd.

Ralph Wainer. *Phylogeography of two Sulawesi rodents: Testing the Effect of Climatic Variation on Population Structure*. PhD thesis, University of Durham, Durham, 2016. URL http://etheses.dur.ac.uk/11531/1/Durham_MScR_Thesis_-_Ralph_Wainer.pdf?DDD1+.

Claire E. Wainwright, Timothy L. Staples, Lachlan S. Charles, Thomas C. Flanagan, Hao Ran Lai, Xingwen Loy, Victoria A. Reynolds, and Margaret M. Mayfield. Links between community ecology theory and ecological restoration are on the rise. *Journal of Applied Ecology*, 55(2):570–581, 3 2018. ISSN 0021-8901. doi: 10.1111/1365-2664.12975.

Anthony Waldron, Vanessa Adams, James Allan, Andy Arnell, Greg Asner, Scott Atkinson, Alessandro Baccini, Jonathan EM Baillie, Andrew Balmford, J Austin Beau, Aaron Bruner, Luke Brander, Eduardo Brondizio, Neil Burgess, K Burkart, Stuart Butchart, Rio Button, Roman Carrasco, William Cheung, Villy Christensen, Andy Clements, Marta Coll, Moreno di Marco, Marine Deguignet, Eric Dinerstein, Erle Ellis, Florian Eppink, Jamison Ervin, Anita Escobedo, John Fa, Alvaro Fernandes-Llamazares, Sanjiv Fernando, Shinichiro Fujimori, Beth Fulton, James Gerber, Stephen Garnett, David Gill, Trisha Gopalakrishna, Nathan Hahn, Ben Halpern, Tomoko Hasegawa, Petr Havlik, Vuokko Heikinheimo, Ryan Heneghan, Ella Henry, Florian Humpenoder, Harry Jonas, Kendall Jones, Lucas Joppa, A R Joshi, Martin Jung, Naomi Kingston, Carissa Klein, Tamas Krisztin, Vicky Lam, Leclere David, Peter Lindsey, Harvey Locke, TE Lovejoy, Philip Madgwick, Yadvinder Malhi, Pernilla Malmer, Martine Maron, Juan Mayorga, Hans van Meijl, Dan Miller, Zsolt Molnar, Nathaniel Mueller, Nibedita Mukherjee, Robin Naidoo, Katia Nakamura, Prakash Nepal, RF Noss, Beth O'Leary, D Olson, Juliano Palcios Abrantes, Midori Paxton, Alexander Popp, Hugh Possingham, Jeff Prestemon, April Reside, Catherine Robinson, John Robinson, Enric Sala, Scherrer Kim, Mark Spalding, Anna Spenceley, Jeroen Steenbeck, Elke Stehfest, Bernardo Strassborg, Rashid Sumaila, Kirsty Swinnerton,

Jocelyne Sze, Derek Tittensor, Tuuli Toivonen, Alejandra Toledo, Pablo Negret Torres, Vause James, Willem-Jan Van Zeist, Oscar Venter, Thais Vilela, Vynne Carly, Piero Visconti, Reg Watson, James Watson, Eric Wikramanayake, Brooke Williams, Brendan Wintle, Stephen Woodley, Wenchao Wu, Kerstin Zander, Yuchen Zhang, and YP Zhang. Protecting 30% of the planet for nature: costs , benefits and economic implications. Working paper analysing the economic implications of the proposed 30% target for areal protection in the draft post-2020 Global Biodiversity Framework. Technical report, 2020. URL https://www.conservation.cam.ac.uk/files/waldron_report_30_by_30_publish.pdf.

Solomon Zena Walelign, Martin Reinhardt Nielsen, and Jette Bredhal Jakobsen. Price Elasticity of Bushmeat Demand in the Greater Serengeti Ecosystem: Insights for Managing the Bushmeat Trade. *Frontiers in Ecology and Evolution*, 7(May):1–17, 5 2019. ISSN 2296-701X. doi: 10.3389/fevo.2019.00162. URL https://www.frontiersin.org/article/10.3389/fevo.2019.00162/full.

Alfred Russel Wallace. *The Malay Archipelago*. Cambridge University Press, Cambridge, 1869a. ISBN 9780511782350. doi: 10.1017/CBO9780511782350. URL http://ebooks.cambridge.org/ref/id/CBO9780511782350.

Alfred Russel Wallace. Natural History of Celebes. In *The Malay Archipelago*, chapter XVIII, pages 424–447. Cambridge University Press, Cambridge, 1869b. doi: 10.1017/CBO9780511782350.020. URL https://www.cambridge.org/core/product/identifier/CBO9780511782350A025/type/book_part.

Helen L. Walls. Wicked problems and a 'wicked' solution. *Globalization and Health*, 14(1):34, 12 2018. ISSN 1744-8603. doi: 10.1186/s12992-018-0353-x. URL https://globalizationandhealth.biomedcentral.com/articles/10.1186/s12992-018-0353-x.

Matthew E. Watts, Ian R. Ball, Romola S. Stewart, Carissa J. Klein, Kerrie Wilson, Charles Steinback, Reinaldo Lourival, Lindsay Kircher, and Hugh P. Possingham. Marxan with Zones: Software for optimal conservation based land- and sea-use zoning. *Environmental Modelling and Software*, 24(12):1513–1521, 2009. ISSN 13648152. doi: 10.1016/j.envsoft.2009.06.005. URL http://dx.doi.org/10.1016/j.envsoft.2009.06.005.

Gabriele Weichart. Minahasa Identity: A Culinary Practice. *Antropologi Indonesia*, Special Volume:55–66, 2004.

Gabriele Weichart. Makan dan minum bersama: feasting commensality in Minahasa, Indonesia. *Anthropology of food*, S3(S3):1–19, 3 2008. ISSN 1609-9168. doi: 10.4000/aof.2212. URL http://journals.openedition.org/aof/2212.

Chris Wemmer and Dick Watling. Ecology and status of the sulawesi palm civet Macrogalidia musschenbroekii schlegel. *Biological Conservation*, 35(1):1–17, 1986. ISSN 00063207. doi: 10.1016/0006-3207(86)90024-8.

Harry G West. We Are Who We Eat With: Food, Distinction, and Commensality — The MIT Press Reader. In Dani Burrows and Aaron Cezar, editors, *Politics of Food*. Sternberg Press, 3 2020. ISBN 9783956795169. URL https://thereader.mitpress.mit.edu/we-are-who-we-eat-with/.

Tony Whitten, Greg S Henderson, and Muslimin Mustafa. *The Ecology of Sulawesi*, volume 4. Gajah Mada University Press, Yogyakarta, 1987. ISBN 0013164465. doi: 10.1177/001316446702700323. URL http://epm.sagepub.com/cgi/doi/10.1177/001316446702700234.

Sigit Wiantoro, Alan T. Hitch, Irene E. Engilis, Hendra Gunawan, and Andrew Engilis. Bats (chiroptera) recorded in the lowland of southeast sulawesi, indonesia with notes on taxonomic status and significant range extensions. *Mammalia*, 81:385–400, 7 2017. ISSN 1864-1547. doi: 10.1515/mammalia-2015-0153. URL https://www.degruyter.com/document/doi/10.1515/mammalia-2015-0153/html.

Edward O Wilson. *Half-earth : our planet's fight for life*. Liveright Publishing Corporation, New York, 2016. ISBN 9781631490828.

Kerrie A. Wilson, Marissa F. McBride, Michael Bode, and Hugh P. Possingham. Prioritizing global conservation efforts. *Nature*, 440(7082):337–340, 2006. ISSN 14764687. doi: 10.1038/nature04366.

World Bank. Sulawesi Development Diagnostic: Achieving Shared Prosperity. Technical report, World Bank, 2015. URL http://documents.worldbank.org/curated/en/707811469181933626/pdf/107184-WP-SulawesiDevelopmentDiagnoticEnglish-PUBLIC.pdf(31.12.2018).

Xiao Xiao, Chris Newman, Christina D. Buesching, David W. Macdonald, and Zhao-Min Zhou. Animal sales from Wuhan wet markets immediately prior to the COVID-19 pandemic. *Scientific Reports*, 11(1):11898, 12 2021. ISSN 2045-2322. doi: 10.1038/s41598-021-91470-2. URL http://www.nature.com/articles/s41598-021-91470-2.

Yayasan Selamatkan Yaki. Deliverable 3.5 Results of Capacity Building and Awareness Raising Strategies. Technical report, Yayasan Selamatkan Yaki Indonesia, 2018.

Xiong Zhang and Amanda C.J. Vincent. Conservation prioritization for seahorses (Hippocampus spp.) at broad spatial scales considering socioeconomic costs. *Biological Conservation*, 235(April):79–88, 2019. ISSN 00063207. doi: 10.1016/j.biocon.2019.04.008. URL https://doi.org/10.1016/j.biocon.2019.04.008.

Wen Zhou, Kaggie Orrick, Al Lim, and Michael Dove. Reframing conservation and development perspectives on bushmeat ¡sup¿*¡/sup¿. *Environmental Research Letters*, 17(1):011001, 1 2022. ISSN 1748-9326. doi: 10.1088/1748-9326/ac3db1. URL https://iopscience.iop.org/article/10.1088/1748-9326/ac3db1.

Li Zhu, Alice C Hughes, Xiao-qian Zhao, Li-jing Zhou, Ke-ping Ma, Xiao-li Shen, Sheng Li, Ming-zhang Liu, Wu-bing Xu, and James E M Watson. Regional scalable priorities for national biodiversity and carbon conservation planning in Asia. *Science Advances*, 7(35):eabe4261, 8 2021. ISSN 2375-2548. doi: 10.1126/sciadv.abe4261. URL https://advances.sciencemag.org/lookup/doi/10.1126/sciadv.abe4261.

Elise F. Zipkin, Amielle DeWan, and J. Andrew Royle. Impacts of forest fragmentation on species richness: a hierarchical approach to community modelling. *Journal of Applied Ecology*, 46(4):815–822, 8 2009. ISSN 00218901. doi: 10.1111/j.1365-2664.2009.01664.x.

URL https://onlinelibrary.wiley.com/doi/full/10.1111/j.1365-2664.2009.01664.xhttps://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2664.2009.01664.xhttps://besjournals.onlinelibrary.wiley.com/doi/10.1111/j.1365-2664.2009.01664.xhttps://onlinelibrary.wiley.

Michael 't Sas-Rolfes, Daniel W.S. Challender, Amy Hinsley, Diogo Veríssimo, and E.J. Milner-Gulland. Illegal Wildlife Trade: Scale, Processes, and Governance. *Annual Review of Environment and Resources*, 44(1):201–228, 10 2019. ISSN 1543-5938. doi: 10.1146/annurev-environ-101718-033253. URL https://www.annualreviews.org/doi/10.1146/annurev-environ-101718-033253.

Appendix

Part IV

Appendix

A

Appendix for Part II

A.1 Appendix for Chapter 3

Table A.1: Wild meat issue mentioned in the selected papers.
*IPLC = Indigenous People and Local Community

Category	Topic Discussed	Sources
Hunting	Unsustainable hunting	(O'Brien & Kinnaird 1996; Argeloo & Dekker 1996; Clayton et al. 1997; O'Brien et al. 2000; Rob J. Lee 2000; Riley 2002; Milner-Gulland & Clayton 2002; Milner-Gulland et al. 2003; Pangau-Adam 2003; Nijman 2005a, 2005b; Corlett 2007; Struebig et al. 2007; Campbell et al. 2008; Meijaard et al. 2011; Harrison et al. 2011; Nijman et al. 2012; Hilser et al. 2013; Davis et al. 2013; Suba et al. 2013; Lange 2014; Sheherazade & Tsang 2015; Farida 2015; Mildenstein et al. 2016; Estrada et al. 2018; Coad et al. 2019a; Arcus Foundation 2020; Latinne et al. 2020; Arini et al. 2020; Lee et al. 2020; Platto et al. 2021; Gomez 2021)

Continued on next page

Table A.1: Wild meat issue mentioned in the selected papers.
*IPLC = Indigenous People and Local Community

Category	Topic Discussed	Sources
	Hunting by IPLC*	(Latinis 1996; Wadley et al. 1997; Bennett et al. 1997; Alvard 2000; Meijaard 2003; Sasaoka 2003, 2008; Rizaldi et al. 2007; Pattiselanno 2007, 2015; Pattiselanno & Koibur 2008, 2018; Pangau-Adam & Noske 2010; Pattiselanno & Arobaya 2011, 2013; Pangau-Adam et al. 2012; Quinten et al. 2014; Pattiselanno & Lubis 2014; Arobaya et al. 2015, 2022; Hamidun et al. 2016; Persoon & Wardani 2017; Manik et al. 2018; Dobson et al. 2019; Pattiselanno et al. 2020; Mulyanto et al. 2021; Sawaki et al. 2022; Wardani 2022; Zhou et al. 2022; Pangau-Adam et al. 2022; Hendra et al. 2023; Supiandi et al. 2023; Leimena et al. 2023)
	Hunting in urban setting/recreational	(Yudha et al. 2022)

Continued on next page

Table A.1: Wild meat issue mentioned in the selected papers.
*IPLC = Indigenous People and Local Community

Category	Topic Discussed	Sources
	Type of animal hunted	(Latinis 1996; Wadley et al. 1997; Bennett et al. 1997; Alvard 2000; Meijaard 2003; Sasaoka 2003, 2008; Rizaldi et al. 2007; Pattiselanno 2007; Pattiselanno & Koibur 2008, 2018; Pangau-Adam & Noske 2010; Pattiselanno & Arobaya 2011, 2013; Pangau-Adam et al. 2012; Quinten et al. 2014; Pattiselanno & Lubis 2014; Arobaya et al. 2015, 2022; Hamidun et al. 2016; Persoon & Wardani 2017; Manik et al. 2018; Dobson et al. 2019; Pattiselanno et al. 2020, 2023; Mulyanto et al. 2021; Sawaki et al. 2022; Wardani 2022; Hendra et al. 2023; Supiandi et al. 2023; Leimena et al. 2023)
	Hunting technique	(Pattiselanno & Arobaya 2011; Pangau-Adam et al. 2012; Yudha et al. 2022; Hendra et al. 2023; Pattiselanno et al. 2023)
	Limited hunting as wild meat	(CITES & GRASP 2006)
	Law enforcement	(Risdianto et al. 2016; Estrada et al. 2020; Hilser et al. 2023)
	Quantification of animal hunted	(Hamidun et al. 2016; Rejeki 2018)

Continued on next page

Table A.1: Wild meat issue mentioned in the selected papers.
*IPLC = Indigenous People and Local Community

Category	Topic Discussed	Sources
Consumption	Wild meat consumption in traditional society	(Alvard 2000; Adams 2004; Caldecott & Miles 2005; Corlett 2007; Sasaoka 2008; Weichart 2008; Pattiselanno & Arobaya 2011; Rist et al. 2012; Davis et al. 2013; Arobaya et al. 2015; Pattiselanno 2015; Farida 2015; Estrada et al. 2018; Pattiselanno et al. 2019, 2023; Wardani 2022; Zhou et al. 2022; Athabu et al. 2022; Hendra et al. 2023)
	Cultural driver in consumption	(Hilser et al. 2013; Sheherazade & Tsang 2015; Gruber 2016; Pattiselanno et al. 2019; Arida et al. 2020, 2021; Arini et al. 2020; Supit et al. 2021)
	Type of animal consumed	(Shepherd et al. 2004; Pudjihastuti et al. 2007; Walker 2007; Saroyo 2011; Quinten et al. 2014; Pattiselanno 2015; Rashid et al. 2015; Farida 2015; Hamidun et al. 2016; Cawthorn & Hoffman 2016; Estrada et al. 2020; Platto et al. 2021; Harahap & Ridwan 2022; Sawaki et al. 2022; Yudha et al. 2022; Hendra et al. 2023)
	Limited consumption as wild meat	(Dickson & Bird 2004; Caldecott & Miles 2005; CITES & GRASP 2006; Campbell et al. 2008; Arcus Foundation 2020)
	Urban consumption as part of luxury	(Bennett & Rao 2002; Campbell et al. 2008; Estrada et al. 2018; Hilser et al. 2023)

Continued on next page

Table A.1: Wild meat issue mentioned in the selected papers.
*IPLC = Indigenous People and Local Community

Category	Topic Discussed	Sources
	Consuming wild meat as medicine	(Jones et al. 2009; Hilser et al. 2013; Farida 2015; Tackett et al. 2022; Harahap & Yonariza 2022; Supiandi et al. 2023)
	Urban consumption as part of recreational, side meat from pest removal	(Yudha et al. 2022)
	Quantifying the amount of wild meat consumed	(Alvard 2000; Pangau-Adam et al. 2012; Pattiselanno 2015; Rowland et al. 2015)
	Changing diet from wild meat (due to local pop decline and other things)	(Pattiselanno 2015; Purwestri et al. 2019)
	Consuming wild meat is no different from other meat	(O'Brien & Kinnaird 1996; Bailey et al. 2021)
Trade	Price of animal and monetary profit from wild meat trade	(Clayton et al. 1997; Mickleburgh et al. 2009; Nijman et al. 2012; Pattiselanno & Lubis 2014; Arobaya et al. 2015; Pattiselanno & Nasi 2015; Sheherazade & Tsang 2015; Rejeki 2018; Kasenda et al. 2019; Pattiselanno et al. 2020, 2023; Arida et al. 2020; Liana & Witno 2021; Masengie et al. 2022)

Continued on next page

Table A.1: Wild meat issue mentioned in the selected papers.
*IPLC = Indigenous People and Local Community

Category	Topic Discussed	Sources
	Number and trends in the animals sold at wild meat markets.	(Clayton et al. 2000; Milner-Gulland & Clayton 2002; Milner-Gulland et al. 2003; Schoppe 2009; Mickleburgh et al. 2009; Pangau-Adam & Noske 2010; Nijman et al. 2012; Pangau-Adam et al. 2012; Luskin et al. 2014; Nijman 2015; Pattiselanno & Nasi 2015; Sheherazade & Tsang 2015; Arcus Foundation 2020; Latinne et al. 2020; Platto et al. 2021; Bailey et al. 2021)
	The global north's bias toward eliminating wild meat from the market due to COVID-19, and its impact on the global south	(Booth et al. 2021b; Zhou et al. 2022)
	Indonesia as supplier for international trade	(Kusrini 2005; Kusrini & Alford 2006; Schoppe 2009; Nijman 2010; Milner-Gulland et al. 2020; Chaber et al. 2021)
	Illegal trade	(CITES & GRASP 2006; Schoppe 2009; ProFauna Indonesia 2012; Hilser et al. 2013, 2023; Lee et al. 2014, 2020; Kiroh et al. 2020; Sandriansyah & Qiftiyah 2020; Gomez 2021; Teodoree 2022)
	Wild meat traded regionally (between island/province)	(Jones et al. 2009; Luskin et al. 2014)
	Quantifying the amount of wild meat traded	(Kusrini 2005; Kusrini & Alford 2006; Latinne et al. 2020; Tanalgo et al. 2023)

Continued on next page

Table A.1: Wild meat issue mentioned in the selected papers.
*IPLC = Indigenous People and Local Community

Category	Topic Discussed	Sources
	Identification of animal/species in the wild meat trade	(Riley 2002; Shepherd et al. 2004; Kusrini & Alford 2006; Walker 2007; Mickleburgh et al. 2009; Pangau-Adam & Noske 2010; Nijman 2010; Nekaris et al. 2010; Saroyo 2011; Pangau-Adam et al. 2012; Sahiu et al. 2017; Wulandari 2018; Nangoy et al. 2019; Latinne et al. 2020; Taogan et al. 2020; Ransaleleh et al. 2020; Bailey et al. 2021; Laatung et al. 2021; Liana & Witno 2021; Sawaki et al. 2022; Pattiselanno et al. 2023)
	Supply chain from rural to urban	(Pattiselanno et al. 2020)
One Health	Pathogen transmission risk between human and animal	(Jones-Engel 2002; Melfi 2010; Harrison et al. 2011; Sheherazade & Tsang 2015; Wulandari 2018; Sikatta & Adisasmito 2020; Yudhana et al. 2020; Pattiselanno et al. 2020; Albers et al. 2020; Nangoy et al. 2021; Nisa et al. 2021; Chaber et al. 2021; Saylors et al. 2021; Teodoree 2022; Brookes et al. 2022; Nugroho et al. 2022; Kusumaningrum et al. 2022)
	Food contaminant from undesired wild meat and health implication	(Rashid et al. 2015; Balia et al. 2018; Reagen 2019)
	Eco-theologist after COVID-19	(Sibarani 2020; Supit et al. 2021; Cahyami 2023)
	Wild meat as traditional medicine	(Lee et al. 2014)
	Wild meat and animal welfare	(Wulandari 2018)

Continued on next page

Table A.1: Wild meat issue mentioned in the selected papers.
*IPLC = Indigenous People and Local Community

Category	Topic Discussed	Sources
	Epidemic disease spread from domesticated animal to wild animals	(Meijaard 2003; Melfi 2010)
	Wild meat market as a point of spillover	(Platto et al. 2021)
	Wild meat market regulations to reduced risk of zoonotic and foodborne disease	(Brookes et al. 2022)
Sustainability	Sustainable harvest of wild meat by IPLC*	(Argeloo & Dekker 1996; Alvard 2000; Pattiselanno & Arobaya 2011; Uyeda et al. 2014; Pattiselanno 2015; Partasasmita et al. 2016; Pattiselanno & Koibur 2018; Coad et al. 2019a; Pattiselanno et al. 2020; Hendra et al. 2023; Leimena et al. 2023)
	Threshold of harvest that is sustainable	(Bennett & Rao 2002; Jones et al. 2009; Nijman et al. 2012; Lee et al. 2014, 2020; Cawthorn & Hoffman 2015; Mildenstein et al. 2016; Rejeki 2018; Nielsen et al. 2018; Arida et al. 2020)
	Substitution of wild meat with other sustainable meat	(Sheherazade & Tsang 2015; Tensen 2016)
Food Security	Wild meat as food security for IPLC* in Eastern Indonesia: West Papua and Maluku	(Latinis 1996; Adiani & Tangkere 2007; Pattiselanno & Arobaya 2011, 2013; Pattiselanno & Lubis 2014; Pattiselanno 2015; Pattiselanno et al. 2019; Sawaki et al. 2022; Arobaya et al. 2022; Maturbongs et al. 2023)
	Wild meat as food security for IPLC* in Sumatra	(Arida et al. 2020; Wardani 2022)

Continued on next page

Table A.1: Wild meat issue mentioned in the selected papers.
*IPLC = Indigenous People and Local Community

Category	Topic Discussed	Sources
	Contribution of wild meat on food security elsewhere	(Cawthorn & Hoffman 2015; Gruber 2016; Rowland et al. 2017)

Table A.2: The list of animals or species described in the records, together with their corresponding regions.

Region	Animal	Animal Categorized	Frequency
Indonesia	Anoa	Anoa	1
Indonesia	Babirusa	Babirusa	1
Indonesia	Bat	Bat	4
Indonesia	Deer	Deer	2
Indonesia	Fish	Fish	1
Indonesia	Frogs	Frogs	1
Indonesia	Butterfly	Invertebrates	1
Indonesia	Corals	Invertebrates	1
Indonesia	Mammal	Mammal	1
Indonesia	Monitor Lizard	Monitor Lizard	2
Indonesia	Macaque	Monkey	3
Indonesia	Reptile	Reptile	1
Indonesia	Rodent	Rodent	2
Indonesia	Seahorse	Seahorse	1
Indonesia	Snake	Snake	1
Indonesia	Wild animal	Wild animal	13
Indonesia	Wild Pig	Wild Pig	1
Java	Bat	Bat	1
Java	Frogs	Frogs	3
Java	Loris	Loris	1
Java	Monitor Lizard	Monitor Lizard	3
Java	Porcupine	Porcupine	3
Java	Rodent	Rodent	1
Java	Snake	Snake	1
Java	Wild animal	Wild animal	1
Java	Wild Pig	Wild Pig	2
Kalimantan	Amphibian	Amphibian	1
Kalimantan	Banteng	Banteng	1
Kalimantan	Bat	Bat	4
Kalimantan	Bird	Bird	4
Kalimantan	Civet	Civet	1
Kalimantan	Deer	Deer	7
Kalimantan	Domestic Dog	Domestic Dog	1
Kalimantan	Eel	Fish	1
Kalimantan	Fish	Fish	2
Kalimantan	Frogs	Frogs	1
Kalimantan	Gibbons	Gibbons	2
Kalimantan	Earthworm	Invertebrates	1
Kalimantan	Lizards	Lizards	1
Kalimantan	Mammal	Mammal	1
Kalimantan	Monitor Lizard	Monitor Lizard	1
Kalimantan	Macaque	Monkey	1

Continued on next page

Region	Animal	Animal Categorized	Frequency
Kalimantan	Monkey	Monkey	1
Kalimantan	Leaf Monkey	Monkey	3
Kalimantan	Orangutan	Orangutan	12
Kalimantan	Pangolin	Pangolin	2
Kalimantan	Porcupine	Porcupine	3
Kalimantan	Reptile	Reptile	1
Kalimantan	Rhino	Rhino	1
Kalimantan	Rodent	Rodent	1
Kalimantan	Skunk	Skunk	1
Kalimantan	Snake	Snake	2
Kalimantan	Sun bear	Sun bear	1
Kalimantan	Turtle	Turtle	3
Kalimantan	Wild animal	Wild animal	4
Kalimantan	Wild Cat	Wild Cat	3
Kalimantan	Wild Pig	Wild Pig	7
Lesser Sunda Is.	Bat	Bat	1
Lesser Sunda Is.	Cuscus	Cuscus	2
Lesser Sunda Is.	Deer	Deer	1
Lesser Sunda Is.	Macaque	Monkey	1
Lesser Sunda Is.	Porcupine	Porcupine	1
Lesser Sunda Is.	Shark	Shark	1
Lesser Sunda Is.	Wild animal	Wild animal	1
Lesser Sunda Is.	Wild Pig	Wild Pig	1
Maluku and Lesser Sunda Is.	Cuscus	Cuscus	5
Maluku and Lesser Sunda Is.	Deer	Deer	2
Maluku and Lesser Sunda Is.	Wild Pig	Wild Pig	2
Maluku Is.	Bird	Bird	1
Maluku Is.	Cuscus	Cuscus	3
Maluku Is.	Deer	Deer	1
Maluku Is.	Terrestrial Bird	Terrestrial birds	1
Maluku Is.	Turtle	Turtle	1
Maluku Is.	Wild Pig	Wild Pig	1
Sulawesi	Anoa	Anoa	7
Sulawesi	Babirusa	Babirusa	9

Continued on next page

Region	Animal	Animal Categorized	Frequency
Sulawesi	Bat	Bat	30
Sulawesi	Bird	Bird	3
Sulawesi	Civet	Civet	1
Sulawesi	Cuscus	Cuscus	7
Sulawesi	Deer	Deer	3
Sulawesi	Domestic Cat	Domestic Cat	1
Sulawesi	Domestic Dog	Domestic Dog	5
Sulawesi	Lizards	Lizards	1
Sulawesi	Mammal	Mammal	3
Sulawesi	Monitor Lizard	Monitor Lizard	2
Sulawesi	Monkey	Monkey	1
Sulawesi	Macaque	Monkey	17
Sulawesi	Primate	Primate	2
Sulawesi	Rodent	Rodent	14
Sulawesi	Snake	Snake	9
Sulawesi	Tarsius	Tarsius	3
Sulawesi	Terrestrial Bird	Terrestrial birds	2
Sulawesi	Turtle	Turtle	3
Sulawesi	Wild animal	Wild animal	8
Sulawesi	Wild Pig	Wild Pig	15
Sumatra	Bat	Bat	1
Sumatra	Bearcat	Bearcat	1
Sumatra	Bird	Bird	8
Sumatra	Deer	Deer	8
Sumatra	Gibbons	Gibbons	2
Sumatra	Hedgehog	Hedgehog	1
Sumatra	Monitor Lizard	Monitor Lizard	2
Sumatra	Leaf Monkey	Monkey	1
Sumatra	Monkey	Monkey	1
Sumatra	Macaque	Monkey	6
Sumatra	Orangutan	Orangutan	2
Sumatra	Pangolin	Pangolin	2
Sumatra	Porcupine	Porcupine	3
Sumatra	Primate	Primate	2
Sumatra	Rodent	Rodent	2
Sumatra	Snake	Snake	3
Sumatra	Sun bear	Sun bear	1
Sumatra	Tapir	Tapir	2
Sumatra	Terrestrial Bird	Terrestrial birds	2
Sumatra	Turtle	Turtle	5
Sumatra	Wild animal	Wild animal	1
Sumatra	Wild Pig	Wild Pig	6
West Papua	Bandicoot	Bandicoot	4
West Papua	Bat	Bat	2
West Papua	Bird	Bird	8

Continued on next page

Region	Animal	Animal Categorized	Frequency
West Papua	Cuscus	Cuscus	10
West Papua	Deer	Deer	15
West Papua	Dusky Pademelons	Dusky Pademelons	5
West Papua	Frogs	Frogs	1
West Papua	Marsupial	Marsupial	1
West Papua	Monitor Lizard	Monitor Lizard	2
West Papua	Pangolin	Pangolin	1
West Papua	Rodent	Rodent	1
West Papua	Terrestrial Bird	Terrestrial birds	3
West Papua	Cassowary	Terrestrial birds	5
West Papua	Tree Kangaroo	Tree Kangaroo	6
West Papua	Turtle	Turtle	2
West Papua	Wild animal	Wild animal	2
West Papua	Wild Pig	Wild Pig	12

Table A.3: The list of uncited records based on their type of publications and disciplines. 101 records did not get cited in the list.

Type of Publications or Discipline	**All**	**Number of uncited**	**Percentage of uncited records**
Journal Article - Q1	67	31	46%
Journal Article - Non-Q	32	19	59%
Journal Article - Q3	18	12	67%
Thesis	9	8	89%
Conference Paper	10	7	70%
Journal Article - Q2	8	5	63%
Book Chapter	12	5	42%
Journal Article - Non-Q, IOP	6	4	67%
Report	14	4	29%
Journal Article - Q4	2	2	100%
Book	3	2	50%
Class Project	1	1	100%
Bulletin	2	1	50%
Grand Total	184	101	55%
Animal Health	6	5	83%
Animal Production	1	1	100%
Animal Science	1	1	100%
Anthropology	13	8	62%
Biodiversity Conservation	123	56	46%
Environmental and resource economics	2	2	100%
Ethnobiology	6	4	67%
Ethnozoology	3	2	67%
Food and health	8	7	88%
Food Science	3	2	67%

Continued on next page

Table A.3 – Continued from previous page

Type of Publications or Discipline	**All**	**Number of uncited**	**Percentage of uncited records**
Forestry	2	2	100%
Human Ecology	3	0	0%
Law	2	2	100%
Meat Science	1	1	100%
Microbiology	1	0	0%
Nutrition	1	1	100%
Public Health	1	1	100%
Theology	4	3	75%
Veterinary	3	3	100%
Grand Total	184	101	55%

A.2 Appendix for Chapter 4

The supplementary material for this paper can be found here: Online supplementary files.

A.3 Appendix for Chapter 5

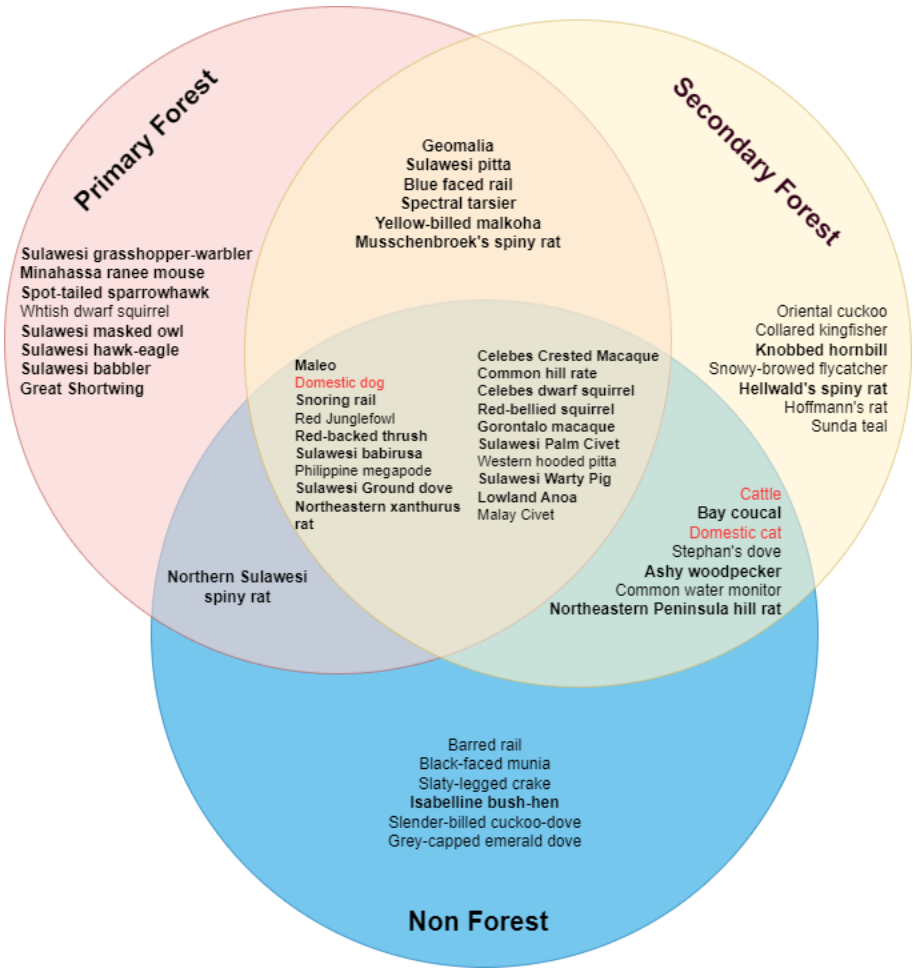


Figure A.1: Species photographed at least once and the habitat type in which they were detected. Species in bold are endemic to Sulawesi, whereas those in red are domesticated or feral.

Table A.4: Summary statistics for all three blocks surveyed using camera traps in Bogani Nani Wartabone National Park, Indonesia (2016–2019).

Camera stations block	**Southeast**	**West**	**North**
Trapping period	15 Sep 2016 – 3 Dec 2017	15 Sep 2018 – 10 Mar 2019	22 Jul – 17 Nov 2019
Total stations (total operated)	61 (68)	53 (53)	114 (115)
Nights of cameras set up (operational or not)	7,115	7,378	11,492
Nights of cameras set up and active (trap nights)	7,115	7,378	11,492
Minimum trap nights	2	4	2
Maximum trap nights	126	147	106
Average trap nights	76	89	82
Minimum area survey coverage (km^2)	678.43	350.23	1,007.61
Average distance between camera (m)	2,302.97	2,242.13	2,247.13

Table A.5: List of animals that can be identified to species level and photographed at least once in the Bogani Nani Wartabone Landscape, Indonesia, with their IUCN Red List status and endemicity.
*NE = Not Evaluated; LC = Least Concern; NT = Near Threatened; VU = Vulnerable; EN = Endangered; CR = Critically Endangered

No	Scientific name	Common name	IUCN status*	Endemic	Southeast	West	North
1	*Accipiter trinotatus*	Spot-tailed sparrowhawk	LC	Yes	-	2	-
2	*Amaurornis isabellina*	Isabelline bush-hen	LC	Yes	-	-	1
3	*Anas gibberifrons*	Sunda teal	NT	No	-	-	1
4	*Aramidopsis plateni*	Snoring rail	VU	Yes	-	-	34
5	*Centropus celebensis*	Bay coucal	LC	Yes	1	-	3
6	*Chalcophaps indica*	Grey-capped emerald dove	LC	No	1	-	2
7	*Chalcophaps stephani*	Stephan's dove	LC	No	1	-	1
8	*Cuculus saturatus*	Oriental Cuckoo	LC	No	-	-	1
9	*Erythropitta celebensis*	Sulawesi pitta	LC	Yes	1	-	8
10	*Ficedula hyperythra*	Snowy-browed flycatcher	LC	No	-	-	1
11	*Gallicolumba tristigmata*	Sulawesi ground dove	LC	Yes	1	10	-
12	*Gallus gallus*	Red junglefowl	LC	No	14	26	36
13	*Geokichla erythronota*	Red-backed thrush	NT	Yes	-	1	8
14	*Geomalia heinrichi*	Geomalia	NT	Yes	-	-	8
15	*Gymnocrex rosenbergii*	Blue-faced rail	VU	Yes	-	1	1
16	*Heinrichia calligyna*	Great shortwing	LC	Yes	-	-	7
17	*Hypotaenidia torquata*	Barred rail	LC	No	-	-	1
18	*Locustella castanea*	Sulawesi grasshopper-warbler	LC	Yes	-	-	1
19	*Lonchura molucca*	Black-faced munia	LC	No	-	-	1
20	*Macrocephalon maleo*	Maleo	EN	Yes	19	93	22
21	*Macropygia amboinensis*	Slender-billed cuckoo-dove	LC	No	-	-	1
22	*Megapodius cumingii*	Philippine megapode	LC	No	3	2	9

Table A.5: Continued

No	Scientific name	Common name	IUCN status*	Endemic	Southeast	West	North
23	*Mulleripicus fulvus*	Ashy woodpecker	LC	Yes	1	-	6
24	*Nisaetus lanceolatus*	Sulawesi hawk-eagle	LC.	Yes	-	1	1
25	*Pitta sordida*	Western hooded pitta	LC	No	-	-	40
26	*Rallina eurizonoides*	Slaty-legged crake	LC	No	-	-	2
27	*Rhamphococcyx calyorhynchus*	Yellow-billed malkoha	LC	Yes	-	1	-
28	*Rhyticeros cassidix*	Knobbed hornbill	VU	Yes	-	-	1
29	*Todiramphus chloris*	Collared kingfisher	LC	No	-	-	1
30	*Trichastoma celebense*	Sulawesi babbler	LC	Yes	-	-	1
31	*Tyto rossenbergii*	Sulawesi masked owl	LC	Yes	1	-	-
32	*Babyrousa celebensis*	Sulawesi babirusa	VU	Yes	12	490	2808
33	*Bos taurus*	Cattle	NE	-	-	61	-
34	*Bubalus depressicornis*	Lowland anoa	EN	Yes	8	100	3007
35	*Bunomys chrysocomus*	Yellow-haired hill rat	LC	Yes	14	-	265
36	*Canis familiaris*	Domestic dog	NE	-	9	3	36
37	*Echiotrix leucura*	Sulawesi spiny rat	EN	Yes	-	-	89
38	*Felis silvestris catus*	Domestic cat	NE	-	-	-	4
39	*Frateromys fratrorum*	Fraternal hill rat	VU	Yes	37	-	71
40	*Haeromys minahassae*	Minahassa ranee mouse	NT	Yes	-	-	5
41	*Macaca nigra*	Celebes crested macaque	CR	Yes	409	-	-
42	*Macaca nigrescens*	Gorontalo macaque	VU	Yes	380	1162	33731
43	*Macrogalidia musschenbroekii*	Sulawesi palm civet	VU	Yes	8	21	558
44	*Maxomys hellwaldii*	Hellwald's spiny rat	LC	Yes	1	-	-
45	*Maxomys musschenbroekii*	Musschenbroek's spiny rat	LC	Yes	185	27	11
46	*Prosciurillus leucomus*	Whitish dwarf squirrel	LC	No	-	-	1
47	*Prosciurillus murinus*	Celebes dwarf squirrel	LC	Yes	34	36	17
48	*Rattus hoffmanni*	Hoffmann's rat	LC	No	5	-	-
49	*Rattus xanthurus*	Yellow-tailed rat	NT	Yes	3	90	344
50	*Rubrisciurus rubriventer*	Red-bellied squirrel	VU	Yes	225	34	42
51	*Sus celebensis*	Sulawesi warty pig	NT	Yes	192	523	7315

Table A.5: Continued

No	Scientific name	Common name	IUCN status*	Endemic	Southeast	West	North
52	*Tarsius tarsier*	Spectral tarsier	VU	Yes	-	-	16
53	*Vivera tangalunga*	Malay civet	LC	No	1	39	533
54	*Varanus salvator*	Common water monitor	LC	No	4	-	20

Table A.6: Coefficient estimates and uncertainties of the community response of the terrestrial species in the Bogani Nani Wartabone Landscape, to environmental and anthropogenic variables.

Community-level hyper-parameters	**mean**	**SD**	**l95**	**u95**
Mean community occupancy	**0.146**	**0.066**	**0.040**	**0.273**
Intercept (ψ)	-1.858	0.519	-2.898	-0.851
Distance to Forest	0.144	0.098	0.000	0.323
Elevation	0.064	0.183	-0.288	0.425
Elevation Squared	0.028	0.072	-0.119	0.162
Vegetation Index	0.069	0.110	-0.147	0.283
Slope	-0.020	0.081	-0.171	0.145
Distance to River	0.017	0.096	-0.169	0.207
Habitat Type: Primary Forest	-0.006	0.076	-0.175	0.148
Habitat Type: Non-Forest	0.045	0.101	-0.138	0.285
Habitat Type: Secondary Forest	-0.039	0.072	-0.200	0.090
Block: North	-0.052	0.086	-0.209	0.124
Block: Southeast	-0.650	0.096	-0.840	-0.467
Block: West	0.702	0.099	0.498	0.883
Mean community detection probability	0.052	0.011	0.032	0.074
Intercept (p)	-2.932	0.222	-3.375	-2.486
Camera Type: Reconyx	-0.138	0.025	-0.185	-0.088
Camera Type: Bushnell	-0.214	0.039	-0.286	-0.134
Camera Type: Cuddeback	0.352	0.030	0.295	0.413

Table A.7: Posterior summary results of the occupancy and detection probability of each species during camera trap surveys in the Bogani Nani Wartabone Landscape. The uncertainties of the mean are shown as standard deviations (SD) and 95% Bayesian credible intervals (2.50% – 97.50%).

Species	Naïve Occupancy	(ψ)				(p)			
		mean	SD	l95	u95	mean	SD	l95	u95
Babyrousa celebensis	0.351	0.370	0.031	0.309	0.429	0.073	0.003	0.067	0.079
Bubalus depressicornis	0.289	0.320	0.029	0.264	0.379	0.038	0.003	0.033	0.043
Bunomys chrysocomus	0.013	0.017	0.008	0.003	0.034	0.135	0.025	0.088	0.182
Echiothrix leucura	0.009	0.013	0.007	0.001	0.027	0.084	0.020	0.049	0.125
Frateromys fratrorum	0.018	0.022	0.010	0.005	0.041	0.063	0.012	0.040	0.085
Gallus gallus	0.158	0.232	0.036	0.162	0.303	0.017	0.003	0.012	0.022
Macaca nigra	0.123	0.131	0.023	0.087	0.176	0.072	0.005	0.062	0.082
Macaca nigrescens	0.759	0.782	0.027	0.727	0.833	0.118	0.003	0.113	0.123
Macrocepahlon maleo	0.123	0.144	0.024	0.098	0.192	0.036	0.004	0.029	0.043
Macrogalidia musschenbroekii	0.289	0.384	0.038	0.308	0.459	0.019	0.002	0.015	0.023
Maxomys musschenbroekii	0.022	0.026	0.010	0.008	0.047	0.094	0.014	0.067	0.121

Continued on next page

Table A.7 – continued from previous page

Species	Naïve Occupancy	(ψ)				(p)			
		mean	SD	l95	u95	mean	SD	l95	u95
Prosciurillus murinus	0.061	0.079	0.020	0.040	0.117	0.026	0.004	0.017	0.034
Rattus xanthurus	0.096	0.105	0.021	0.066	0.145	0.059	0.006	0.048	0.069
Rubrisciurus rubriventer	0.118	0.136	0.023	0.093	0.183	0.039	0.004	0.031	0.048
Sus celebensis	0.693	0.756	0.030	0.696	0.815	0.056	0.002	0.052	0.060
Tarsius tarsier	0.018	0.049	0.059	0.005	0.114	0.012	0.007	0.000	0.024
Vivera tangalunga	0.197	0.233	0.030	0.174	0.290	0.029	0.003	0.024	0.034

A.3.1 JAGS code terrestrial species Multi species Occupancy Model (MSOM).

```
  model {
 for(k in 1:nSobs){  # Loop through species
  # Likelihood
  for(i in 1:nSites) {
     # Ecological model
    logit(psi[i, k]) <- b0[k] + bAccess[k] * AccessS[i] +
    bElev[k] * ElevS[i] +  bNDVI[k] * NDVIS[i] +
    bSlope[k] * SlopeS[i] + bElev2[k] * ElevS2[i] +
    bRiver[k] * RiverS[i] + bLULC[LULC[i]]
     z[i, k] ~ dbern(psi[i, k])

     # Observation model
     logit(p[i, k]) <- lp[k] + aCam[Cam[i]]
     y[i, k] ~ dbin(p[i, k] * z[i, k], nOcc[i])
  }

  # Priors (species level)
  b0[k] ~ dnorm(mu.b0, tau.b0)
  mu.eta[k] <- mu.lp + rho * sd.lp/sd.b0 *
      (b0[k] - mu.b0)
  lp[k] ~ dnorm(mu.eta[k], tau.eta)

  bAccess[k] ~ dnorm(mu.Access, tau.Access)
  bSlope[k] ~ dnorm(mu.Slope, tau.Slope)
  bElev[k] ~ dnorm(mu.Elev, tau.Elev)
  bElev2[k] ~ dnorm(mu.Elev2, tau.Elev2)
  bRiver[k] ~ dnorm(mu.River, tau.River)
  bNDVI[k] ~ dnorm(mu.NDVI, tau.NDVI)
}

# Hyperpriors (community level)
b0.mean ~ dbeta(1, 1)
mu.b0 <- logit(b0.mean)
sd.b0 ~ dunif(0, 5)
tau.b0 <- 1/sd.b0^2
p.mean ~ dbeta(1, 1)
mu.lp <- logit(p.mean)
sd.lp ~ dunif(0, 5)
tau.lp <- 1/sd.lp^2

mu.Access ~ dunif(-5, 5)
sd.Access ~ dunif(0, 5)
tau.Access <- 1/sd.Access^2
mu.Slope ~ dunif(-5, 5)
sd.Slope ~ dunif(0,5)
```

```
  tau.Slope <- 1/sd.Slope^2
  mu.Elev ~ dunif(-5, 5)
  sd.Elev ~ dunif(0,5)
  tau.Elev <- 1/sd.Elev^2
  mu.Elev2 ~ dunif(-5, 5)
  sd.Elev2 ~ dunif(0,5)
  tau.Elev2 <- 1/sd.Elev2^2
  mu.River ~ dunif(-5, 5)
  sd.River ~ dunif(0,5)
  tau.River <- 1/sd.River^2
  mu.NDVI ~ dunif(-5, 5)
  sd.NDVI ~ dunif(0,5)
  tau.NDVI <- 1/sd.NDVI^2

  rho ~ dunif(-1, 1)
  tau.eta <- tau.lp/(1 - rho^2)

  # For random LULC
  for(d in 1:nLULC){
    temp2[d] ~ dnorm(mu.LULC, tau.LULC)
  }
  bLULC <- temp2 - mean(temp2)
  mu.LULC ~ dnorm(0, 0.001)
  tau.LULC <- 1/(sd.LULC^2)
  sd.LULC ~ dt(0, tau, 4) T(0, )

  # For random camera effect
  for(c in 1:nCam){
    temp[c] ~ dnorm(mu.aCam, tau.aCam)
  }
  aCam <- temp - mean(temp)
  mu.aCam ~ dnorm(0, 0.001)
  tau.aCam <- 1/(sd.aCam^2)
  sd.aCam ~ dt(0, tau, 4) T(0, )

  # Derived quantities
  for(k in 1:nSobs) {
    Nocc.fs[k] <- sum(z[, k]) # No. of occupied sites for each species
  }
  for(i in 1:nSites) {
    Nsite[i] <- sum(z[i, ]) # No of occurring species at each site
  }
  for(k in 1:nSobs) {
  mean.psi[k] <- mean(psi[, k])
  mean.p[k] <- mean(p[, k])
  }

}
```

A.3.2 Code for Causal Inference with Structural Causal Modeling (SCM).

```
    ####### Step 1 Define a conceptual model (a DAG)
library(dagitty)
theme_set(theme_dag())

spmod1 <- dagify(SpRich ~ Intrusion + Access_Dist,
                 Intrusion ~ Access_Dist,
                SpRich ~ Market,
                   SpRich ~ Demography)

ggdag(spmod1, text_size = 2.5,
            node_size = 20)


####### Step 2 Choose a statistical test  -----------------
library(piecewiseSEM)
sp_psem1 <- psem(
  lmer(SpRich ~ I(Access_Dist) + I(Intrusion) + (1|Year), data = df),
  lmer(I(Intrusion) ~ I(Access_Dist) + (1|Year), data = df)
)
summary(sp_psem1)

library("multcompView")

sp_psem2 <- psem(
  lmer(SpRich ~ Market + I(Demography) + (1|Year), data = df),
  lmer(I(Demography) ~ Market + (1|Year), data = df)
)
summary(sp_psem2)

lmer(SpRich ~ Intrusion + Access_Dist + Demography * Market +
    (1|Year), data = df) %>%
  summary()
lmer(SpRich ~ Intrusion + Access_Dist + Demography * Market_Dist +
    (1|Year), data = df) %>%
  summary()

####### Step 4 Identify confounding variables

### 1st adjustment  -----------------
adj1 <- spmod1 %>%
  ggdag_paths(from="Access_Dist", to = "SpRich", shadow = TRUE,
              node_size = 18,
              text_size = 2.5,
              label_size = text_size,
```

```
              text_col = "black",
              label_col = text_col)

adjustmentSets(spmod1,
               exposure = "Access_Dist",
               outcome = "SpRich",
               type = "minimal",
               effect = "total")

adjustmentSets(spmod1,
               exposure = "Access_Dist",
               outcome = "SpRich",
               type = "minimal",
               effect = "direct")

adjustmentSets(spmod1,
               exposure = "Access_Dist",
               outcome = "SpRich",
               type = "canonical",
               effect = "total")

####### Step 5 Test for causality with your statistical test
mod_sprich_min <- lmer(SpRich ~ I(Access_Dist) + (1|Year), data = df)
summary(mod_sprich_min)
mod <- lmer(SpRich ~ I(Access_Dist) + I(Intrusion) + (1|Year), data = df)
summary(mod)

library(sjPlot)
(fe.effects <- plot_model(mod, show.values = TRUE))
library(glmmTMB)
(re.effects <- plot_model(mod, type = 're', show.values = TRUE))

lmer(SpRich ~ I(Access_Dist) + I(Demography) + Market + (1|Year),
    data = df) %>%
  summary()

####### Step 6 repeat for other causes
### 2nd adjustment  -----------------
adj2 <- spmod1 %>%
  ggdag_paths(from="Intrusion", to = "SpRich", shadow = TRUE,
              node_size = 18,
              text_size = 2.5,
              label_size = text_size,
              text_col = "black",
              label_col = text_col)

adjustmentSets(spmod1,
               exposure = "Intrusion",
```

```
                outcome = "SpRich",
                type = "minimal",
                effect = "total")

adjustmentSets(spmod1,
                exposure = "Intrusion",
                outcome = "SpRich",
                type = "minimal",
                effect = "direct")

adjustmentSets(spmod1,
                exposure = "Intrusion",
                outcome = "SpRich",
                type = "canonical",
                effect = "total")

mod1 <- lmer(SpRich ~ Intrusion + Access_Dist + (1|Year), data = df)
  summary(mod1)

lmer(SpRich ~ Intrusion + Access_Dist + Demography + Market +
    (1|Year), data = df) %>%
  summary()

### 3rd adjustment  -----------------
adj3 <- spmod1 %>%
  ggdag_paths(from="Demography", to = "SpRich", shadow = TRUE,
              node_size = 18,
              text_size = 2.5,
              label_size = text_size,
              text_col = "black",
              label_col = text_col)

adjustmentSets(spmod1,
                exposure = "Demography",
                outcome = "SpRich",
                type = "canonical",
                effect = "total")
lmer(SpRich ~ I(Demography) + I(Access_Dist) + I(Intrusion) +
                Market +(1|Year), data = df) %>%
  summary()

adjustmentSets(spmod1,
                exposure = "Demography",
                outcome = "SpRich",
                type = "minimal",
                effect = "total")

adjustmentSets(spmod1,
```

```
                exposure = "Demography",
                outcome = "SpRich",
                type = "minimal",
                effect = "direct")

mod3 <- lmer(SpRich ~ I(Demography) + (1|Year), data = df)
summary(mod3)

### 4th adjustment  -----------------
adj4 <- spmod1 %>%
  ggdag_paths(from="Market", to = "SpRich", shadow = TRUE,
              node_size = 18,
              text_size = 2.5,
              label_size = text_size,
              text_col = "black",
              label_col = text_col)

adjustmentSets(spmod1,
               exposure = "Market",
               outcome = "SpRich",
               type = "minimal",
               effect = "total")

adjustmentSets(spmod1,
               exposure = "Market",
               outcome = "SpRich",
               type = "minimal",
               effect = "direct")

adjustmentSets(spmod1,
               exposure = "Market",
               outcome = "SpRich",
               type = "canonical",
               effect = "total")

mod4 <- lmer(SpRich ~ Market + (1|Year), data = df)
summary(mod4)

(fe.effects <- plot_model(mod4, show.values = TRUE))
(re.effects <- plot_model(mod4, type = 're', show.values = TRUE))
```

A.4 Appendix for Chapter 6

A.4.1 Wild meat vendors semi-structure interview

Enumerator: _____
Catatan enumerator mengenai consent/persetujuan lisan:

- Responden diberikan penjelasan mengenai penelitian? Ya/Tidak
- Lembar consent/persetujuan dibacakan dan disetujui secara lisan? Ya/Tidak
- Percakapan dalam wawancara direkam dengan ijin responden? Ya/Tidak
- Enumerator membuat catatan di buku notes? Ya/Tidak
- Responden setuju untuk ucapannya dikutip dengan tetap menjaga kerahasiaan identitas? Ya/Tidak
- Responden tidak mau dikutip ucapannya sama sekali? Ya/Tidak

Lanjutkan wawancara hanya jika responden memberikan consent/persetujuan.

ID responden: _____ (ID_desa-Inisial enumerator-
Jenis Survey-No urut responden)
Jenis Kelamin: Laki-Laki / Perempuan
Tanggal wawancara: _____
Jam wawancara dimulai: _____ (contoh: 15:00)
Jam wawancara berakhir: _____ (contoh: 16:00)

WAWANCARA DIMULAI

1. Jenis kelamin penjual: Laki-laki / Perempuan
2. Umur penjual:
a. 18-24 b. 25-34 c. 35-44
d. 45-54 e. 45-54 f. > 65
3. Tingkat pendidikan:
a. SD b. SMP c. SMA d. Sarjana
e. S2 f. S3 g. Tidak sekolah
4. Menikah/tidak menikah: Jumlah anak (kalau ada):
5. Agama: _____ Suku: _____
6. Kota/desa dimana penjual tinggal: _____
7. Jumlah anggota keluarga yang tinggal dengan penjual: _____
8. Apakah menjadi penjual daging satwa ini mata pencaharian utama? _____
9. Apakah ada mata pencaharian lainnya?
a. Bertani
b. Berburu
c. Nelayan
d. Berdagang (diluar pasar ini)
e. Karyawan/bekerja di tempat lain
f. Wiraswasta
g. Lainnya...
10. Apa saja yang dijual:
a. Daging satwa (termasuk anjing dan kucing)
b. Ikan dari laut atau sungai
c. Lainnya

11. Berapa hari dalam seminggu/sebulan anda berjualan disini? _____
12. Berapa tahun anda sudah berjualan? _____
13. Apakah anda tergabung dalam ikatan/asosiasi penjual? _____
14. Apakah toko ini punya anda sendiri, atau anda bekerja untuk
    orang lain? _____
15. Apakah anda juga berjualan di pasar/areal lain?
    Kalau iya, bisa sebutkan dimana? _____
16. Supply daging datang dari mana?
a. Berburu sendiri
b. Beli dari pemburu
c. Beli dari pengepul
d. Lainnya...
17. Kalau jawabannya b/c/d: Apakah anda tahu asal dari mana
    daging ini diburu? ____
18. Apakah anda punya perjanjian resmi dengan pengepul, atau
    apakah perjanjian mengirim stok daging sifatnya informal?
19. Apakah ada hari-hari khusus stok daging datang? _____
20. Berapa biasanya jumlah stok daging per jenis yang anda beli? _____
21. Siapa yang menentukan harga beli daging dari pengepul?
    apakah anda, dari pengepul, atau ada proses tawar menawar?
22. Apakah anda memesan jenis satwa tertentu dari pengepul, atau apakah
    anda memilih dari jenis-jenis yang disediakan oleh pengepul?
23. Jenis daging satwa apa yang anda lebih suka jual? Mengapa?
24. Apakah penghasilan dari berjualan daging satwa selama lima tahun terakhir
    meningkat, berkurang, atau sama saja? Mengapa?
25. Bisa anda jelaskan/sebutkan tiga alasan anda menjadi penjual daging satwa?
1. _____
2. _____
3. _____

26. Bisa anda jelaskan/sebutkan tiga tantangan/permasalahan
    yang anda hadapi menjadi penjual daging satwa?
1. _____
2. _____
3. _____

27. Apa yang menurut anda bisa dilakukan untuk menyelesaikan Sebagian
 tantangan/ permasalahan itu?
28. Apa biaya utama lain dalam berjualan daging satwa
    (diluar membeli stok daging)?
    a. Penyimpanan dan pemrosesan daging
    b. Pengiriman daging (transport)
    c. Upah pekerja
    d. Listrik dan air
    e. Ijin dan pajak
    f. Denda
    g. Sewa toko/kios
    h. Lainnya...

29. Persepsi volume pasar, sebelum pandemik, saat lockdown, dan sekarang
• Apakah ada perbedaan jumlah pembeli sebelum pandemi dan sekarang?
• Apakah ada perbedaan volume supply/stok daging sebelum pandemi dan sekarang?
30. Berapa pendapatan bersih mingguan dari berjualan daging satwa?
1 Kurang dari Rp. 1.000.000 2 Rp. 1.000.000-2.500.000
3 Rp. 2.500.001 { 4.000.000 4 Rp. 4.000.001 { 5.500.000
5 Rp. 5.500.001 { 7.000.000 6 Rp. 7.000.001 { 9.500.000
7 Lebih dari Rp. 9.500.000 8 Lainnya
9 No answer

Terima kasih!

A.4.2 Wild meat market monitoring

Enumerator: _____
Nama Pasar: _____
Tanggal pengamatan: _____
Jam pengamatan dimulai: _____ (contoh: 15:00)
Jam pengamatan berakhir: _____ (contoh: 16:00)

Informasi mengenai pasar ini: _____
(Situasi yang mencolok misalnya penjual atau pembeli
yang lebih sepi dari biasanya)

Jumlah total pedagang daging: _____
Jumlah pedagang yang menjual daging satwa: _____
2. Daging yang dijual:
Kategori: a. Daging satwa; b. Daging ternak;
c. Ikan; d. Lainnya
Spesies:
Kondisi:
a. Mentah
b. Diasap
c. Dipanggang
d. Masih hidup
Dijual dalam unit apa:
a. Kg
b. Utuh
c. Lainnya...
Harga per unit dalam rupiah
Perkiraan jumlah: dalam kg atau unit total dari seluruh kios
Kategori Spesies/Jenis Kondisi Unit jual Harga/unit Perkiraan Jumlah

Table A.8: Markets that were surveyed, as well as the number of survey days. Langowan is the only market that has been consistently surveyed over the years.
*The market was surveyed for at least that number of days.

Market	Airmadidi	Amurang	Bersehati	Dumoga	Freshmart	Girian	Ibolian	Imandi	Karombasan	Kawangkoan	Langowan	Motoling	Pakuure	Poopo	Tomohon	Tompaso Baru	Grand Total
Regency	North Minahasa	South Minahasa	Manado City	Bolaang Mongondow	Manado City	Bitung City	Bolaang Mongondow	Bolaang Mongondow	Manado City	Minahasa	Minahasa	South Minahasa	South Minahasa	South Minahasa	Tomohon City (Minahasa)	South Minahasa	
1992							3						4				7
1993							13	25			26					64	
1994							15	15			14					44	
1995								10*									10
1996																	
1997								10*									10
1998								11*									1999
							12*									12	
2000																	
2001																	
2002																	
2003																	
2004																	
2005																	
2006																	
2007																	
2008																	
2009																	
2010																	
2011	10	9					9	10		9	10		9	10		9	10
	9	10		9	10		47										
2012																	
2013																	
2014																	
2015	1	1			3	9		1	3	1	3			1	3	1	19
2016																	
2017																	
2018	3	3		3	3		3	3	3	3	3			3	3	3	30
2019	2	3		2	3		2	3	3	3	3			3	3	3	27
2020																	
2021																	
2022		16	16	16	4		17	16	20	22	17		24		168		
2023		7	10	9	2		9	11	12	12	7		11		90		
Grand Total	16	39	26	25	6	5	6	26	27	77	148	30	6	1	100	10	558

Table A.9: Types of wild meat sold in Freshmart (a modern market in Manado city), Karombasan and Bersehati (traditional markets in Manado city), and the three big wild meat markets of Tomohon, Kawangkoan, and Langowan.

Freshmart	**Karombasan**	**Bersehati**	**Tomohon**	**Kawangkoan**	**Langowan**
Dog	Dog	Dog	Dog	Dog	Dog
Wild pig	Wild pig	Wild pig	Wild pig	Wild pig	Wild pig
Bats	Bats	Bats	Monitor lizard	Bats	Monitor lizard
	Cat		Quail (bird)	Small bats	Bats (small, yaki (flying fox))
	Snake (python)		Bats (Big bats, small bats, medium-sized bats)	Frog	Frog
			Frog	Cat	Cat
			Cat	Cucus	Dwarf cuscus
			Rats (big, small, black-tailed, white-tailed)	White-tailed rats	Rats (big, white-tailed, small, forest, paddy rats)
			Snake (python)	Snake (python)	Squirrel
			Buff-banded rail (weris)		Snake (python)
					Buff-banded rail (weris)

Table A.10: Types of wild meat sold in four rural wild meat markets.

Amurang	**Motoling**	**Imandi**	**Dumoga**
Dog	Dog	Dog	Dog
Wild pig	Wild pig	Wild pig	Wild pig
Bats	Bats	Bats	Bats
Rats	Frog	Small bats	Small bats
Snake (python)	Cat	Banana bats	Banana bats
	Cuscus	Medium sized bats	Medium sized bats
	Dwarf cuscus	Yaki bats	Yaki bats
	Sulawesi civet	Dwarf cuscus	Dwarf cuscus
	Rats (white-tailed, paddy)	Rats (big, white-tailed, forest, small, paddy, medium-sized)	Rats (big, white-tailed, forest, small, paddy, medium-sized)
	Squirrel	Snake (python)	Snake (python)
	Snake (python)	Buff-banded rail (weris)	
		Black macaques	

A.5 Appendix for Chapter 7

A.5.1 Consumer Survey questionnaire.

Enumerator: _____

Catatan enumerator mengenai consent/persetujuan lisan:
- Responden diberikan penjelasan mengenai penelitian? Ya/Tidak
- Lembar consent/persetujuan dibacakan dan disetujui secara lisan? Ya/Tidak
- Percakapan dalam wawancara direkam dengan ijin responden? Ya/Tidak
- Enumerator membuat catatan di buku notes? Ya/Tidak
- Responden setuju untuk ucapannya dikutip dengan tetap menjaga kerahasiaan identitas? Ya/Tidak
- Responden tidak mau dikutip ucapannya sama sekali? Ya/Tidak

Lanjutkan wawancara hanya jika responden memberikan consent/persetujuan.

ID responden: _____ (ID_desa-Inisial enumerator-Jenis Survey-No urut responden)
Jenis Kelamin: Laki-Laki / Perempuan
Tanggal wawancara: _____
Jam wawancara dimulai: _____ (contoh: 15:00)
Jam wawancara berakhir: _____ (contoh: 16:00)
Dimana wawancara dilakukan: _____

WAWANCARA DIMULAI

I. PERKENALAN
Darimana anda berasal?
1. Umur:
Kategori umur: (jika responden tidak ingin menyebutkan umur pasti)
a. 18-24 b. 25-34 c. 35-44
d. 45-54 e. 45-54 f. > 65
2. Tingkat pendidikan:
a. SD b. SMP c. SMA d. Sarjana
e. S2 f. S3 g. Tidak sekolah
3. Menikah/tidak menikah: _____ Jumlah anak (kalau ada): ____
4. Anda besar dimana? _____
5. Orangtua dari daerah mana, desa apa? _____
6. Agama: _____ Suku: _____
7. Sudah berapa lama anda tinggal daerah ini? _____
8. Apa yang anda lakukan untuk mencari nafkah? _____
II. KONSUMSI DAGING SATWA

9. Seberapa sering anda makan daging:
- Daging ternak (daging merah dan unggas)
- Daging satwa (termasuk RW dan kucing)

Pilihan frequensi
a) Setiap hari
b) Seminggu sekali
c) Setiap 2-3 minggu

d) Setiap bulan
e) Setiap 2-3 bulan
f) Setahun sekali
g) Kurang dari setahun sekali
h) Tidak pernah

Jenis daging hewan Frekuensi
1. Daging ternak/domestikasi secara umum
2. Babi ternak
3. Sapi
4. Kambing
5. Kerbau
6. Ayam
7. Bebek
8. Ikan
9. Daging non-ternak secara umum
10. Babi hutan
11. Paniki
12. Tikus
13. Ular
14. Yaki
15. Cuscus
16. Babi hutan
17. Babi rusa
18. Anoa
19. Anjing
20. Kucing
21. Biawak
22. Kodok
23. Maleo
24. Burung (sebutkan jenisnya)
25. Lainnya...

10. Daging ternak apa yang paling suka/favorit dikonsumsi? _____
11. Daging satwa apa yang paling suka/favorit dikonsumsi? _____
12. Antara daging satwa dan ternak, mana yang lebih favorit? _____
Bisa jelaskan mengapa: _____
13. Apakah anak (kalau punya) atau generasi yang lebih muda,
    juga suka makan daging satwa? _____
14. Berapa harga daging satwa favorit itu per unit (bisa kg, utuh, DLL,
    sebutkan unitnya)? _____
15. Apakah anda akan tetap beli bila harganya naik? _____
Catat harga tertinggi dimana responden masih mau membeli: _____
Catat bila ada perubahan frekuensi membeli: _____
    _____ (lebih jarang misalnya)
16. Apakah ada perubahan dalam jenis dan jumlah satwa yang dimakan sekarang
    dibanding lima tahun lalu? tolong jelaskan
Jika ada perubahan dalam pasokan

Kalau responden menjawab ini, pilih alasannya mengapa (bisa lebih dari 1)
- Karena ada penegakan hukum
- Karena pandemik (minta jelaskan)
- Karena ada masalah dari pengiriman/transportasi daging
- Karena perburuan untuk daging satwa berkurang
- Karena pemasok mengirim pasokan sedikit/berkurang
- Lainnya

Penjelasan: _____

Jika ada perubahan dalam permintaan

Kalau responden menjawab ini, pilih alasannya mengapa (bisa lebih dari 1)
- Karena ada penegakan hokum
- Karena pandemik (minta jelaskan)
- Karena pembeli kesulitan ekonomi
- Karena takut zoonosis
- Alasan kesehatan lain (co: kolesterol)
- Karena beralih ke daging ternak
- Lainnya...

Penjelasan: _____

III. KEPERCAYAAN TERKAIT KONSUMSI DAGING SATWA

17. Bisakah anda bantu saya untuk mengerti mengapa anda makan daging satwa?
Gali alasan dibalik kepercayaan/jawaban mengapa mereka makan daging
- Karena enak
- Karena murah
- Ada khasiat baik untuk kesehatan
- Karena terbiasa makan
- Karena saya tahu cara memasaknya
- Karena orangtua dan keluarga juga makan
- Karena bergengsi (prestis)
- Karena jarang
- Karena takut penyakit dari hewan (zoonosis)
- Lainnya..

Penjelasan: _____

18. Menurut anda apakah anak (kalau punya) atau generasi yang lebih muda juga memiliki kepercayaan/alasan ini? _____
Tolong jelaskan _____

19. Dibandingkan dengan daging satwa, apa pendapat anda soal daging ternak? ___

IV. FAKTOR KONTROL

20. Mengapa anda makan daging satwa x kali dalam xxx (frekuensi dari pertanyaan no 11)? _____(Contoh: Apa alasannya makan sesering, atau sejarang, itu)
21. Kejadian apa yang bisa membuat anda berubah menjadi makan lebih sering atau makan lebih jarang/sedikit dibanding sebelumnya?
Gali alasan atau penjelasan dari jawabannya, misalnya:

- Harga lebih murah/mahal
- Karena kesehatan
- Karena takut tertular penyakit (zoonosis)
- Karena takut ditangkap/hukuman
- Lainnya...

Penjelasan: _____
Terima kasih!

A.5.2 Profile survey questionnaire.

DATA DESA
Nama desa :
Jumlah populasi : _____(laki-laki); _____(Perempuan); _____(KK)
Etnis/Suku : _____(Minahasa); _____(Mongondow); _____(Gorontalo)
_____(Sangir); _____(Bugis); _____(Lainnya)
==========

Enumerator: _____

Catatan enumerator mengenai consent/persetujuan lisan:
- Responden diberikan penjelasan mengenai penelitian? Ya/Tidak
- Lembar consent/persetujuan dibacakan dan disetujui secara lisan? Ya/Tidak
- Percakapan dalam wawancara direkam dengan ijin responden? Ya/Tidak
- Enumerator membuat catatan di buku notes? Ya/Tidak
- Responden setuju untuk ucapannya dikutip dengan tetap menjaga kerahasiaan identitas? Ya/Tidak
- Responden tidak mau dikutip ucapannya sama sekali? Ya/Tidak

Lanjutkan wawancara hanya jika responden memberikan consent/persetujuan.

ID responden: _____ (ID_desa-Inisial enumerator-Jenis Survey-No urut responden)
Tanggal wawancara: _____
Jam wawancara dimulai: _____ (contoh: 15:00)
Jam wawancara berakhir: _____ (contoh: 16:00)
Dimana wawancara dilakukan: _____

WAWANCARA DIMULAI

VI. PERKENALAN
Darimana anda berasal?
31. Umur:
Kategori umur: (jika responden tidak ingin menyebutkan umur pasti)
a. 18-24 b. 25-34 c. 35-44
d. 45-54 e. 45-54 f. > 65
32. Tingkat pendidikan:
a. SD b. SMP c. SMA d. Sarjana
e. S2 f. S3 g. Tidak sekolah

33. Menikah/tidak menikah: _____ Jumlah anak (kalau ada): _____
34. Anda besar dimana? _____
35. Orangtua dari daerah mana, desa apa? _____
36. Agama: _____ Suku: _____
37. Sudah berapa lama anda tinggal daerah ini? _____
38. Apa yang anda lakukan untuk mencari nafkah? _____

VII. Konsumsi daging satwa

1. Di desa ini, menurut anda berapa persen penduduk yang memakan daging satwa?
_____ (Gunakan teknik hitung-biji untuk menghitung proporsi)
2. Kami punya beberapa kartu bergambar hewan sebagai berikut (tunjukkan kartunya).
Menggunakan kartu ini, bisakah anda bantu kami untuk mengelompokkan gambar hewan-hewan kedalam kelompok:
a) Hewan yang ada disini _____
(buat dua tumpukan kartu, satu untuk hewan yang ada di sekitar desa, satu lagi yang tidak ada)
b) Hewan yang diburu _____
(dari tumpukan kartu hewan yang ada di sekitar desa, minta mereka untuk pisahkan lagi menjadi dua tumpuk antara yang diburu dan tidak)
c) Hewan yang dimakan _____
3. Hewan mana yang disukai oleh masyarakat untuk dimakan? _____
4. Seberapa sering masyarakat memakan daging satwa?
a) Setiap hari
b) Setiap minggu
c) Setiap bulan
d) Setiap beberapa bulan
e) Setiap tahun
f) Kurang dari sekali setahun
5. Apakah ada hari-hari khusus (berkaitan dengan perayaan acara keagamaan atau tradisi) saat masyarakat memakan daging satwa lebih banyak dari hari biasa? _____
6. Apakah ada alasan khusus masyarakat berburu dan memakan daging satwa? _____
Dari mana biasanya masyarakat mendapatkan daging satwa?
(Gunakan teknik hitung-biji, bagi menjadi: diburu sendiri, dibeli dari pemburu atau tetangga, dibeli di pasar desa, dibeli di pasar kota, makan di rumah makan)

Terima kasih!

A.5.3 Verbal Consent Guidance

Persetujuan untuk berpartisipasi sebagai responden dalam penelitian:
Understanding the Wild Meat Supply Chain in northern Sulawesi, Indonesia

Central University Research Ethics Committee (CUREC) approval

reference: R76942/RE002

Selamat pagi/siang/sore/malam, nama saya _____,
Saya adalah mahasiswa/peneliti yang sedang melakukan penelitian dari Unsrat bekerjasama dengan University of Oxford. Judul penelitian ini adalah "Memahami rantai pasok daging satwa liar di Sulawesi bagian utara".
Sesuai dengan judulnya, kami berusaha menggambarkan secara detail rantai pasok daging satwa dari pemburu, pengumpul, pasar, hingga ke konsumen. Wawancara akan berlangsung selama kira-kira 30 menit hingga satu jam. Partisipasi anda sebagai responden akan sangat berarti untuk membantu kami memahami hal tersebut, dan kami sangat menghargainya.
Partisipasi dalam wawancara ini bersifat sukarela, dan anda berhak menolak menjawab pertanyaan wawancara. Wawancara juga bersifat anonim dengan jumlah responden yang besar. Respon dan jawaban anda di wawancara ini tidak akan memiliki implikasi apapun terhadap and, atau keluarga and.
Kami tidak akan mencatat nama anda dan kami menjamin hasil dari wawancara akan kami rahasiakan dari pihak lain. Data wawancara akan disimpan di server milik University of Oxford di dalam folder dengan password dan hanya dapat diakses oleh peneliti dari Universitas Sam Ratulangi dan University of Oxford.
Data hanya akan digunakan di dalam penulisan thesis program S3 dan publikasi ilmiah, dan akan dihapus dari server setelahnya.
Respon anda dalam wawancara akan sangat berguna untuk membuat rencana lingkungan yang berkelanjutkan, sehingga kami akan sangat menghargai bila and mau berpartisipasi hingga akhir wawancara.
Kalau anda ingin bertanya lebih lanjut atau mengajukan keberatan, silahkan menghubungi kontak peneliti utama Wulan Pusparini, melalui no WhatsApp 0811118815.
Terima kasih!

Daftar persetujuan responden:

- Saya memahami maksud dari penelitian ini dan saya telah diberi waktu untuk bertanya untuk mendapatkan informasi yang lebih jelas.
- Saya mengerti bahwa partisipasi saya bersifat sukarela dan says bisa menarik kembali jawaban saya tanpa diperlukan alasan apapun.
- Saya mengetahui siapa yang memiliki akses terhadap data, bagaimana data akan disimpan, dan bagaimana data akan digunakan.
- Saya memahami bahwa identitas saya tidak bisa dikenali dari hasil penelitian yang ditulis dalam thesis atau publikasi ilmiah.
- Saya setuju untuk respon saya dalam wawancara direkam.
- Pilih salah satu:
  - Saya setuju untuk pertanyaan saya dikutip, atau
  - Saya tidak setuju kalau pernyataan saya dikutip
- Saya tahu kemana saya harus mengajukan keberatan.

- Saya setuju untuk berpartisipasi di dalam penelitian ini.

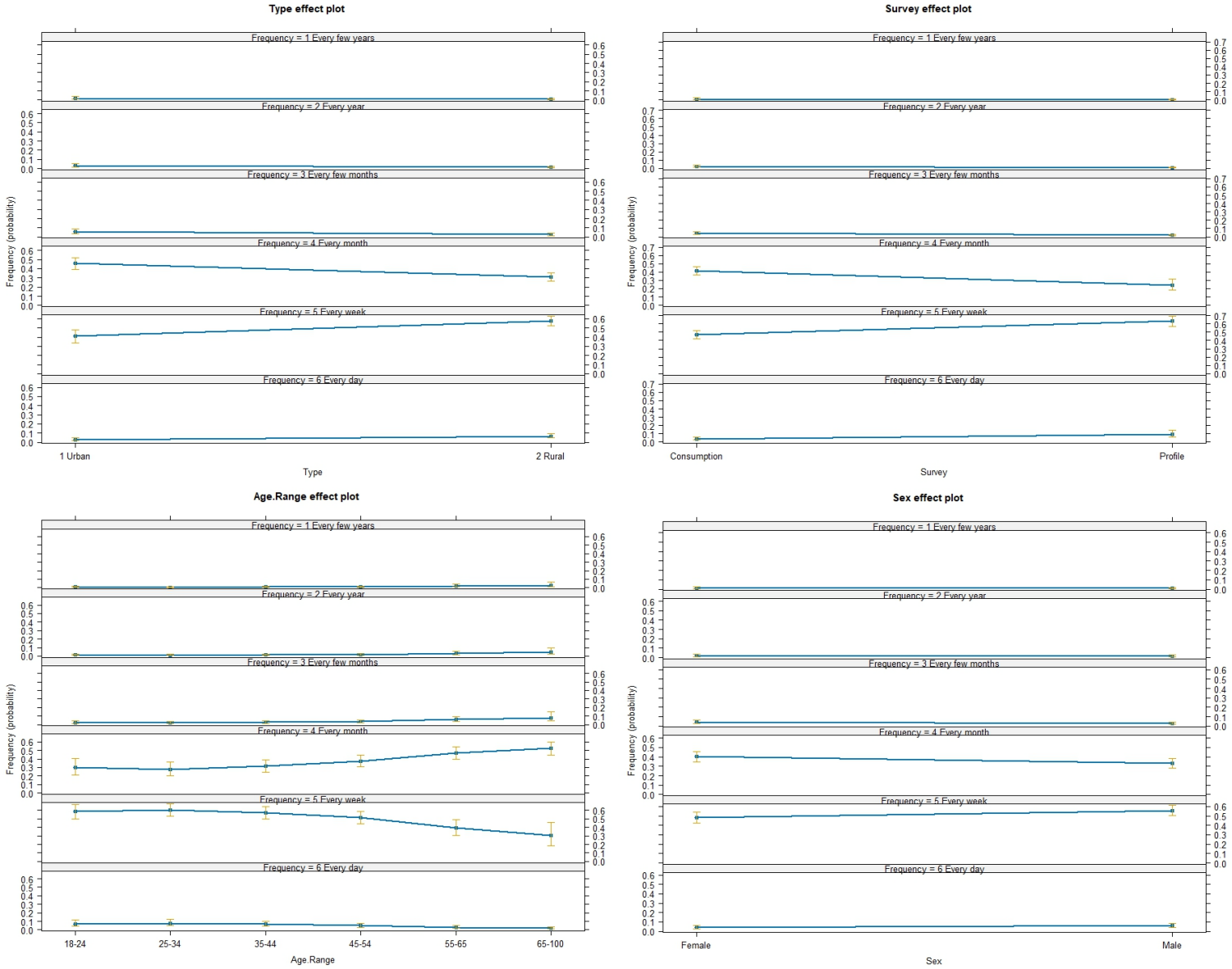


Figure A.2: The association between predictors and frequency of consumption

Table A.11: Demography of the Consumption and Profile Survey's Respondents

Category	Consumption survey (n = 373)	Profile survey (n = 155)
Sex		
Female	182 (49%)	71 (46%)
Male	191 (51%)	80 (52%)
NA		4 (3%)
Age		
18-24	51 (14%)	9 (6%)
25-34	73 (20%)	15 (10%)
35-44	82 (22%)	38 (25%)
45-54	94 (25%)	46 (30%)
55-64	54 (14%)	31 (20%)
65 and above	19 (5%)	16 (10%)
Attained education		
Primary school	71 (19%)	64 (41%)
Junior high school	84 (23%)	42 (27%)
High school	162 (43%)	40 (26%)
Diploma	5 (1%)	1 (1%)
College	50 (13%)	3 (2%)
Graduate	1 (0%)	
NA		5 (3%)
Principle Occupation		
Civil servant	8 (2%)	8 (5%)
Farmer	88 (24%)	65 (42%)
Housewife	103 (28%)	45 (29%)
Merchant	14 (4%)	3 (2%)
Miner	17 (5%)	6 (4%)
Priest	2 (1%)	
Professional	7 (2%)	4 (3%)
Retired	5 (1%)	
Self-employed	27 (7%)	3 (2%)
Service worker	22 (6%)	8 (5%)
Skilled worker	14 (4%)	2 (1%)
Student	23 (6%)	
Unemployed	21 (6%)	7 (5%)
Unskilled worker	19 (5%)	4 (3%)
NA	3 (1%)	
Geography		
Rural	194 (52%)	155 (100%)
Urban	179 (48%)	

Table A.12: The odds ratio of the predictor's variable on the frequency of wild meat consumption. The odds ratio value less than 1 means the odds are higher for consuming wild meat more frequently, and the odds more than 1 means otherwise.

Variable	**Odds Ratio**	**Lower CI**	**Upper CI**	**p-value**
Type: Rural*	0.43	0.29	0.64	0.00004
Survey: Profile*	0.39	0.25	0.60	0.00003
Sex: Male*	0.70	0.50	0.98	0.04053
Age Range: 25-34*	0.87	0.46	1.65	0.66910
Age Range: 35-44	0.99	0.54	1.83	0.97257
Age Range: 45-54	1.37	0.76	2.50	0.29654
Age Range: 55-65	2.41	1.25	4.68	0.00862
Age Range: 65-100	3.89	1.66	9.15	0.00177

Table A.13: Situation that the respondents in consumption surveys reported will make them change their wild meat consumption habit.

Survey Respondent	**Age Range = 18-24**	**Age Range = 25-34**	**Age Range = 35-44**	**Age Range = 45-54**	**Age Range = 55-65**	**Age Range = ≥ 65**	**Total (373)**
Health Issue	4	16	19	28	28	10	105
No Change	17	15	21	18	7	5	83
Economy	4	17	15	17	3	0	56
Less Supply	9	11	7	11	5	1	44
Economy	1	7	4	5	1	1	19
Social Event	5	2	5	2	2	0	16
Available or already served	2	2	4	0	0	0	8
Healthy	0	2	1	2	1	0	6
Not served	0	3	1	1	1	0	6
Less hobby	3	0	0	2	1	0	6
Fraudulent rat meat	0	3	0	2	0	0	5
Tasty	0	2	0	1	0	0	3
Family member ask for it	1	0	1	0	0	0	2
Bored	0	0	2	0	0	0	2
Fresh Meat	0	0	0	1	0	0	1
Back to village	0	1	0	0	0	0	1
Old Meat	0	1	0	0	0	0	1
Illegal	0	0	0	1	0	0	1
Migrate to other province	0	1	0	0	0	0	1
Busy	0	1	0	0	0	0	1
Total	46	84	80	91	49	17	367

That is all.
And as always,
Free Palestine.