WILDLIFE ATLAS OF SABAH

MAPS AND CONSERVATION

Edited by Glyn Davies



in collaboration with



Kota Kinabalu
2022

Supported by:
Development of this book was made possible with funding from HSBC, Unilever, Beiersdorf, WWF-UK, WWF-Netherlands, and WWF-Germany.

Wildlife Atlas of Sabah: maps and conservation. 2022.
Ed. G. Davies. Kota Kinabalu: WWF-Malaysia.

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ISBN 978-967-0237-73-2

Published by:
WWF-Malaysia
1, Jalan PJS 5/28A,
Petaling Jaya Commercial Centre,
46150 Petaling Jaya,
Selangor, Malaysia

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Front cover: Forest canopy © Mazidi Abd Ghani/WWF-Malaysia. Map on the front cover shows records in the Wildlife Atlas of Sabah database (see page 8).
Back cover (clockwise): Bornean Elephant © Mazidi Abd Ghani/WWF-Malaysia, Prevost's Squirrel © Adrian Choo/WWF-Malaysia, Bornean Yellow Muntjac © WWF-Malaysia, Red Leaf Monkey © Mark Louis Benedict

Printed in Taiwan.



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Foreword

Chief Minister of Sabah

Sabah, with an area spanning 72,500 square kilometres, is known for its high diversity of plants and animals, as well as various ecosystems comprising beautiful tropical rainforest, wetlands, beaches and islands, coral reefs and mountains. It is the extraordinary diversity of habitats from ocean deep to mountain high that harbours such a vast wealth of flora and fauna. The forests house more than 10,000 species of wild plant species, including some 6,000 flowering plants. In addition, the natural ecosystems of Sabah support a diversity of wildlife including mammals, amphibians, reptiles, birds, freshwater fish, marine fish and thousands of invertebrate species. Sabah is home to the iconic Bornean Orangutan, Proboscis Monkey, Banteng, Clouded Leopard and Bornean Elephant.



Our existing and unique biodiversity is the reason that Sabah is a popular destination among local and international visitors. They came in droves to personally observe and enjoy this natural biodiversity. The tourism industry is forecasted to contribute more than 10% of Sabah's GDP, under the 5-year Sabah Maju Jaya (SMJ) development plan. Sabah has internationally recognised conservation areas, such as Danum Valley, Maliau Basin, Imbak Canyon, Tabin, Kinabalu World Heritage Site, Crocker Range Biosphere Reserve and Lower Kinabatangan and Segama Wetlands Ramsar site, as well as our marine parks, because biodiversity underpins the health of our planet which has a direct impact on all our lives.

Declining biodiversity lowers an ecosystem's productivity and lowers the quality of ecosystem services. This includes the ability of our forests and sea grass beds to absorb carbon, and so mitigate climate change impacts. We must all work to address the climate change and nature loss challenges we face, and they are linked.

In Sabah, the primary drivers of biodiversity loss are the exponential growth of the human population, increased consumption as people strive for more affluent lifestyles and reduced resource efficiency, and invasive species leading to the conversion our forests and wetlands to urban and agricultural uses. Climate change could well become a primary driver as the 21st century progresses. Therefore, our Sabah Biodiversity Centre looks at the challenges and opportunities of protecting wildlife to ensure sustainable development in Sabah. The Sustainable Development Goals 2030 are used as a benchmark for future development in Sabah, and this Wildlife Atlas of Sabah can contribute to the planning and management of the development in Sabah in a more sustainable and effective manner.

I wish to congratulate the Sabah Biodiversity Centre, WWF-Malaysia and Sabah Wildlife Department for coming up with this important wildlife data system for the State.



DATUK SERI PANGLIMA HAJI HAJIJI HAJI NOOR
Chief Minister of Sabah

"SABAH MAJU JAYA"

Foreword

Sabah State Secretary



Sabah is blessed with rich biodiversity that benefits the people both in socioeconomic development and the growth of our economy. Our wildlife species such as the Bornean Elephant, Bornean Orangutan, Proboscis Monkey, and scenic natural destinations have been important tourism products providing revenue to Sabah. In addition, unique features of biodiversity in the state highlights an important research destination for researchers all over the world. Research activities involving access to our biological resources has started since early 1900s. It is important to document and compile all these research discoveries to ensure that it will benefit and contribute to the long-term management and conservation of biodiversity in the State in accordance with the implementation of the Sabah Biodiversity Enactment 2000.

I observe that Sabah is currently undergoing rapid development in various sectors under the implementation of Hala Tuju Sabah Maju Jaya (Pelan Pembangunan SMJ 1.0) introduced by YAB Datuk Seri Panglima Haji Hajiji bin Haji Noor, the Chief Minister of Sabah. Despite the rapid development for the betterment of the people of Sabah, we must ensure that the development plans that we take lead go together with sustainable development models and practices to protect the biodiversity.

This is where research results driven by data and solid evidence contribute particularly to recommend best practices and to guide the government decision-making process, including mainstreaming biodiversity in development activities. Research activities need to be more practical and should be used for decision-making and not just to fulfil academic requirements. This is in line with Strategy 4 of the Sabah Biodiversity Strategy 2012–2022, which aims to improve our understanding about biodiversity so that we can manage our resources efficiently and with sustainable practices.

As the Chairman of the Sabah Biodiversity Council, I am pleased that both local and international researchers have contributed to the Wildlife Atlas of Sabah. I am informed that this publication contains collection of information on Sabah's wildlife over the past 50 years will provide a basis to understand how rapidly our biodiversity and our landscape has changed. Another important output from the exercise is the utilization of digitalization in documenting our nature by the uses of the data and GIS mapping. I recognize that through digitalization we can identify drivers of change, and analysing these data can guide us to a better approach for new conservation and development opportunities.

Congratulations to WWF-Malaysia, both local and international researchers involved in contributing their research findings to produce the first ever Wildlife Atlas of Sabah. The Sabah Biodiversity Council will continue to support Sabah Biodiversity Centre efforts to compile biodiversity data and research findings for the benefit of the State and future generations.

Thank you.

YB. DATUK SERI PANGLIMA SR. HAJI SAFAR BIN UNTONG, JP
Sabah State Secretary and Chairman of the Sabah Biodiversity Council

Preface

Sabah Biodiversity Centre



A systematic database which can fulfill the requirements of both researchers and policy makers is critical for ensuring the success of any conservation programme. In order to get the best possible outcome for any development, especially when it involves irreversible or permanently altering a landscape, the decision makers should be guided by relevant data available on the area. There are always costs involved for any development project and we have to justify them in analyzing development proposals. Therefore, we need a reliable and up-to-date database for decision makers.

Sabah Biodiversity Centre (SaBC) has been developing a database called Sabah Biodiversity Integrated Information System (SaBIIS), since 2019. We intend to keep all old and incoming data of Sabah's biodiversity in the SaBIIS, and to record changes to flora and fauna distribution, which can be correlated with physical development in Sabah.

Data from WWF-Malaysia and other contributors will be uploaded into SaBIIS. In order to compliment the initiative, SaBC has appointed Sabah Net Sdn Bhd to upgrade SaBIIS with Geographical Information Systems (GIS) layers. One of the characteristics of the upgraded system will be to allow ordinary people, or citizen scientists, to contribute to the database once appropriate protocols have been developed for their participation.

The initiative provides a platform for partnership between government agencies and the people of Sabah, which is required for successful conservation. The people of Sabah then become our partner instead of an object of conservation. Any change in distribution of flora and fauna will be recorded in the database, and can be analyzed not only by academicians but also by the decision makers for future development projects.

The collaboration also allows partnership between government agencies, research institutions and NGOs such as WWF-Malaysia. The willingness of contributors, organisations and individuals, to share data is commendable; without them we would not be able to access historical records for systematic evaluation of the changes in flora and fauna populations for future planning. This strategic partnership is critical for the successful conservation of biodiversity in Sabah.

GERALD JETONY, PhD
Secretary, Sabah Biodiversity Centre

Preface

Sabah Wildlife Department



The Wildlife Section of Sabah Forestry Department worked with WWF-Malaysia and other government departments to conduct the first systematic conservation survey of wildlife in Sabah State (1979–1981), and I joined Sabah Forestry Department as a junior game warden some five years after these survey results were published. As we developed from that time to become the newly formed Sabah Wildlife Department in 1988, so we continued to make use of the results from the surveys to guide management and policy.

There have been a number of state-wide surveys in Sabah over the years, most recently a systematic set of conservation action plans which have examined the conservation situation for key species in Sabah's natural heritage: Bornean Banteng, Sunda Clouded Leopard, Bornean Elephant, Bornean Orangutan and Proboscis Monkey. All have made important recommendations, and it is welcome to have this new Wildlife Atlas of Sabah to bring a summary of the most recent information from a wider range of species into one volume, to inform up-to-date decision-making.

The State has gone through a period of very rapid economic development over the last four decades, and information is needed to raise awareness amongst policy makers and the general public of the challenges the State must address to achieve sustainable development. In some areas there is a challenge of supporting human-wildlife co-existence, in others the need to address emerging new diseases, such as the African Swine Fever devastating Bearded Pig populations in Borneo, and to these can be added the intensive and illegal hunting and trading in wildlife, such as the global trade in pangolins.

These topics are all considered in this book, to provide a range of different stakeholders with information for planning development policies and projects that take account of wildlife, and thereby give Sabah truly sustainable development. I congratulate my colleagues in Sabah Biodiversity Centre for supporting this important subject, that we would like to share across Sabah government, businesses and society, and I appreciate the input from many collaborators.

YBHG TUAN AUGUSTINE TUUGA
Director, Sabah Wildlife Department

Editor's Note



The inspiration for this volume came from Dwight D. Davis, who wrote an excellent monograph on *Mammals of the Lowlands Forests of North Borneo* in 1962. This early systematic account of the wildlife in Sabah remains a reliable source of species' descriptions, with notes on behaviour and ecology, but it is long out of print and few people use it as a reference. This is of concern because much past knowledge and many historical records are being lost. It is time to move away from "notebooks are locked in desk drawers", or "the hard disk has crashed", and have a reliable, retrievable and updatable record of Sabah's wildlife.

To this end we have developed a Wildlife Atlas database, as a platform for storing information on Sabah's wildlife, and using these data with other published reports to produce a conservation atlas. It builds on a baseline that was established 40 years ago through WWF-Malaysia's *Faunal Survey of Sabah* (1982), and allows us to look at change to wildlife populations during a period of rapid economic development within the State. The Sabah Biodiversity Centre will host this database.

There has also been a radical change in the way wildlife records are gathered during this period, especially through the reliance on camera-trapping technology. This, in turn, has influenced peoples' perceptions of rainforest, with many species that do not feature in camera-traps often getting less attention. So an effort has been made here to elaborate on the primates and squirrels, which are less well known for this reason, along with some birds whose plight highlights broader conservation issues.

Finally, it is hoped that this will be the first in a series of *Wildlife in Sabah* volumes that the Sabah Biodiversity Centre can champion. There is limited time and space to describe all of Sabah's rich wildlife heritage in one volume, and so only a selection has been considered. Future volumes can address other species, as well as present new understanding and findings as they are gathered.

There are many Thank Yous to note. To Dr Gerald Jetony and colleagues at the Sabah Biodiversity Centre for supporting this project. To colleagues at WWF-Malaysia who provided field data and brought the Wildlife Atlas database to life, especially: Adi Shabrani. Many researchers and conservationists who have specialist knowledge of Sabah's wildlife contributed data and wrote chapters, and acted as peer reviewers to this book. It has been a truly collaborative effort and these contributions are gratefully acknowledged here, and detailed in each chapter.

GLYN DAVIES, PhD
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Acknowledgements

The Author Profiles show the very able scientists and conservation experts, who contributed to the Wildlife Atlas of Sabah (WAS), and many thanks are extended to all of the colleagues and friends listed who authored chapters and assisted with chapter reviews.

A number of important government figures have also been involved in the WAS project. Dr Jamili Nais, previous Permanent Secretary of Ministry of Tourism, Culture and Environment, and Tuan Augustine Tuuga, Director Sabah Wildlife Department, keenly encouraged the initiation of the project; Dr Gerald Jetony, Director Sabah Biodiversity Centre, was supportive throughout; Dr Robert Ong, Director Forest Research Centre, lent support, data and maps; and Dr Maklarin Lakin, Director Sabah Parks, aided our survey work. Our great appreciation to all of them, and to their government teams who have supported surveys and provided field records, as well as to many other people whose generous contributions are listed at the end of each chapter.

Within WWF-Malaysia, in addition to the strong support of CEO Sophia Lim, Conservation Director Henry Chan, and Head of Conservation, Sabah Robecca Jumin, as well as ex-CEO Dino Sharma and previous Head of Conservation, Sabah, John Tay, many other colleagues have contributed field records. Special mention must go to the Orangutan team: Donna Simon, Bob Kapis, Tinrus Tinduk and Zuraimi Rahim who worked with Glyn Davies on general wildlife surveys at many forest sites over the past four years to fill gaps in our knowledge, and Lydia Ayog, Debbie Aduk and Agnesia Sapati who provided administrative and IT support.

The Wildlife Atlas of Sabah database was designed and nurtured from a few records to well over 170,000 today by Adi Shabrani, who should be proud of the many maps in this book that have been informed by that database. The WAS team: Suzika Juiling, Jane Wong, Dee Arnielia Gundeh and Angela Lim built on this good work, and have worked tirelessly with authors and designers to deliver this book. Finally, our thanks to Natural History Productions, Datuk CL Chan and HC Chan, for their enthusiasm and designs.

Financial support to WWF-Malaysia for wildlife surveys, database development and publication was provided by: HSBC, Unilever, Beiersdorf, WWF-UK (Nicola Loweth), WWF-Netherlands (Hans Beukeboom) and WWF-Germany (Ilka Petersen). To all of whom we express our many thanks.

Finally, my appreciation to my wife, Sylvia, for joining me in this Sabah adventure, for the many hours of surveys, writing and editing this document has absorbed.

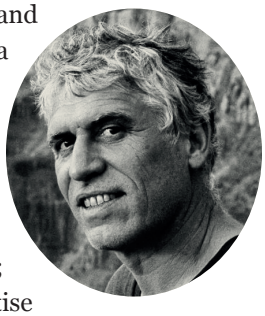
Glyn Davies
Kota Kinabalu
June 2022

Author Profiles



Abdul Hamid Ahmad (PhD) served at Universiti Kebangsaan Malaysia in 1995 before joining Universiti Malaysia Sabah (UMS) in 1995. He received a PhD in Zoology in 2002 from the University of Queensland in Australia. He is a Professor in Zoology and was a Director at the Institute for Tropical Biology and Conservation and a Dean at the Faculty of Sustainable Agriculture at UMS. He studies vertebrate ecology but much of his interest has been in studying larger vertebrates, which includes the saltwater crocodile and the Bornean Banteng, and is a member of the IUCN/SSC Asian Wild Cattle, Asian Rhino and the Megapode Specialist Group. He is also a part of avlocal Malaysian team that has developed interest and expertise in Advanced Reproductive Technology (ART) to be used in conservation of endangered species and in improvement of livestock, and has acquired a laboratory for that purpose.

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Marc Ancrenaz (PhD) is the co-founder of the French NGO HUTAN, and runs the Kinabatangan Orangutan Conservation Programme (KOCP), a community-based initiative located in Sabah, Malaysian Borneo. He is a co-founder of PONGO Alliance that aims to make coexistence between orangutans and people within agricultural landscapes a reality; the co-founder of the "Borneo Futures Initiative" that aims at providing cutting edge science to increase awareness, collaboration and understanding amongst decision makers, media, NGOs and the general public in Borneo; and a scientific adviser for the Sabah Wildlife Department. His expertise includes wildlife research, medicine, population management and policy formulation with 30 years of experience in wildlife range countries (Congo, Gabon, Saudi Arabia, Indonesia and Malaysia).

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Siau Keh Shyan Diana Anthony is a Malaysian born in the state of Sabah. She graduated with a Bachelor's Degree in Town and Regional Planning and Masters Degree in Environmental Science (Biodiversity). Diana is registered as a Graduate Member of the Malaysia Institute of Planners (MIP) and *Lembaga Perancang Bandar Malaysia* (LPBM). She has been working with WWF-Malaysia since 2000, and currently leads the GIS team in the Sabah Office with a strong interest in geographical information system and its applications. She is working on various conservation projects involving spatial database development and management, local community mapping, wildlife survey mapping, forest quality assessment and forest land cover classification, using satellite imagery, spatial analysis on orangutan nest distribution and home-ranging patterns.

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Henry Bernard (PhD) was born in Papar, Sabah. He received his B.Sc. (Honours) in Zoology from the Department of Zoology, University of Malaya, Kuala Lumpur, in 1992. He obtained his M.Sc. in Wildlife Management and Control from the Department of Animal and Microbial Sciences, University of Reading, U.K. in 1996 and subsequently, Ph.D. in Zoology from the Vertebrate Department, Copenhagen University, Denmark in 2003. Henry worked as an Assistant Fisheries Officer and Wildlife Officer at Department of Fisheries Sabah and Sabah Wildlife Department respectively, from 1992–1995, before joining Universiti Malaysia Sabah (UMS) as a lecturer in 1997. Henry is currently a Professor at the Institute for Tropical Biology and Conservation in UMS. Henry's primary research interest is in animal ecology and biodiversity. He studies the environmental factors that influence animal distribution and abundance and makes the results useful for the environment and nature conservation.

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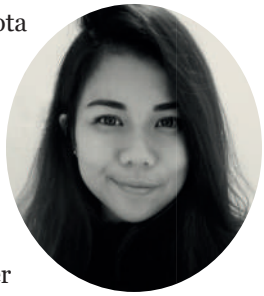
Jedediah F. Brodie (PhD) is a conservation ecologist who studies mammals, plants, and their interactions. He specializes in getting dirty, sweaty, and parasite-ridden through field work across the tropics and in Alaska. He has worked extensively in the rainforests of Southeast Asia, particularly in Borneo, Thailand, and Wallacea. Jedediah was a Fulbright Research Scholar in Malaysia, a David Smith Conservation Research Fellow, and Communications Director for the Society for Conservation Biology Asia Section. He is currently the Craighead Chair of Conservation at the University of Montana. Jedediah's current work focuses on landscape connectivity for large mammals, and he works closely with Malaysian and international partners to help plan wildlife corridors and other conservation areas.

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Cheryl Cheah (PhD) has been working in the field of wildlife conservation with over 12 years of experience. She started her career in WWF-Malaysia in 2014 and is presently the Manager for Elephant Conservation. Her key areas of work include studying the ecological requirements of elephants, fostering coexistence between people and elephants through collaborations with multi-stakeholders, securing connectivity areas for the movement of wildlife, and advocating for sustainable infrastructure. Through Cheryl and her team's continuous engagement with the plantation industry, they have helped secure close to 1,500 ha of land outside of protected areas for connectivity. She holds a PhD degree from Universiti Putra Malaysia and her areas of expertise include human-elephant conflict management, habitat connectivity, policy advocacy, and wildlife ecology. Cheryl is currently a member of the IUCN SSC Asian Elephant Specialist Group (AsESG).

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Melynda Cheok was born in the quiet town of Labuan and raised in Kota Kinabalu, Sabah. After spending most of her life in Malaysian Borneo, she is now based in Terengganu as the Wildlife Analyst for Panthera Malaysia's Kenyir Project. Her first real-time exposure to wildlife conservation work was during her volunteering based work in Danau Girang Field Centre, which essentially led her to get an MSc in Zoology from Universiti Malaysia Sarawak. Prior to holding the current position, Mel has also worked with the Bornean Sun Bear Conservation Centre and Reef Check Malaysia. Her past experiences in Borneo have involved ethnozoology studies, environmental education, and community-based ecotourism. She has always been keen on conservation works and she is looking forward to a future with a fair balance between wildlife needs and human necessities.
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Glyn Davies (PhD) started his career with WWF-Malaysia in Sabah, in 1979, and has continued as a leader in the fields of conservation and development. He has 30 years of experience, working in India, Sierra Leone, Kenya, Cameroon, the European Commission, United Kingdom and USA, and returned to Sabah in 2018 to support the Sabah Landscapes Programme. Glyn carried out his PhD on Red Leaf Monkeys in Sepilok and has authored/edited a number of scientific books and papers. He is currently Senior Adviser to WWF-Malaysia and Honorary Professor at Durrell Institute of Conservation and Ecology, University of Kent, UK.
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Geoffrey Davison (PhD) started his conservation career in 1976 during surveys of Danum Valley and from 1990 he worked for WWF-Malaysia (1990–2004) in Kuala Lumpur and Kota Kinabalu. Before that he was teaching in Universiti Kebangsaan Malaysia (1980–1990). He is an Honorary Life Member of the Malaysian Nature Society and has also represented the UNEP World Commission on Protected Areas and various IUCN Species Survival Commission specialist groups. He is the author for *Birds of Mount Kinabalu, Borneo*, *A Naturalist's Guide to Birds of Malaysia* and *Wild Singapore*. He is currently with the National Parks Board, Singapore.
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Meaghan N. Evans (PhD) is a wildlife ecologist whose research focuses on quantifying faunal responses and adaptations to changing landscapes. In collaboration with Danau Girang Field Centre and Sabah Wildlife Department, she assessed the ecology of mammalian carnivores in the agriculturally fragmented Lower Kinabatangan Floodplain. Her multidisciplinary research synthesises patterns in the movement, health, and ecotoxicological profiles of persistent civet species within the region. Her principal interest lies in the translation of rigorous science to solutions-oriented conservation management actions. Meaghan currently works for the Florida Fish and Wildlife Research Institute as a quantitative biologist.
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Faisal Md. Noor (PhD) was born and raised in Sandakan, Sabah. He is a development practitioner having experienced working 15 years in different countries; Indonesia, Philippines, East Africa and Germany, including Sabah, in the environmental field focusing on sustainable agriculture and forestry development. He has a Masters degree in soil science from the Colorado State University, USA, and a PhD in Geoecology from Carolo Wilhelminchen Technique University, Germany. He is currently the Programme Leader for the Sabah Landscapes Programme at WWF-Malaysia.
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Penny Gardner (PhD) is a tropical forest ecologist with a background in research and conservation of threatened species in Southeast Asia and West Africa, and is interested in solving problems related to sampling of cryptic species that are difficult to detect in remote tropical forest landscapes using a combination of tools and approaches, such as remote sensing, statistical modelling, non-invasive survey methods including remote infrared camera trapping, sign detection, molecular analysis using faecal DNA, UAV droning, and canopy access. Her work in Borneo has entailed conducting large-scale surveys to confirm remnant herds of (*Bos javanicus lowi*) into order to estimate population parameters and population genetic structure, investigating invertebrates that provide ecosystem services in tropical forests and the pollen morphology of dipterocarp trees. In West Africa Penny's work incorporates distribution modelling of species communities and undertaking landcover classification mapping in Sierra Leone and Liberia to inform land-use planning by local stakeholders will enable local stakeholders.
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Benoit Goossens (PhD) is the Director of the Danau Girang Field Centre in the Lower Kinabatangan Wildlife Sanctuary, a research and training facility co-managed by Sabah Wildlife Department and Cardiff University, where he leads projects on biodiversity responses to habitat fragmentation and degradation. Benoit is also a Professor at Cardiff University and a member of the IUCN SSC's Asian Wild Cattle, Crocodile, Asian Elephant and Primate Specialist Groups.
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Roshan Guharajan (PhD) has a background in monitoring terrestrial large mammals via camera traps, especially in mixed-use forest landscapes. He has relied on species distribution models to examine suitable habitat and how these might change over time. Currently, he is involved in wildlife protection, and is interested in how community co-management and policing reforms can effectively contribute towards this.

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Jessica Haysom is a PhD student with the Durrell Institute of Conservation and Ecology (DICE), UK, researching arboreal mammals in Borneo and currently writing her thesis on this topic. She is interested in both whole-system ecology — how rainforests function, how their resident species interact, and how they respond to habitat disturbance — as well as being fascinated by individual species, especially Borneo's diverse, sometimes bizarre, and poorly-known squirrels and flying squirrels.

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Andrew James Hearn's (PhD) interests lie in the ecology, conservation and intraguild interactions of rainforest mammals. His current research, now being undertaken within the framework of a DPhil at the WildCRU, investigates the factors that influence the abundance, distribution and movements of a guild of tropical forest felids in Borneo, and explores the mechanisms that enable them to persist in the fragmented landscape of contemporary Borneo. His focal species include the Sunda clouded leopard (*Neofelis diardi*), marbled cat (*Pardofelis* marmorata), Bornean bay (*Catopuma badia*), flat-headed cat (*Prionailurus planiceps*) and leopard cats (*P. bengalensis*), although from time to time he can be found exploring the delights of other, non-felid fauna.

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Suzika Juiling is passionate in research on terrestrial biodiversity conservation and integrating it with geospatial information systems. She graduated from Universiti Putra Malaysia with a Bachelor's degree in Forestry Science and pursued her Master's degree in Forestry Science (Ecology) at Univerisiti Malaysia Sabah, with research on the effects of climate change on the distribution of figs in Sabah, particularly the orangutan food plant species. Suzika worked on the High Conservation Value assessment (IUCN status) and distribution of the endemic orchids in Sabah. She was involved in the assessment of Borneo endemic dipterocarp species and Sabah endemic tree species for the IUCN Red List. She is currently managing the Wildlife Atlas of Sabah project at WWF-Malaysia.

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Ravinder Kaur (PhD) completed her PhD in University Malaya in 2020, studying endangered hornbills and their breeding behaviour in Kinabatangan for over six years. She works closely with her husband Sanjitpaal Singh, an award winning nature and wildlife photographer. Together they founded a social enterprise called Gaia and it is dedicated to research and conservation of hornbills in Malaysia. In Greek mythology, Gaia means Earth. Gaia strives to grow hornbill preferred food plants, restore dilapidated nest cavities of hornbills, and custom make artificial nest boxes with project partners that pioneered the artificial nest box project; HUTAN-KOCP, Chester Zoo, Beauval Zoo and Phoenix Zoo. Recently, the team received international recognition; the Marsh Christian Award 2020 and the Future Conservationist Leadership Award 2017 for their work with endangered hornbills and artificial nest boxes. Currently, Yayasan Sime Darby is a long-term funder of Gaia's hornbill project in Malaysia.

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David J. Kurz (PhD) is a conservation scientist who has been studying Sabah's ecosystems since 2015. He carried out his PhD research on the connections between Indigenous peoples and bearded pigs in Sabah and Sarawak. In particular, David collaborated with Kadazandusun-Murut (KDM) researchers and communities to explore ways that KDM bearded pig hunting has continued and changed over the years in Sabah. Additionally, David is collaborating with local partners to GPS collar bearded pigs in Sabah and learn more about the pigs' mysterious movements. He is grateful to partner with Danau Girang Field Centre, Universiti Malaysia Sabah, Sabah Wildlife Department, Wildlife Rescue Unit, Sabah Parks, Sabah Forestry Department, WWF-Malaysia, Sabah Biodiversity Centre, and the Bornean Sun Bear Conservation Centre. David lives in the United States and is married to his wonderful wife, Evelyne.

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Maklarin Lakim (PhD) obtained his BSc (Zoology) and MSc (Biodiversity Management) from Universiti Kebangsaan Malaysia. He obtained his PhD (Primate Ecology) from Universiti Malaysia Sabah. He has been appointed as Director of Sabah Parks since 2020, where his research focuses on ecology and systematics of amphibians and reptiles in Malaysia. He is also a Research Associate at Universiti Malaysia Sabah. For 14 years, he studied Red Leaf Monkey and Pig-tailed Macaque ecology in Tawau Hills Park. He is the author of *Red Leaf Monkey: Borneo's Exclusive Primate*. Apart from studying primates, he has also co-authored numerous research papers on other mammals, birds, reptiles and frogs species ecology.

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Lim Hong-Ye (aka Hugo) is a Research Assistant at the civil society entity, Forever Sabah, where he specialises in the use of Geographic Information System (GIS). He develops and analyses spatial data for interdisciplinary projects ranging from High Conservation Value assessment to understanding the socio-environmental impact of the Pan-Borneo Highway and recently the Sabah Renewable Energy Rural Electrification Roadmap. He has extensive experience in wildlife surveys using the camera trapping approach. He was also part of the Bornean Banteng Programme at Danau Girang Field Centre between 2014–2016, conducting a state-wide camera trap survey to ascertain the remnant banteng population and distribution in Sabah.
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The late **Titol Peter Malim** (ADK) was Deputy Director II of Sabah Wildlife Department, with a Bachelor's (Hons) in Zoology from Universiti Kebangsaan Malaysia. Specialising in mammals, he served as a wildlife officer for more than 32 years. Peter spoke regularly at local and international conferences and was active in wildlife research and surveys. In addition to being an avid wildlife person, he was a local counterpart for international researchers working in Sabah as well as co-author of wildlife articles in international journals. During his career, Peter was known as a dedicated, soft spoken and down-to-earth person. His go-to motto was '*Peace. Love. Harmony*'.



Hisashi Matsubayashi (PhD) is a Professor of Tokyo University of Agriculture. He studied the ecology of Lesser Mousedeer in Sepilok from 1998 to 2001, and in Tabin 2002, and obtained his PhD from Tokyo Institute of Technology in 2002. Since 2003, he has been conducting research on mammals' use of natural salt licks in Deramakot and collaborating with Mr. Peter Lagan, Sabah Forestry Department, published "Natural Salt-Licks and Mammals in Deramakot: Their importance and why it should be conserved" in 2014. He worked at Unversiti Malaysia Sabah from 2010 to 2012. From that time until present, he has been conducting research on conservation of Bornean Banteng in Sabah, collaborating with Dr Abdul Hamid Ahmad of UMS. They published "First molecular data on Bornean Banteng (*Bos javanicus lowi*) from Sabah, Malaysian Borneo" in Mammalia in 2014.
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Ikki Matsuda (PhD) is an Associate Professor at Chubu University Academy of Emerging Sciences, specially appointed Associate Professor at the Wildlife Research Center of Kyoto University, Japan, and Research Associate of Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah. His expertise in primate ecology, in particular of the proboscis monkey, is based on extensive fieldwork. He has been working continuously since 2005 with Sabah Wildlife Department, Sabah Forestry Department and Universiti Malaysia Sabah to study primates inhabiting the lower Kinabatangan in Sabah. He is co-author of *The Natural History of the Proboscis Monkey* (Natural History Publication, 2011) and co-editor of *Primates in Flooded Habitats: Ecology and Conservation* (Cambridge University Press, 2019) and *The Colobines: Natural History, Behaviour and Ecological Diversity* (Cambridge University Press, 2022).

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Miyabi Nakabayashi (PhD) has conducted research on civets including binturongs in Sabah since 2010. Her study sites include Tabin Wildlife Reserve, Danum Valley Conservation Area, Maliau Basin Conservation Area and Kabili-Sepilok Forest Reserve. Recently she has been working on seed dispersal, especially figs and large-seeded plants. She received her PhD at Kyoto University in 2015, and is an assistant professor at Hiroshima University, Japan.

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Nurzhafarina Othman (PhD) first encountered Bornean Elephants in Lower Kinabatangan in 2007. Seeing the difficulties faced by the elephants to survive in their natural habitat, unwanted and misunderstood by people, she committed to enhance the protection of the Bornean Elephant in Sabah and Malaysia. She holds a PhD from Cardiff University, where she learned about elephants' movement ecology and behaviour. Currently, she is a Senior Lecturer at Universiti Malaysia Sabah and the founder of Pertubuhan Pemuliharaan Biodiversiti Sabah or locally known as Seratu Aatai. She believes that everyone has a role to play, and together we will give a better future to our Bornean Elephants.

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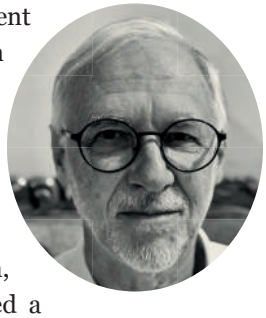
Yosuke Otani's (PhD) research explores the socioecology of primates and wildlife management. He received his PhD from Kyoto University. He currently works at the CO Design Center and the Cross–Boundary Innovation Program, Osaka University.

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Elisa Panjang was born in Sandakan, Sabah. She is currently employed as a Pangolin Conservation Officer at Danau Girang Field Centre, where she oversees pangolin education and public awareness. She has a Bachelor of Science in Conservation Biology and a Master of Science in Ecology Process from Universiti Malaysia Sabah. Elisa is also nearing the end of her PhD studies at Cardiff University, with a focus on Sunda Pangolin landscape ecology and behavioural studies in Kinabatangan, Sabah. She has over ten years of experience in pangolin research, conservation, and education in Sabah.

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John Payne (PhD) also known as Junaidi Payne, is a biologist and permanent resident of Sabah. His PhD degree was awarded for research done on squirrels in Krau Wildlife Reserve in Peninsular Malaysia in the mid-1970s. He led WWF work in Sabah from 1982 to 1998, spending much of the early years seeking Sumatran rhinos, and advocating for captive breeding as well as establishment of Tabin Wildlife Reserve. As the various institutions concerned with this species fragmented globally from 1986 onwards, he moved to other subjects including orangutans, Kinabatangan floodplain, conservation strategy and new protected areas. From 2008, he managed a non-governmental organization, Borneo Rhino Alliance. After the last two Sumatran rhinos in Malaysia died in 2019, he led the re-branding of the Alliance as 'bringing back our rare animals', an avenue to address lessons learned, and promote recovery and active management of large mammal populations.

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Quentin Phillipps has a broad interest in the history, wildlife and natural history of Borneo. He was born in Sandakan, Sabah in 1951 and grew up on Tuaran Rubber Estate. He was educated at Sabah College, Kota Kinabalu; Bedales School, Hampshire, UK; and King's College Cambridge, where he studied Japanese and economics. Currently he divides his time between London, where he owns a property business, and Tanjung Aru, Kota Kinabalu. Quentin is the joint author (with his sister Karen) of the *Phillipps' Field Guide to the Birds of Borneo*, and the *Phillipps' Field Guide to the Mammals of Borneo*. Quentin is currently collaborating on a group project to build a web site (borneoficus.info) and produce a field guide to the 150 species of Bornean figs.

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John Sha (Phd) is a Singaporean primatologist who has 20 years of experience researching non-human primates in Asia (Singapore, Malaysia, Japan and China), both in the wild and in captivity. He specializes in applied research that has direct implications for conservation, including captive wildlife management, human-primate interface and ecology of wildlife in human-altered environments. Over the past two decades, he has held both management and academic positions, where he was involved in the conduct, initiation and facilitation of numerous conservation and research projects; and formulation and implementation of various administrative and scientific policies. He is currently a Senior Researcher at the National Parks Board, Singapore.

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Adi Shabrani was the Manager for Wildlife Atlas of Sabah. Prior to joining WWF-Malaysia, he worked within various conservation projects with Universiti Malaysia Sarawak, Sarawak Energy Berhad, Leibniz Institute of Zoo and Wildlife, South East Asian Rainforest Partnership and Universiti Brunei Darussalam. In addition to his stint in wildlife conservation, Adi had taught in several government secondary schools in Sarawak as substitute teacher. Adi received his BSc and MSc from Universiti Malaysia Sarawak. He currently resides in the US to complete his doctorate with the University of Montana.

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Frederick H. Sheldon (PhD) is the George H. Lowery, Jr., Professor of Natural Science and Curator of Genetic Resources at the Louisiana State University Museum of Natural Science. As an ornithologist, he studies the evolution and systematics of birds, particularly the natural history of birds in the Malay Archipelago. He has worked in Sabah since 1976, and over the last 20 years has concentrated intensively on a range of projects from the biogeographic history of Sabah's avifauna to the ecology and conservation of its forest birds in plantations.

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Donna Simon is the Manager for Orangutan Conservation under the Sabah Landscapes Programme in WWF-Malaysia. She has worked for WWF since 2011, focusing on Bornean Orangutan conservation. Her earlier work involved studying orangutan behaviour in badly degraded forests in Bukit Piton Forest Reserve that was undergoing restoration. In 2014, together with two dedicated field assistants, their intensive work on mapping aerial nest surveys using helicopters contributed up-to-date information on orangutan distribution in Sabah. It is also the greatest survey effort for these great apes. This information has helped to protect orangutan habitat as Class I in Sungai Lulunguyon Forest Reserve; identify important corridors for habitat connectivity; and restore degraded orangutan habitats in Sabah.

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Leona Wai hails from Penampang, Sabah. She graduated with a Master's degree from Universiti Malaysia Sabah in 2019. Her Master project focused on the ecology of otters in the Lower Kinabatangan Wildlife Sanctuary. She is a member of the IUCN Otter Specialist Group and the Malaysia Otter Network. Leona worked as Otter Conservation Officer at Danau Girang Field Centre for almost 5 years and has been involved in multiple otter research projects around Sabah.

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Jane Wong is currently a Data Processing Officer based in WWF-Malaysia's Kota Kinabalu Office, co-managing the Wildlife Atlas of Sabah and liaising closely with Sabah Biodiversity Centre (SaBC) and SabahNet to contribute in the development of the Sabah Biodiversity Integrated Information System. A Sabahan raised in Kota Kinabalu, Jane is passionate about conservation. She obtained her BSc. in Animal Resource Science and Management from Universiti Malaysia Sarawak. She spent 10 weeks of Industrial Training at Danau Girang Field Centre from June to August 2019. Building on her knowledge and skills in zoological studies, she worked as a Research Officer in Expanse Consulting Sdn Bhd supporting the technical and policy research team and stakeholder engagement.

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Wong Siew Te is a wildlife biologist and a tropical forest ecologist. He is the CEO and the Founder of the Bornean Sun Bear Conservation Centre in Sabah. He did his Diploma in Veterinary and Animal Science in National Pingtung University of Science and Technology, Taiwan, and all his BSc, MSc and doctorate majoring in Wildlife Biology at the University of Montana, USA. Dr Wong has been awarded with numerous awards and recognitions of his works on sun bears. Among them are "Member-Order of the Defender of State" (Darjah Johan Negeri, D.J.N.) by the Governor of Penang State, Malaysia; an Honorary Doctorate from the University of Sunshine Coast, Australia; "My Country Hero" by the Government of Malaysia; and "CNN Hero" by Cable News Network (CNN), USA.

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Zainal Zahari Zainuddin is a wildlife veterinarian since 1985 and currently works on propagating wild figs to restore wildlife habitats in Sabah. While with the Department of Wildlife and National Parks, Malaysia (1985–2010), he specialized in large mammal translocation, reproduction and diseases, the most common being elephants, rhinos, Seladang, Malayan tapir and Malayan tiger. He was also involved with training on wild capture of elephants (Vietnam, Cambodia, Sri Lanka) and rhinos (Indonesia) for translocation and research. He is presently with the Borneo Rhino Alliance. Apart from work related to assisted reproductive technologies, he is also looking into the sciences that are threatening endangered or near extinct, large mammal species.

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Abbreviations

ASF	African Swine Fever
asl	Above sea level
BSBCC	Bornean Sun Bear Conservation Centre
ca.	Circa
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
COVID-19	Coronavirus disease 2019
DGFC	Danau Girang Field Centre
DICE	Durrell Institute of Conservation and Ecology, University of Kent
DWNP	Department of Wildlife and National Parks, Peninsular Malaysia (PERHILITAN)
ENSO	El Niño–Southern Oscillation
FELDA	Federal Land Development Authority
FMU	Forest Management Unit
FPIC	Free, Prior and Informed Consent
FR	Forest Reserve
FRC	Forest Research Centre
FSC	Forest Stewardship Council
GIS	Geographic Information System
GPS	Global Positioning System
HCV	High Conservation Value
HEC	Human-elephant Conflict
HIV/AIDS	Human Immunodeficiency Virus/Acquired immunodeficiency Syndrome
HUTAN-KOCP	HUTAN-Kinabatangan Orangutan Conservation Programme (KOCP)
ID	Identification number
IUCN	International Union for Conservation of Nature
JCSC	Jurisdictional Certification Steering Committee, Sabah
Ka	Kilo-annum (thousand years)
KDM	Kadazandusun-Murut
KOPEL Bhd	Koperasi Pelancongan Mukim Batu Puteh Kinabatangan Berhad
LKWS	Lower Kinabatangan Wildlife Sanctuary
Ma	Mega-annum (million years)
MER	Managed Elephant Range

MSPO	Malaysian Sustainable Palm Oil
MYR	Malaysian Ringgit
NGO	Non-governmental organization
Pers. comm.	Personal communication
Pers. obs.	Personal observation
PONGO Alliance	Oil Palm Growers and Conservation Practitioners Collaborate for Orangutan Conservation
REDD	United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation
RIL	Reduced Impact Logging
RSPO	Roundtable on Sustainable Palm Oil
SaBC	Sabah Biodiversity Centre
SEARRP	SE Asia Rainforest Research Partnership
SEEN	Sabah Environmental Education Network
SDG	United Nations Sustainable Development Goals
SFD	Sabah Forestry Department
SLDB	Sabah Land Development Board
SVW	Save Vietnam Wildlife
SWD	Sabah Wildlife Department
TPA	Totally Protected Area
UNFCCC	United Nations Framework Convention on Climate Change
UMS	Universiti Malaysia Sabah
UNEP-WCMC	The UN Environment Programme World Conservation Monitoring Centre
USD	United States Dollar
VJR	Virgin Jungle Reserve
WR	Wildlife Reserve
WWF	World Wide Fund for Nature
WWF-Malaysia	National conservation organisation, which is part of WWF
YS	Yayasan Sabah Group (Sabah Foundation)

1

Introduction

Glyn Davies, Adi Shabrani, Suzika Juiling and Jane Wong

Historical Background

Scientific exploration of Sabah's mammals began in the mid-1880s, including expeditions to Mt. Kinabalu, Sandakan and other east coast areas to collect museum specimens. This was followed by more thorough taxonomic investigations in the early 1900s (Chasen & Kloss, 1931), and studies of animals in the interior from the mid-1900s (e.g. Davis, 1962). With this knowledge, and that gained from studies elsewhere in Borneo, mammal species lists were produced for Borneo by Medway (now Cranbrook) in 1977, to more popular field guides of the mammals of Borneo by Payne et al. (1985) and Phillipps and Phillipps (2018).

Davis' excellent early surveys looked at the lowlands of Sabah in the 1950s, but it would be another 30 years before more detailed faunal surveys were conducted across the State in the early 1980s (Davies & Payne, 1982), followed by the *Mammals of Sabah* (Yasuma & Andau, 2000) with notes on taxonomy, ecology and general areas of occurrence. All of these reports are now outdated and have been overtaken by changes in taxonomy, increases in our knowledge of species' distributions, and improved ecological understanding.

Various state-wide surveys have been carried out to look at single species in recent times, such as the orangutan (Ancrenaz et al., 2005; Payne, 1987; Simon et al., 2019), and the current species conservation action plans for: Bornean Orangutan, Proboscis Monkey, Bornean Banteng, Sunda Clouded Leopard, Bornean Elephant (Sabah Wildlife Department/Danau Girang Field Centre, 2019), as well as Borneo-wide conservation reviews such as the synthesis of information from studies of carnivores (Wilting et al., 2016).

To support conservation and sustainable development planning in Sabah, however, it is important to provide up-to-date information from within the State, and to try and bring information on different species into a single volume.

Purpose of the Wildlife Atlas of Sabah

With the goal of producing information on Sabah's wildlife in a single place, which can be accessed by a broad audience, several principles guided the production of this Wildlife Atlas.

First was to establish a wildlife atlas database, as a platform on which to gather and share reliable records of species' presence and absence in different parts of the State, using standardised fields for all records that are verified for accuracy to allow comparison from credible sources, and over

different time periods. This has brought to light a great deal of unpublished and often unreported information. For example, WWF-Malaysia has been able to share some 15 years of species records, alongside those of other environmental groups, companies, government units and research teams.

Second, the very rapid economic development over the past 50 years, with corresponding changes in forest habitats and agricultural landscapes (e.g. Gaveau et al., 2016) leave people uncertain as to what species occurred where in the past. Efforts have been made to document as many historical records as possible so that policy decisions can be better informed of changes in Sabah's biological wealth. This gives some indication of areas from which species have been lost, and where data allow it is also possible to estimate population declines that correspond to these reductions in species' ranges.

Third, there is an opportunity to treat the Wildlife Atlas as a 'living document', whereby new records are continuously added to the database, and the species chapters are updated in digital format. Care will need to be taken to ensure the accuracy of the Wildlife Atlas, through verification and curation of all new records, but it does open the opportunity for citizen science engagement, especially with such groups as nature guides in the tourism sector, and amateur bird watchers and nature photographers.

The audience for this information is intended to be government officers with responsibilities for policy development and technical advisers, both public and private sector, who are preparing environmental assessments for development projects and certification of sustainable production of timber and agricultural commodities. It is also of interest to research and conservation communities, as well as the active nature tourism sector which can both use this information and provide further records of species occurrences.

Looking ahead, this work can provide a framework for wildlife monitoring through a digital, open-source format for annual assessments, which, in turn, may inform conservation policy and practice, and offers an opportunity to establish a state-wide wildlife monitoring system. In this way, Sabah can show how it is delivering on international commitments to the Convention on Biological Diversity and the Sustainable Development Goals, and ensure future generations enjoy the natural heritage wealth which was gifted by their parents.

To achieve these aims a collaborative approach has been essential, to bring together information from many sources and linking with the knowledge of specialists who have studied wildlife in Sabah. Researchers and technical officers have generously shared their data and understanding, and given up time to write the species chapters, and reviewers have also made important contributions. The role of WWF-Malaysia has been to establish the Wildlife Atlas database and oversee accurate input from publications, reports and many contributors' research findings (listed in each species chapter). Thereafter, to work with authors, and with the Sabah Biodiversity Centre to facilitate production of this volume.

Wildlife Species Selection

In the 1950s Davis (1962) listed 135 mammal species in Sabah, noting about one third were nocturnal, and over half arboreal, and for both reasons these species are very hard to study in the dense forest vegetation. The current estimate is now 216 mammal species in Sabah (Phillipps & Phillipps, 2018; Table 1), and the challenge to gather detailed information on many species in the wild has not diminished.

Table 1. Mammal species in Sabah (Phillipps & Phillipps, 2018)

Order	Borneo	Sabah	Sabah (near) Endemic Species
	No. of species		Common names
Eulipotyphla (Shrews)	10	10	Black Shrew, Bornean Water Shrew
Scandentia (Treeshrews)	10	7	-
Dermoptera (Colugos)	1	1	-
Chiroptera (Bats)	98	91	Gomantong Myotis
Primata	21	12	Sabah Leaf Monkey
Pholidata (Pangolins)	1	1	-
Rodentia (Rats, Squirrels, Porcupines)	66	59	Kinabalu Squirrel, Mountain Maxomys, Emmon's Tree-Rat
Carnivora	26	26	-
Proboscidea (Elephants)	(1)	1	Bornean Elephant
Perissodactyla (Odd-toed Ungulates)	1	1*	-
Artiodactyla (Even-toed Ungulates)	7	7	-
TOTAL	**242**	**216**	**8**

*Declared locally extinct in Malaysia in 2019

For the purposes of this Wildlife Atlas, therefore, it has been necessary to select a subset of species, based on the availability of detailed study findings, as well as specialist authors to write the chapters, and using the following selection criteria:

It is important to include rare species, which need urgent conservation attention, many of which are iconic and an important part of Sabah's cultural heritage. These are often flagship species for public awareness campaigns and nature tourism development, and they are also the focus of environmental impact and conservation value assessments.

It is also important to include a range of species — such as terrestrial animals that move along the forest floor, compared with arboreal species moving through the tree crowns. And species were also selected which lived in different habitats, so reflecting the range of wild spaces available in Sabah: unlogged and logged forests, agricultural landscapes, riverine habitats and wetlands.

Finally, some species which are targeted for commercial hunting and the wildlife trade were included to show the particular threats from these forms of human exploitation.

Following these selection criteria, as well as the availability of field data mentioned earlier, 31 mammal species and 6 bird species have been selected for the species chapters (Table 2). The English common names for species in this Atlas follows the *Phillipps' Field Guide to the Mammals of Borneo* (2018).

Table 2. List of species chapters

Groups	Species
Primates (8 species)	Bornean Orangutan *(Pongo pygmaeus)*
	North Bornean Gibbon *(Hylobates funereus)*
	Red Leaf Monkey *(Presbytis rubicunda)*
	Sabah Leaf Monkey (*Presbytis sabana*)
	Hose's Leaf Monkey *(Presbytis hosei)*
	Proboscis Monkey *(Nasalis larvatus)* **(r)**
	Long-tailed Macaque (*Macaca fascicularis)*
	Southern Pig-tailed Macaque *(Macaca nemestrina)*
Elephant and Ungulates (9 species)	Bornean Elephant *(Elephas maximus)*
	Sumatran Rhinoceros *(Dicerorhinus sumatrensis)*
	Bearded Pig *(Sus barbatus)*
	Bornean Banteng *(Bos javanicus)**
	Sambar Deer *(Rusa unicolor)*
	Bornean Yellow Muntjac *(Muntiacus atherodes)*
	Red Muntjac *(Muntiacus muntjak)*
	Lesser Mousedeer *(Tragulus kanchil)*
	Greater Mousedeer *(Tragulus napu)*
Carnivores and Pangolin (8 species)	Bornean Sun Bear *(Helarctos malayanus)**
	Smooth-coated Otter *(Lutrogale perspicillata)* **(r)**
	Asian Small-clawed Otter *(Aonyx cinereus)* **(r)**
	Hairy-nosed Otter (*Lutra sumatrana)* **(r)**
	Malay Civet (*Viverra tangalunga)*
	Binturong *(Arctictis binturong)*
	Sunda Clouded Leopard (*Neofelis diardi*)
	Sunda Pangolin (*Manis javanica*)
Squirrels (6 species)	Red Giant Flying Squirrel *(Petaurista petaurista)*
	Black Flying Squirrel *(Aeromys tephromelas)*
	Thomas's Flying Squirrel *(Aeromys thomasi)*
	Giant Squirrel *(Ratufa affinis)*
	Prevost's Squirrel *(Callosciurus prevostii)*
	Tufted Ground Squirrel (*Rheithrosciurus macrotis*)
Hornbills and other birds (6 species)	Great Argus Pheasant *(Argusianus argus)*
	Storm's Stork *(Ciconia stormi)* **(r)**
	Helmeted Hornbill *(Rhinoplax vigil)*
	Rhinoceros Hornbill (*Buceros rhinoceros*)
	Straw-headed Bulbul *(Pycnonotus zeylanicus)**
	White-crowned Shama *(Copsychus stricklandii)**

TOTAL: 31 mammal & 6 bird species (r = to riverine species; * = traded/hunted species)

Data sources

In the past three decades there has been a wealth of ecological studies in Sabah which have informed this Atlas. These include: the South East Asia Rainforest Research Partnership (SEARRP), with a particular focus in and around Yayasan Sabah Conservation Areas: Danum Valley since the 1980s, and more recently in the Maliau Basin/Kalabakan areas and Imbak Canyon; studies by Japanese researchers (Chubu, Hiroshima, Kyoto, Nihon, and Osaka universities) in Danum, Sepilok, Tabin, Deramakot/Tangkulap and Trus Madi; long-term ecological research programmes based on the Kinabatangan River carried out by Danau Girang Field Centre and HUTAN Kinabatangan Orangutan Conservation Project; projects by WildCru (Oxford University), University of Montana, Liebnitz Institute for Zoo and Wildlife Research, and many others.

These have all produced field records and research papers, combined with unpublished reports such as High Conservation Value assessments carried out by companies in forest concessions and plantation areas, all of which have been sought for inclusion in the chapters that follow. The sources of data used to inform the species chapters can be divided into four main types:

1. Published papers and reports which are technically accurate, and provide details of location, species and date;
2. Unpublished 'grey' literature from credible sources which also provide the required data;
3. Raw field data provided in a standardised format from field surveys and research as part of the Wildlife Atlas of Sabah project;
4. Information was added from electronic searches of websites (Annex 2). Data were reviewed and extracted, from 1960 to 2020.

Despite this wealth of information, it is important to point out some biases which have resulted in an uneven distribution of field records from across Sabah (Figure 1).

Most researchers tend to conduct studies within well-defined areas that are easily accessible and/or locations that are particularly diverse in terms of their taxon of interest, such as: Kinabalu Park, Tawau Hills Park, Kinabatangan Wildlife Sanctuary, Deramakot/Tangkulap Forest Reserves, Danum Valley and Maliau Basin conservation areas. And as a consequence, there is a lack of records from south-west Sabah and north of the Kota Kinabalu-Sandakan Road.

There is also an inevitable bias towards large-bodied and diurnal species, which are often easier to see and study from direct sightings, as well as indirect sightings (calls, tracks, dung, etc.). There tends to be fewer records of arboreal species, which are not captured in camera traps, and smaller and nocturnal species, such as the many bats and rodents.

There have been few systematic surveys of wildlife living in agricultural croplands, which mean that few records have been gathered from the monoculture oil palm plantations which account for about 20% of Sabah's landmass, and other cultivated areas.

Wildlife Atlas of Sabah Database and Maps

The Wildlife Atlas of Sabah Database contains 176,383 species records (as at April 2022), with the earliest record from 1870 (museum specimen). The database is categorised into two types of data; raw field data, and information extracted from published and unpublished literature. Raw field data

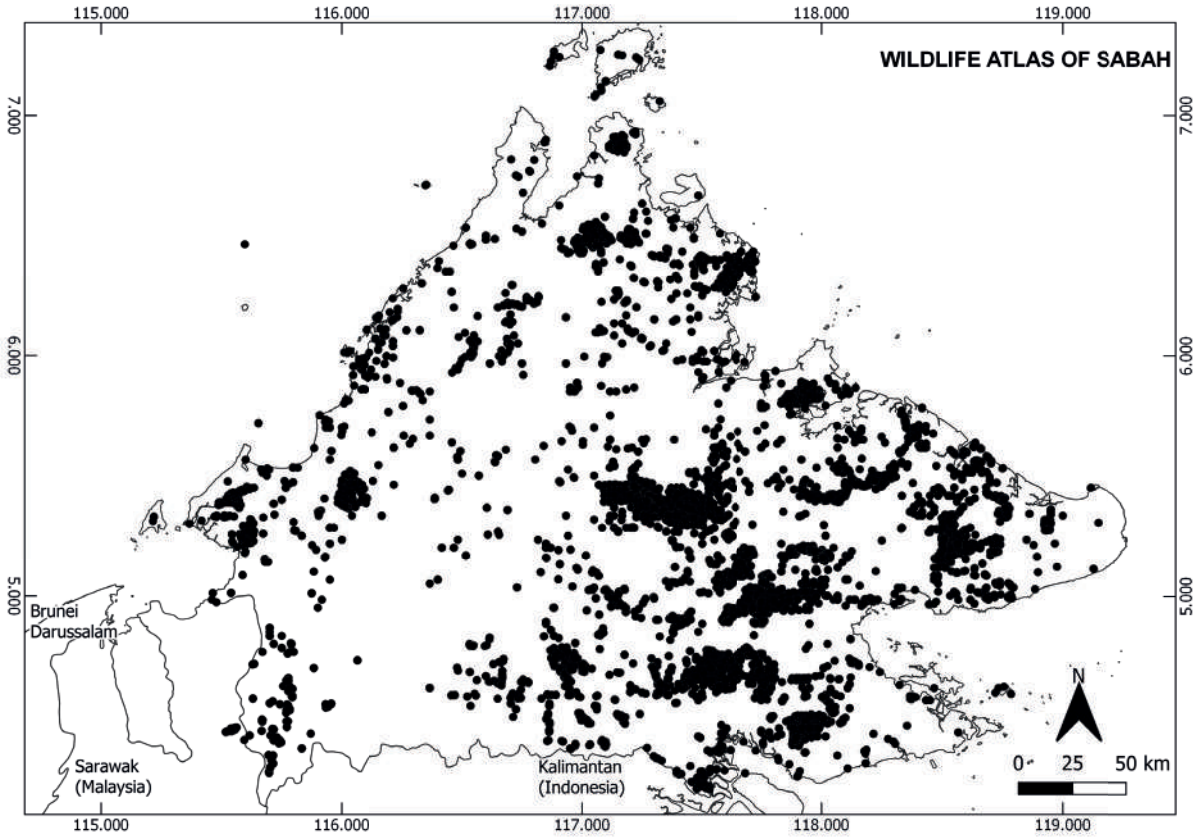


Figure 1. Distribution of wildlife records in the Wildlife Atlas of Sabah Database.

recorded on physical sheets were organised according to location and year to produce a systematic physical library, and were digitised to portable document format (PDF) to enable digital library users to systematically access original sources for data verification and follow-up. Published and unpublished data collected were organised into Excel Spreadsheets, and included fields directly related to the records of animal species, such as GPS coordinates, geographic descriptions and collection methodology (see Annex 1).

The verified data from the aforementioned databases were extracted and compiled into a Wildlife Atlas of Sabah (WAS) Database stored in MS Excel Spreadsheet format to allow cross access by other applications, to facilitate access to the WAS Database for a wide range of users, such as the Sabah Biodiversity Centre.

Managing very large datasets can be challenging due to limitations in both software and hardware capabilities. To reduce loads because of limitations in processing capacity in digital data curation, the database is split into three sections (MS Excel Spreadsheet — .xlsx files): (1) WWF central database, consisting of data collected by WWF-Malaysia from field surveys and monitoring work; (2) Database provide by non-WWF contributors from their field surveys; and (3) Data from journals, articles, reports and other reputable publications.

From these databases, a comma separated value file (.csv) is then produced by combining all data points from the three Excel Spreadsheet files. From this single value file, the database will then need to be further split into individual species datasets for building species-specific maps. This was

accomplished using R, an open source statistical computing programme (see https://www.r-project.org), to build the 37 datasets for each of the species listed in the species chapters. Most prominently, the R package 'plyr' and 'dplyr' were used to streamline the process in data sorting.

Centralised, big biodiversity databases containing aggregated data from various sources are prone to numerous data errors. In order to minimise this, the database is reviewed at least once a month by a panel of reviewers. Some of the key changes that need frequent review were: taxonomy and common names, status of forest reserve protection and wildlife legal protection. In addition, the coordinates were checked to ensure they matched the described localities. Any records that contained error, especially on the locality coordinates, were removed from the database.

It is essential to back up the databases to recover and retrieve data in case problems arise, such as system crash, disk failure or accidental deletion of data. At least two different formats were chosen as a backup strategy; on Google Cloud and on hard drives, and data are backed up once a month.

Similar to data management, open source software was also used to build maps and manage GIS data for WAS. All the maps were built using QGIS (see: https://www.qgis.org/en/site/) software. Shapefiles of some of the layers were locally built by WWF-Malaysia, and some were available as open source data. For each species chapter, a map of species records for different decades was built in different layers of habitat polygons, such as areas with particular legal status or habitat types.

Species records are represented as points, generated from the latitude and longitude readings for each record, and coloured according to different decades (see Figure 2). As mentioned previously, data used in building the maps originated from various sources. This gives rise to limitation to the data collected because different sources can have different methods and standards in collecting data. While it is possible to control the quality of information (as listed in Annex 1) in the Wildlife Atlas Database, methods used might yield different levels of data refinement. For example, data from camera traps or museum specimens can contain detailed information on location, but data extracted from reports or publications may contain limited information, such as only list of species inventory with no information on how many individuals were recorded, or precisely where in given a forest block.

Numbers of records can also be skewed towards the 2000s and afterwards (Figure 2), because of the widespread use of camera traps from that period to now. As a result, for each point, only the most recent records will be visible on the map, while earlier records for that location will be obscured underneath the most recent marking of a record overlapped by the software. Thus, a single point on the map can possibly represent multiple records over time in the same place.

Hence, the species occurrences maps stand with two assumptions:

1. Each point only indicates an occurrence of animal presence, without including the number of individuals. A single 'point' in the map can represent either an individual or a group of animals, or even secondary signs of animal presence such as dung, claw marks or nests. However, when the data are available from scientific papers, specific maps were built to show population estimates.
2. At many sites, where there is a record on the map, it is likely that the species has been present at that place for a long time. This may not always be the case, but there are almost no 'absent' records in the database, and it is assumed that presence now most probably indicates presence in the past.

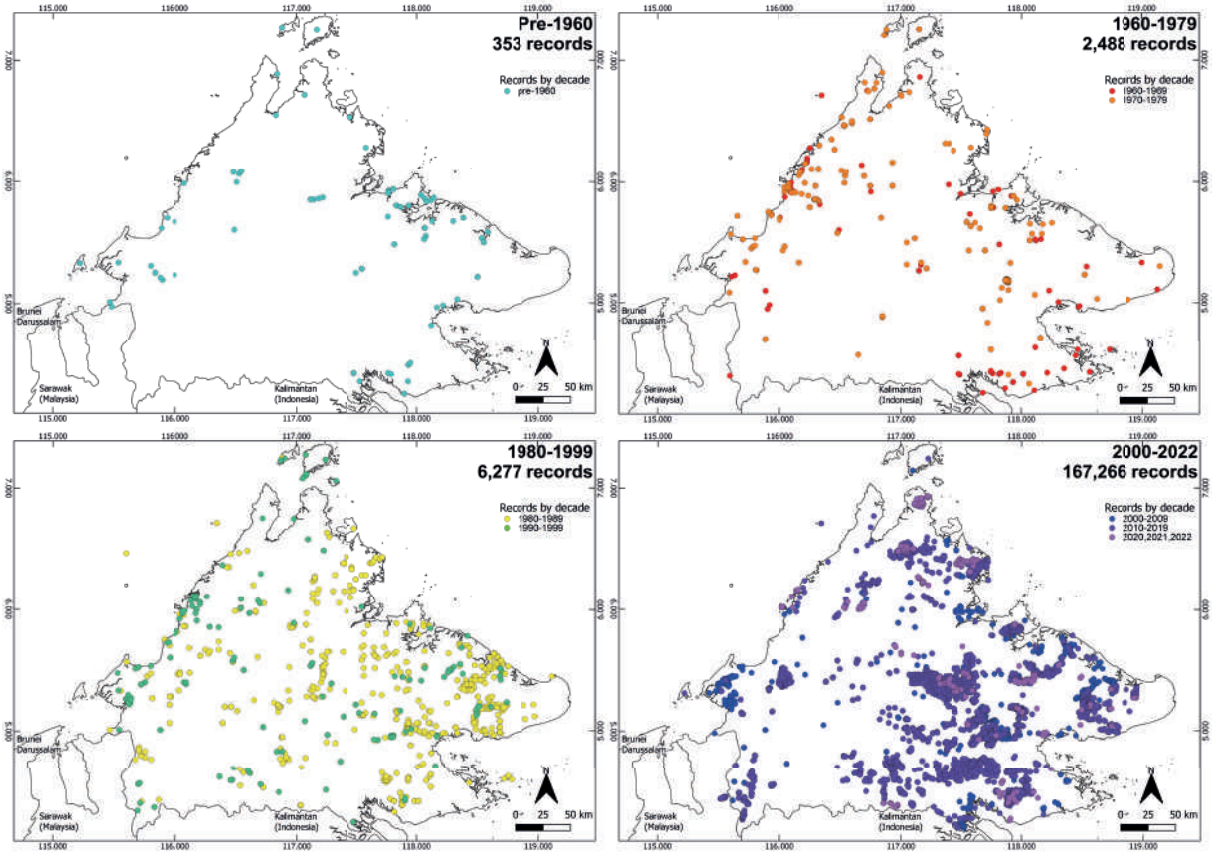


Figure 2. Maps of records from pre-1960 to 2022, showing different numbers of records in four periods

Based on these two assumptions, the readers should consider the species' maps for information on a species' distribution within Sabah. The maps generally do not show population abundance, which is included in the text where this is known, and do not show migration patterns between seasons or between years. Moving forward, new surveys and studies will provide additional information, and past records will be uncovered — all of which will add to the online dataset, and allow periodic updates to be produced to track the health of Sabah's wildlife populations.

Annex 1. Parameters recorded on the Wildlife Atlas Database.

No.	Parameters	Notes
1	**Source**	Origin of the data. This could be the name of an institution, a person or a publication's authors.
2	Identification number (ID)	Unique identification number for a record, following the original designation for raw field data. For data recorded from publications, this number is assigned by sequence.
3	Track log/camera trap ID	The unique ID as recorded in a GPS device/camera traps.
4	Date, Month, **Year**	Date for wildlife record
5	Time	Time for a wildlife record, in hh:mm:ss format
6	**Latitude**	Latitude in degree decimal format
7	**Longitude**	Longitude in degree decimal format
8	Locality	Referring to the specific position of the wildlife record. This can be the name of a trail, a *kampung* or an area.
9	Forest Reserve (FR) name/ Forest Management Unit (FMU) number	Name of the forest reserve/FMU, if the wildlife was recorded in one. Follows Sabah Forestry Department (SFD) designation.
10	FR class	Forest reserve class, following Sabah Forestry Department classifications
11	**Class, Genus, Species, Common name**	Information on wildlife taxonomy
12	Detection method	Indication of the evidence of wildlife presence. This can be direct observation, photographic, audio (e.g. animal call), track, dung, claw mark or footprint.
13	Survey method	Method used in obtaining a wildlife observation, such as by surveying along a transect line, camera trapping and opportunistic.
14	Picture	Indication of photo available for wildlife observation (yes or no).
15	Sabah Wildlife Conservation Enactment 1997 (SWCE) status	Protection status according to SWCE.
16	International Union of Conservation of Nature (IUCN) Red List status	Conservation status according to the IUCN Red List.
17	Habitat type	Type of forested habitat where wildlife was observed, in numerical classification: (1) Montane forest, (2) Mangrove forest, (3) Peat swamp forest, (4) Primary dipterocarp forest, (5) Secondary dipterocarp forest, (6) Actively logged forest, (7) Agricultural plantation, (8) Pasture/ bush, (9) Housing/Settlement and (10) Cleared land.
18	Habitat description	General description or notes on the habitat where wildlife was recorded.
19	Observer/Collector	Name of collector or observer that witnessed the wildlife recorded.
20	Notes	Additional/interesting notes on the wildlife, its particular behaviour, physical descriptions and etc.
21	Library reference	Indicates the file name of the stored physical/ digital field notes/publications.

Bold: *Compulsory information needed to build maps*

Data sources

Types	Name	No. of records	Notes
Digital library	WWF-Malaysia Knowledge Management Centre wwf.libsys.my	314	The digital library focuses on a specific content and allows users to fine-tune search results. We formulated a search strategy using appropriate keywords, such as 'Borneo', 'Sabah', 'wildlife', 'mammal', 'faunal', or 'bird' and 'survey', 'distribution', or 'diversity', followed by the corresponding name of protected forest area and we also searched for all possible combinations of keywords (e.g. Kulamba wildlife survey; birds of Gaya Island).
	Biodiversity Heritage Library biodiversitylibrary.org	9	
	National University of Singapore (NUS) — Library & Lee Kong Chian Natural History Museum digitalgems.nus.edu.sg	112	
Search engine	Google Scholar scholar.google.com	1917	We also used the aforementioned keywords in Google Scholar, as this search engine provides a wider content found in the digital library, grey literature and content from university repositories, such as UMS Institutional Repository and Kyoto University Research Information Repository.
Data repository	eMammal emammal.si.edu	2866	A cyber-tool that manages and archives data for camera trap research projects. The uploaded camera trap pictures were reviewed and archived at the Smithsonian Data Repository.
	Vert Net vertnet.org	5	A tool to share open access biodiversity data, supported by the National Science Foundation (US).
	Zenodo zenodo.org	1223	A data repository that publishes validated datasets collected by many, including the Stability of Altered Forest Ecosystems Project (SAFE).
	The Western Foundation of Vertebrate Zoology Museum (WFVZ) wfvz.org	1	A zoological museum with records of more than 4,500 bird specimens (skins, wings, egg sets and nests) from Sabah in its online database.
Digital specimen data	Birdtours birdtours.co.uk	1	Birdtours website is a UK-based platform for birders all over the world. This website also provides information on bird watching trip reports.
Trip report	Mammal watching mammalwatching.com	45	This website provides information of mammal watching trip reports.
	WWF-Malaysia Kota Kinabalu Library	12	Books and scientific expeditions that are not available online.

2

Biogeography

M. Faisal Mohd Noor and Diana Anthony

The island of Borneo (743,330 km²) is the third largest in the world and is divided into three countries: Kalimantan Indonesia in the south (539,238 km² or 73% land area); two East Malaysian states, Sabah and Sarawak, in the north and north-west (198,447 km² or 26%), and Brunei Darussalam (5,765 km² or 1%) between them in the north-west.

Early History

Borneo is a part of Sundaland, the biogeographical region of Southeast Asia that encompasses the Sunda shelf, a south-eastern extension of the Asian continental shelf (Figure 1). Most of Sundaland

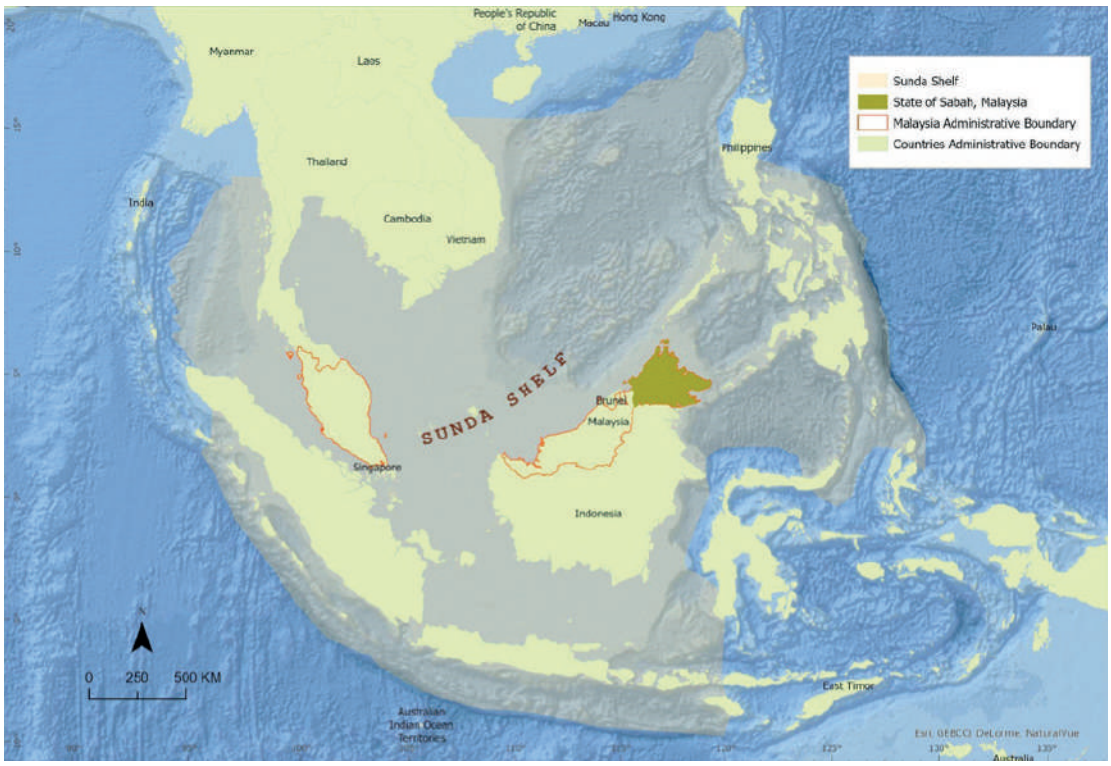


Figure 1. Sundaland (Source: Doust and Sumner, 2007)

is now under water, but it was entirely exposed as dry land numerous times during the global glacial events of the Pleistocene. When completely exposed, Sundaland forms a subcontinent of about 1,800,000 km^2. The current lands of the Sunda shelf are the Greater Sunda Islands (Borneo, Java, Sumatra, and Palawan), the Malay Peninsula and many smaller islands (Molengraaff, 1921; Sheldon et al., 2014). The ocean covering the Sunda shelf is quite shallow and includes the South China Sea, the Gulf of Thailand and the Java Sea, with depths averaging less than 100 m. The current Sundaic lands include substantial mountain ranges (from about 1,000–4,000 m in elevation), volcanoes, alluvial plains, lakes, swamps. These lands constitute one of the two greatest concentrations of terrestrial and freshwater species diversity on Earth (Leonard et al., 2015; Lohman et al., 2011; World Bank, 2001).

Ancient environmental fluctuations have had a remarkable impact on patterns of species diversity and occurrence in Sundaland. Specifically, the sea-level changes that repeatedly connected and disconnected Borneo, Java, Sumatra and the Malay Peninsula alternately drove colonization and isolation events that mixed and separated populations of species. Habitat changes within Borneo corresponding to periods of cool-dry versus warm-wet conditions alternately caused savanna grasslands and woodlands versus rainforest to expand and contract. This dynamic mix of colonization, isolation, and shifting habitats acted as a speciation pump, driving biodiversity we see today in Borneo.

Another key factor in promoting Bornean biodiversity is the island's age and diverse landscape. Borneo is much older than Sumatra and Java. The western part of Borneo has been in existence since the Mesozoic era (over 66 million years), whereas eastern Borneo emerged some 45-25 million years ago (Hall, 2013). The geological main force responsible for Borneo's mixture of mountains, rolling hills, and extensive lowlands was the clash of continental plates starting in the Eocene (Moss & Wilson, 1998). Plate movement caused the interior of Borneo to be pushed up into an enormous mountain chain, which subsequently underwent massive erosion due to tropical rainfall. That erosion wore the mountains down to the peaks and rolling hills currently found in central Borneo, and the extensive debris and sediment caused by the erosion built the lowlands and coastal plains of the island. Most of the mountains of Borneo are either the worn remnants of the central mountain range, e.g. Mt. Trusmadi (2,642 m) and Mt. Lotung (1,781 m), or isolated volcanoes, e.g. Mt. Magdalena (1,307 m) and Mt. Lucia (1,200 m) in Tawau Hills Park. The one prominent exception to this pattern is Mt. Kinabalu. Kinabalu is a resistant remnant of the once mighty central mountain range. It consists of extremely hard volcanic rock that intruded under the softer rock of the range. As the softer montane rock eroded away, the hard volcanic rock of Kinabalu was exposed, resulting in the 4,000 m pinnacles of today.

In addition to these geological events, immense climatic changes over the long term strongly influenced Bornean biodiversity. During the Palaeocene and Eocene (66–34 Mega-annum (Ma)) the overall climate of Earth was warm and wet, ideal for the evolution of tropical forest fauna and flora, and these conditions pervaded Borneo (Morley, 2000). But following this tropical period was the colder and drier Oligocene (34–23 Ma), when rainforest in Borneo retreated to the large and ancient mountains of the north-east. In this region the altitude and relative proximity of the mountains to the coast resulted in orographic rainfall, which provided the wetter conditions required by rainforest, and refugia were presumably maintained for a variety of flora and fauna (Sheldon et al., 2015). At the same time, most of the rest of Sundaland was covered in drier habitat (Morley, 2000). Following the Oligocene came the warmer and wetter Miocene (23–5 Ma) and the consequent

explosion of tropical flora and fauna, then the colder and drier Pliocene (5–2.6 Ma), when forests again retreated to north-east Borneo, as well as the mountains of Sumatra and Java, which by this time had developed substantially.

Climatic conditions during the most recent geological epoch, the Pleistocene (2.6 million to 12 thousand years ago), continued this cycle but at a faster tempo. Cold and dry periods lasted between 40,000 to 100,000 years, when sea levels dropped to expose the Sunda shelf and united Sundaland into a single landmass, which was dominated by dry habitats. These periods were interspersed with shorter spells of some 10,000 years with warmer, wetter conditions when sea levels rose and tropical forests re-expanded across the Sunda landmasses. The transition between drier and wetter extremes created a patchwork of forest, non-forest and wetland habitats spreading out from forested montane refugia. The isolation and reconnection of Borneo with the other Sunda islands happened at least nine times during the Pleistocene (Bintaja et al., 2005), and greatly contributed to the species richness and endemism of wildlife for Borneo in general (Leonard et al., 2015), and Sabah in particular (e.g. Sheldon et al., 2015).

Climate

Sabah enjoys a tropical climate with mean daily temperatures of 32°C but can reach up to 34°C on warmer days. Most parts of Sabah receive rain averaging ca. 3,000 mm per annum, hence humidity

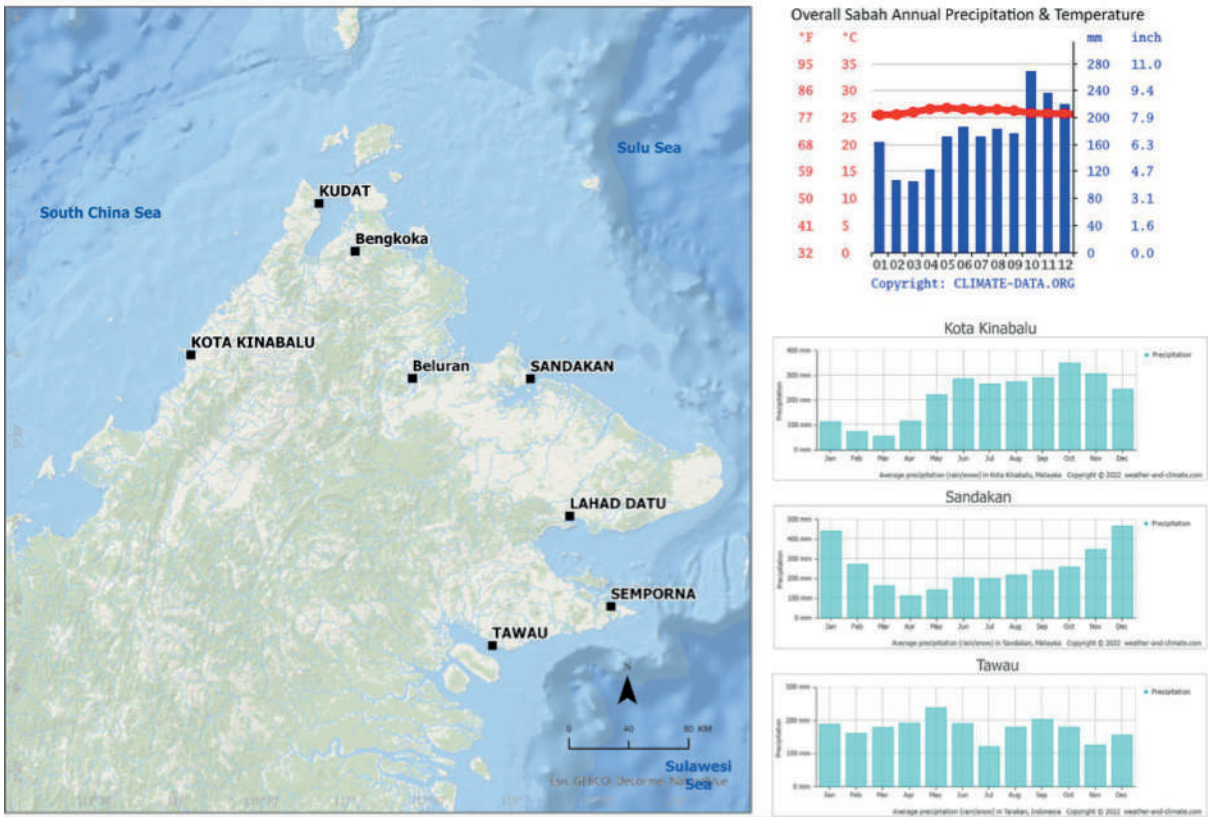


Figure 2. Sabah average monthly rainfall (Source: World Weather & Climate Information & Climate-Data.org)

is relatively high ranging from 80–98% depending on the time of year as well as location. The climate of Sabah is influenced by the monsoons with the north-east monsoon occurring between November and March while the south-west monsoon from May to September. These monsoon periods bring prolonged rains, interrupted by two inter-monsoon periods from October to November and April to May (Figure 2). It is during the inter-monsoon that prolonged droughts can occur associated with the oscillating warming and cooling waters, referred to as the El Niño–Southern Oscillation (ENSO) Cycle, in the Pacific Ocean.

Although Sabah has been known as the Land Below the Wind in the past, recent storms (e.g. Greg Storm in 1996 and Vamei Cyclone in 2001) originating from the South China Sea and the Philippines Sea caused some serious flooding and landslides within the State. Approximately 20 tropical cyclones enter the Philippines yearly, and 10 are expected to turn into typhoons with five having the potential to be destructive. Sabah is vulnerable to the 'tail effects' of these typhoons if they move further south from their normal east to west path of destruction (Yusuf & Francisco, 2009).

Drought is a recurrent event in Borneo (MacAlpine et al., 2018). There have been three episodes of prolonged drought events associated with the ENSO events in the periods: 1993–1997, 2008–2012 and 2015–2016. Past studies have reported differences in drought impacts by forest types (Miyamoto et al., 2021). Tree mortality tends to increase at lower elevation below 700 m affecting most in peat swamp forest and mixed dipterocarp forest, but not on higher elevations above 1,700 m on ultramafic soils. Large trees were also generally more vulnerable to prolonged droughts resulting in mortality (Phillips et al., 2010). Of significance, forest losses associated with fires affect the habits, food resources and movements of wildlife populations.

In terms of changing patterns of climate, rainfall records over 30 years (1977–2007) have shown significant change in distribution of rainfall patterns (Figure 3).

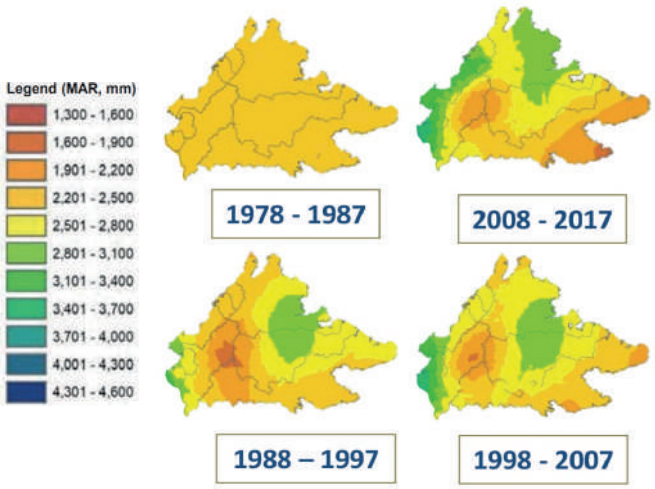


Figure 3. Changing rainfall patterns in Sabah (Source: Sabah Meteorological Department)

Landforms and Soils

Sabah is located at the northern part of Borneo, and has a total landmass of 7.34 million ha. The western region of Sabah is characterised by narrow coastal plains and low-lying areas running in a northeast–southwest direction. This landform gradually changes to rugged mountains in the central region with the Crocker-Trusmadi Range defining the north-south spine, and the Waitland–Brassey the east-west spine. This rugged terrain with nine mountain peaks makes up 70% of Sabah's landmass with the highest peak recorded at Mt. Kinabalu (4,101 m). The hilly terrain in the central region breaks into undulating hills and lowland towards the eastern region of Sabah.

Geologically, Mt. Kinabalu is composed of the Late Miocene granite (Cottam et al., 2010;

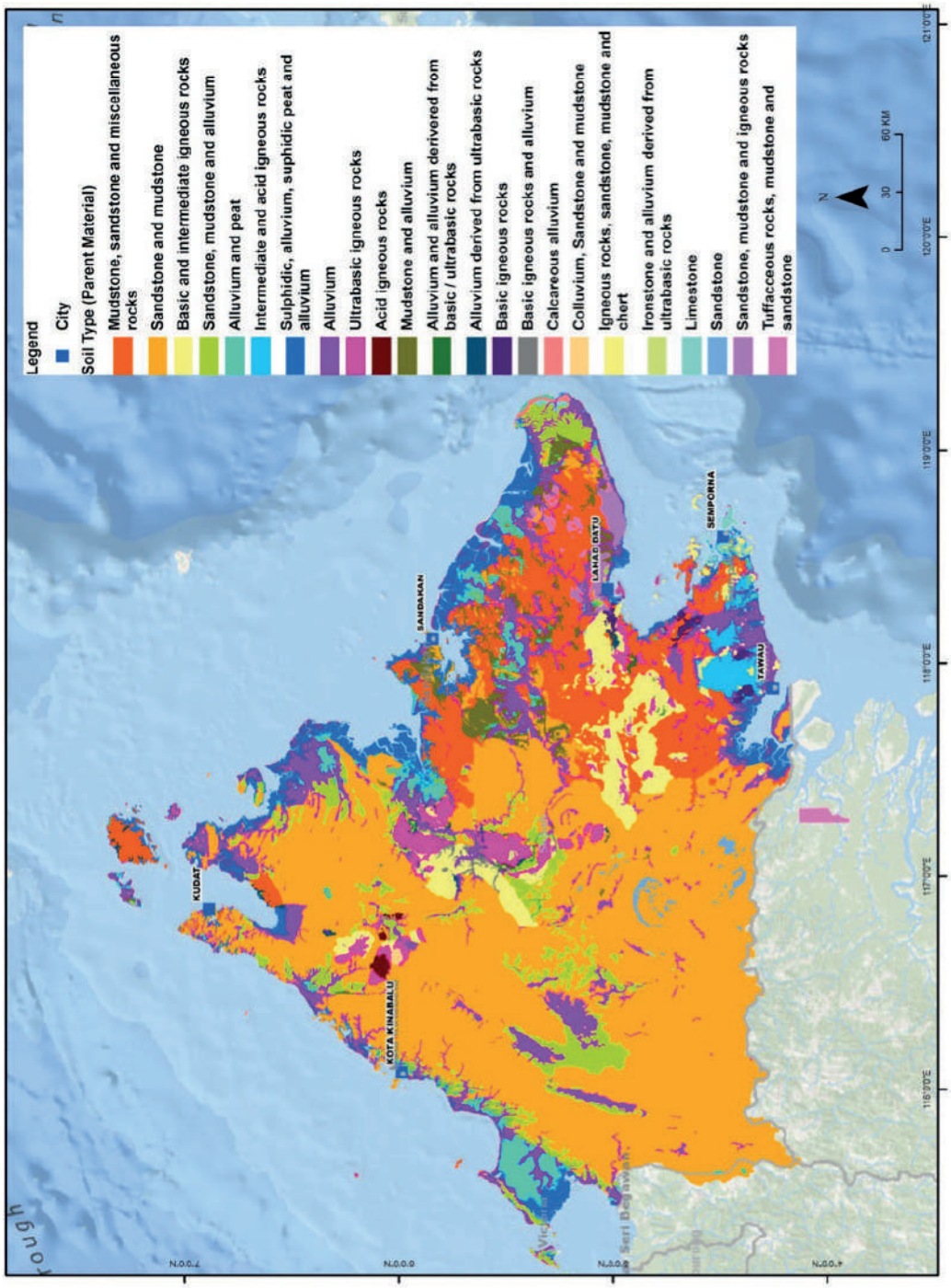
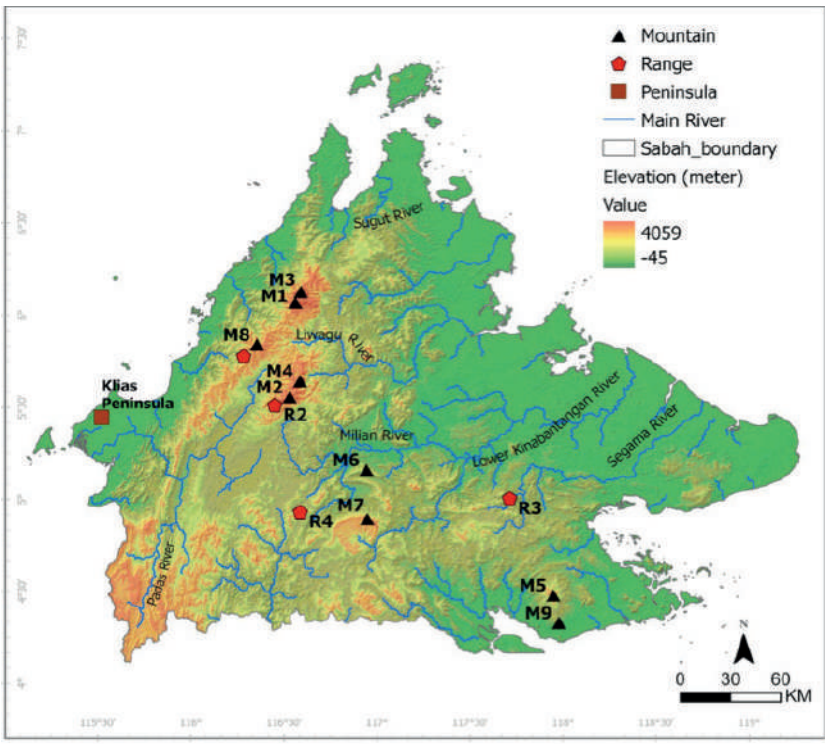


Figure 4. Soil map (Source: Malaysia National Mapping)

Jacobson, 1970), different from Trusmadi which is formed from thick dark shale beds interbedded with thin sandstone layers. The basement rock of this part of Sabah is an ophiolite mélange, an ocean-floor subduction rock probably of Cretaceous age (Hall et al., 2008). The Labuk Highlands (1,200 m) in the eastern region of Sabah forms part of the Crocker Range consisting of ultrabasic massifs (often called ultramafic) which account for only 1% of Borneo's land area (MacKinnon et al., 1996). Individually these mountains are separated by faulted strips of pillow basalt and sedimentary rocks.

The continuous weathering of the mountains over decades has produced soils derived from sedimentary rocks of the Crocker and Trus Madi formations with properties deferring with elevation (Wong et al., 2020). Sedimentary rock formations consisting of sandstone, shale, claystone and limestone are widespread in Sabah (Figure 4). In the western lowlands, these soils are associated with floodwaters drained by major rivers such as the Sg. Kadamain, Sg. Tuaran and Sg. Papar. The soils developed from these floodplains are riverine alluvium, and these have supported early plantation development since the 1880s. The oldest volcanic rocks, such as those found in Tinagat Hill, are mainly of Pliocene age (5.4 to 2.4 Ma), and provide the whole Tawau–Kunak area in eastern Sabah with fertile parent material for cultivation, with the earliest commodity crops being abaca, rubber, cocoa and oil palm that replaced the original lowland forests.



Mountain Information Table

ID	Name	Height
M1	Mt. Kinabalu	4,095 m
M2	Mt. Trusmadi	2,642 m
M3	Mt. Tambuyukon	2,579 m
M4	Mt. Kaingaran	2476 m
M5	Mt. Magdalena	1,310 m
M6	Imbak Conyon	1,1120 m
M7	Maiau Basin	1,667 m
M8	Mt. Alab	1,951 m
M9	Mt. Andrassy	655 m

Range Information Table

ID	Name
R1	Crocker Range
R2	Trusmadi Range
R3	Brassey Range
R4	Waitland Range

Figure 5. Mountain ranges and peaks in Sabah (Source: NASA Shuttle Radar Topography Mission)

River Systems

Sabah has an extensive river system (Figure 5). Rivers that drain into the west coast include Sg. Moyog, Sg. Babagon and Sg. Padas, and those that discharge their water in the north are Sg. Bandau, Sg. Kinorum and Sg. Pitas. Among the rivers draining into the eastern Sabah are Sg. Liwagu, Sg. Sugut, Sg. Segama, Sg. Tawau and Sg. Kinabatangan. Being the longest at 560 km, Sg. Kinabatangan has its headwaters in the mountains of south-central of Sabah, and together with the Sg. Segama and Sg. Sugut, these rivers discharge their waters into the Sulu Sea.

The riparian vegetation in these large river systems provide important habitats and connectivity for wildlife to move from one forest patch to another. In 1997, the lower Kinabatangan floodplain comprising of 28,000 ha was declared the 'Kinabatangan Corridor of Life' to protect its rich flora and fauna biodiversity. Up to 40 species of freshwater fishes have been reported as endemic to Sabah (Sabah Biodiversity Conservation Strategy, 2012). These major river networks provide the lowland areas with alluvial soils. These rivers play an important role in the socio-economic development of Sabah's population including the provision of drinking water, recreation and protein for the rural poor. In addition, the upstream waters of these major rivers are habitats for aquatic as well as wild animals.

Forest Formations

The forest of Borneo is one of the oldest in geological history which have evolved since the Mesozoic Era lasting from about 252 to 62 Ma comprising of the Triassic Period (250–200 Ma), Jurassic Period (200–145 Ma) and Cretaceous Period (145–65 Ma). Its present existence is thought to have evolved in response to changes in the physical environment during ancient times. At global scale, tectonic movements that split landmasses and uplift landforms as well as changes in sea level, encompassing the Sundaland, had influenced the distribution of plants and animals and their diversity. Their limits are also determined by regional climatic factors (temperature and precipitation) and differences in topography and edaphic factors as well as anthropogenic impacts.

According to recent work by the Sabah Forestry Department (Nilus et al., 2014), the forest formations consist of nine types; namely, (1) Beach Forest (58,580 ha or 0.8%), (2) Mangrove Forest (413,688 ha or 5.6%), (3) Peat Swamp Forest (118,977 ha or 1.7%), (4) Freshwater Swamp Forest (334,336 ha or 4.5%), (5) Lowland Mixed Dipterocarp Forest (3,481,238 ha or 47.1%), (6) Upland Mixed Dipterocarp Forest (1,360,906 ha or 18.4%), Heath Forest (1,227,565 ha or 16.6%), Limestone Forest (4,254 ha or 0.1%), Ultramafic Forest (198,428 ha or 2.7%) and Montane Forest (195,878 ha or 2.6%) (Figure 6).

Beach Forest

Beach forests can be found along the coastal areas and islands of Sabah with a total extent of 58,580 ha representing 0.8% of the total landmass of Sabah. On land, pristine beach forests exist in scattered places in the west coast and northern region of Sabah. The forest vegetation is characterized by low stature shrubs (*Barringtonia asiatica*, *Pandanus odoratissimus*) along the beaches and inland trees of the species *Hernandia peltate*, *Terminalia catappa*, *Callophyllum innophyllum*, *Pongamia pinnata* and *Casuarina equisetifolia*. This forest type is favoured by crustaceans and insects competing for resources as well as reptiles and avifauna population using the beach forest as stepping stone along their migrating routes. In pristine beach forest, the presence of Bearded Pigs, squirrels and macaques have been reported (Zakaria & Rajpar, 2015).

Mangrove Forest

Mangrove forests cover a greater part along the eastern and south-eastern coasts, with a total extent of 413,688 ha representing 5.6% of the total landmass of Sabah, and over half of Malaysia's mangroves are found in Sabah. Generally, the Avicenna-Sonneratia mangrove forest is found in the seaward zone, and at the main mangrove zone, away from the river mouth, the Rhizophora mangrove forest exists. Further inland, Bruguiera mangrove forest is most common. The mangrove forest transient to the Nipa Forest in the upstream due to greater freshwater content. The importance of mangrove ecosystems in providing goods (e.g. poles, charcoal) and services (e.g. protecting shorelines) have been well-documented.

Swamp Forest

Swamp forests may be broadly separated into peat swamp forest and freshwater swamp forest. Together, they occupy 453,313 ha or 6.1% of the total landmass of Sabah. The largest extent of peat swamp forest is found on the Klias Peninsula, while freshwater swamp forests can be found along major river systems such as Sg. Kinabatangan, Sg. Segama, Sg. Sugut and Sg. Padas. This forest is seasonally inundated by flood waters during the monsoon periods. Common trees species of this forest formation are those in the family of Dipterocarpaceae (e.g. *Parashorea* spp., *Hopea* spp., *Vatica* spp.) and Fabaceae (e.g. *Cassia* spp. and *Sindora* spp.). Other important families are Rubiaceae (e.g. *Pleiocarpidia* spp.) and Moraceae (e.g. *Artocarpus* spp., *Ficus* spp.).

Mixed Dipterocarp Forest

Mixed Dipterocarp Forests (MDF) is named after the dominant tree family Dipterocarpaceae comprising of 16 genera and 600 to 700 species. In Sabah, the altitudinal zonation of this forest formation is 0 to 500 m asl as Lowland Mixed Dipterocarp Forest (LMDF), and 500 to 1,000 m asl as Upland Mixed Dipterocarp Forest (UMDF) (Sabah Forestry Department, 2003). The defining features of these forest formations are their species composition, tree density or basal area as well as forest structure.

LMDFs are scattered across the landscape of Sabah covering less than 22% or 600,000 ha of its historical extent. The dominant trees in the upper canopy are usually in the family Dipterocarpaceae (*Shorea* spp., *Anisoptera* spp., *Cotylelobium* spp., *Dryobalanops* spp., *Hopea* spp.), and in the tree family Myrtaceae (*Syzygium* spp., *Tristaniopsis* spp.). Common trees in the understorey are represented by tree family Anacardiaceae (*Mangifera* spp.) and Myrtaceae. The forest structure typically shows saplings in the range of 10,000 to 15,000/ha in primary forest while only 20 to 40/ha for large trees. The upper canopy is typically greater than 40 m high followed by 3 or 4 intermediate canopy layers. Seedlings and saplings in the understorey regenerate and accelerate their growth through gaps created by tree falls that increase the light available. A prominent feature of this forest formation is the presence of lianas and epiphytes.

The UMDF occupies 1.36 million ha or 18.4% of Sabah's landmass. These forest formations contain climax species of the altitudinal zone immediately above the LMDF. A subtle difference between the UMDF and LMDF is in the specific composition of the dominants and in tree density and basal area. The vertical structure in these forest formations typically exhibit 3 to 5 vertical layers depending on the extent of disturbance. There are also differences in tree spatial distribution associated with local topography, soil types and moisture regimes.

The flowering/fruiting patterns of trees in dipterocarp forests are complex, and fall into two

distinct categories: a) species that are mainly restricted to a synchronised flowering and fruiting syndrome within a particular season; and b) those that regularly flower outside the main flowering/fruiting season, sometimes throughout the year (Appanah, 1993). When many individuals fruit together, it is termed "mast fruiting", and some of the earliest surveys in Sabah (Wood, 1956) found over two-thirds of trees from 200 or so dipterocarp species fruited during one strong mast fruiting event, but much less so in non-mast fruiting years. During mast fruiting events, the wildlife community gets to feed on the fallen fruits in substantial quality.

Heath Forest

Heath forest, also known as Kerangas forest, is a fragile ecosystem founded on podzolic soils which are generally infertile because of low nitrogen content and higher content of sands. The podzolic soils

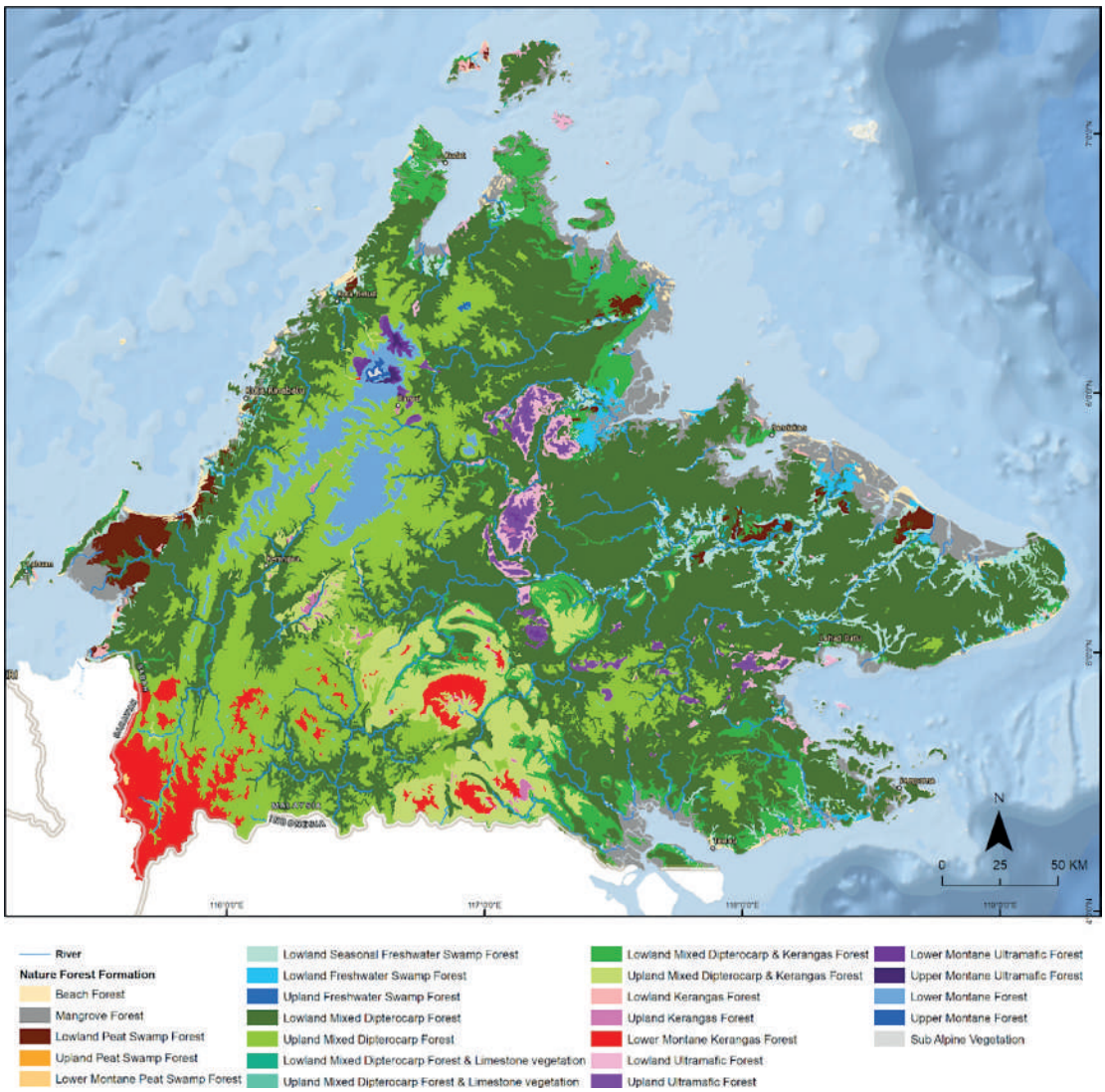


Figure 6. Major natural forest types before land conversion to agriculture (Source: Forest Research Centre, Sabah Forestry Department)

also have poor water retention and are extremely acidic, hence limiting to plant growth. Where trees exist, they are stunted in height and small in diameters (Kartawinata 1978; 1980; Whitmore 1984). Heath forests are generally less species-rich than other lowland rainforests (Proctor et al., 1983). Trees that dominated this forest are in the family Myrtaceae (*Tristaniopsis obovata* and *Garcinia miquelii*, *Mezzetia* sp., *Syzygium* sp. and *Xylopia ferruginea*) (Sabah Forestry Department, 2015). This forest type is also characterized by the presence of insectivorous plants such as the variety of Bornean pitcher plants (*Nepenthes* spp.). The present extent of Heath Forest is 1.23 million ha or representing 16.6% of the total landmass of Sabah (Quintela-Sabaris et al., 2019) found mostly in the south-western part of Sabah and at the ridges of Maliau Basin.

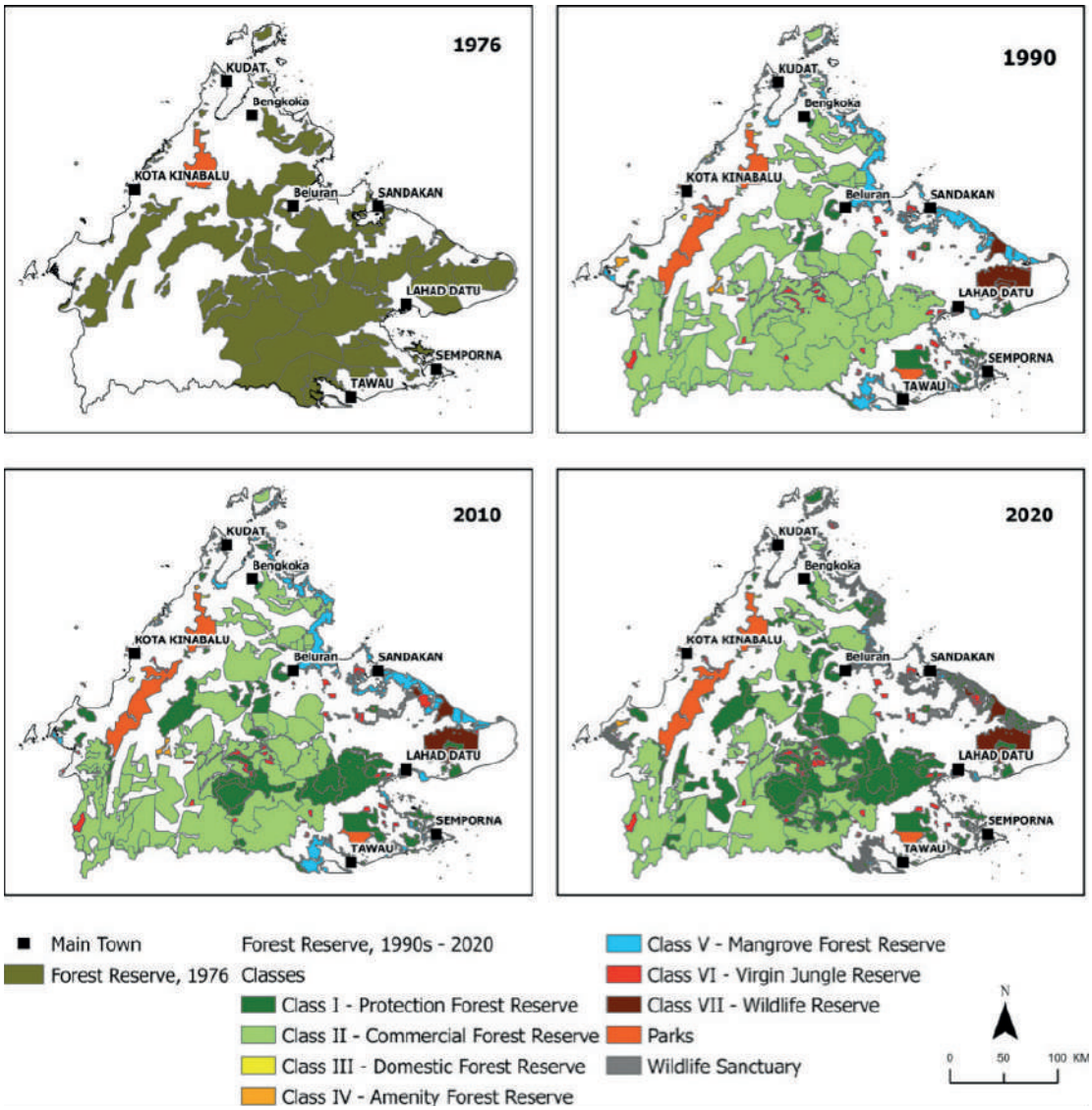


Figure 7. Changing pattern of Forest Reserves, beginning in the mid-1980s when large blocks of lowland forest in the east was given over to agriculture and areas in the south-west gazetted as Forest Reserves. Parks were established by 1985, and Class I FRs identified from 2010 onwards.

Ultramafic Forest

The Ultramafic Forest of Sabah can be found on 198,428 ha or 4.7% of Sabah's landmass out of the 350,000 ha ultramafic outcrops reported for Sabah (Proctor et al., 1988; Quintela-Sabaris et al., 2019; Repin, 1998; van der Ent et al., 2015). The largest ultramafic outcrops are around Mt. Kinabalu, Hampuan and Kulung Hill, Morou Porou, Bidu-Bidu Hills, Meliau Range, Mount Tawai and Mount Silam, spanning sea level up to nearly 3,100 m asl. Ultramafic soils are generally deficient in plant-essential nutrients such as nitrogen, phosphorus, potassium and sulphur. However, it has been reported that the ultramafic flora of Sabah was one of the richest in the region, containing a recorded 4,252 species in 207 families and 1,047 genera with a high proportion of endemics. The conservation value of ultramafic forest is in its remarkable biological capacity to absorb heavy metals and metalloids (e.g. nickel, manganese) in leaf tissues from contaminated soils (Quintela-Sabaris et al., 2020).

Montane Forest

The mountain forest formations can be sub-divided into Lower (1,000–2,500 m asl) and Upper Montane Forest (2,500–3,500 m asl). On Lower Montane Forest, trees in the family Fagaceae (e.g. *Castanopsis* spp., *Lithocarpus* spp., *Quercus* spp.), Myrtaceae (e.g. *Syzygium* spp., *Tristaniopsis* spp.), Clusiaceae (e.g. *Garcinia* spp., *Calophyllum* spp.), Podocarpaceae (e.g. *Agathis* spp., *Podocarpus* spp., *Dacrydium* spp., *Phyllocladus* spp., *Falcifolium* spp.), and Lauraceae (e.g. *Gymnostoma* spp.) are found (Kueh et al., 2017; Suratman et al., 2011). On Upper Montane Forest, conifers and oaks species become more dominant and exhibit low stature with prominent small diameter stems due to the relatively young and thin soil associated with this landform. Sightings of ungulates, squirrels and birds have been reported in Lower Montane Forest. Wildlife sightings in the Upper Montane Forest are rare because of the lack of food resources.

It is important to bear in mind that the altitudinal zonation of different forest formations varies on different mountains. On smaller, isolated mountains, especially those near the coast such as Mt. Silam and the Tawau Hills, the transition between upland and montane, and between the various types of dipterocarp forest formation, is at much lower altitude. On larger mountain ranges and massifs, the forest formations change at higher altitude – which is known as the *Massenerhebung* effect (Whitmore, 1998). The overall impact in Sabah has been to standardise the altitudinal zones for mixed dipterocarp forests: Lowland at 0–200 m; Upland at 200–500 m; Hill at 500–1,000 m; then Lower Montane at 1,000–1,500 m and Upper Montane above 1,500 m (R. Ong, pers. comm.).

Changes in Forest Cover

Over the last 12 decades, the net global loss in forests was reported to be 4.7 million ha per year (FAO, 2020). In contrast, only one-tenth of this loss has been reinstated through reforestation and natural regeneration. A similar trend is happening in Sabah's forest since the 1970s.

The timber boom in the 1970s had accounted for 55% of total exports and State revenue (Sabah State Government, 1981). Most of this revenue comes from logging the Class II Commercial Forest Reserve and converting forest in State land into mono-culture plantations. A new timber policy was introduced in 1976 in order to have better management of the industry with the main goals of reducing log exports, improving local wood-based industries, and raising a timber levy loyalty to 70% (Keong, 1981). This change brought timber revenue increases from 150 million in 1975 to 1,050

million in 1979 (Kinabalu Sabah Times, 1979).

For the states of Sabah and Sarawak, WWF-Malaysia recorded a forest loss of 1.9 million ha between 2004 to 2017. This is 33% out of the 5.9 million ha of forest loss identified for the whole of Borneo over the same period. For Sabah almost half of the forests have disappeared between 1973 to 2020 to human made landscapes (croplands, built up areas and barelands), especially for the lowland forest in the east coast (Kinabatangan floodplain) mainly to oil palm cultivation which stands at 1.78 million ha state-wide (Department of Statistics Malaysia, 2017). Expansion of oil palm in particular seems unstoppable as currently no other crop can compete with the economic benefits of oil palm. The expansion today is mostly based on smallholders' land despite the suitable lands and soils for this crop being very limited in Sabah.

It can be said that deforestation in Sabah started to accelerate with the industrialisation policy introduced between 1980 to 2000, with more areas opened for oil palm cultivation. By 2010, it was estimated that less than 70,000 ha of undisturbed lowland dipterocarp forests remained with almost none outside of the officially recognized protected areas (Reynolds et al., 2011). In terms of habitat loss, the disappearance of old growth (unlogged) forest throughout the State's Commercial Forest Reserves has been dramatic from about 27,671 km^2 in 1980 to only 700 km2 in 2010 — less than one percent of the State (Payne & Davies, 2013).

Between 1970–1990, timber wealth was mostly spent on agricultural development as 70% of the population was engaged in agriculture. Poverty alleviation strategies involved land opening and hence rapid conversion of forest lands to agriculture and settlements. A new land alienation policy was introduced in 1977 which involved the identification and degazettement of more than 360,000 ha of forest reserves for agricultural settlement and schemes (Keong, 1981), and state agencies were established and empowered to lease forest lands and to organise communities for agricultural development, mainly on commodity monocrops such as rubber, cocoa and oil palm. This pattern of changing permanent forest estate is shown in Figure 7 (page 20), and the current state is shown in Figure 8.

Agricultural Landscape

The agricultural sector in Sabah has been based on a commercial scale, where commodity crops starting with abaca, tobacco, rubber, cocoa, rubber and lastly oil palm were introduced as early as the 1880s. The extension of these different crops was driven by the global commodity markets, and resulted in the creation of a legal framework in which individual ownership and sale of land became possible in Sabah. Thus, a cash economy emerged but it was also the starting point of fragmentation and loss of forest due to the monocrop systems.

Historically, the first major grant of land allocated for plantation in December 1882 was 40,000 acres for initiating tobacco cultivation. The tobacco boom was, however, short-lived and cultivation shifted to the more remunerative plantation crop, rubber. In scope and extent, the rubber industry that peaked in the 1960s proved to be of greater significance to North Borneo, and impacted local farming and land rights as it was recognised as being as important as food crop (rice) at that time. Two other major export crops which declined earlier were copra (coconut based product) and hemp.

During the Third Malaysia Plan (1975–1980), the total cocoa area in Sabah reached 60,000 ha, and the State successfully established almost 20,000 ha of oil palm. At its peak in the mid-1980s, the cocoa growing area had expanded to more than 400,000 ha, placing the State among the

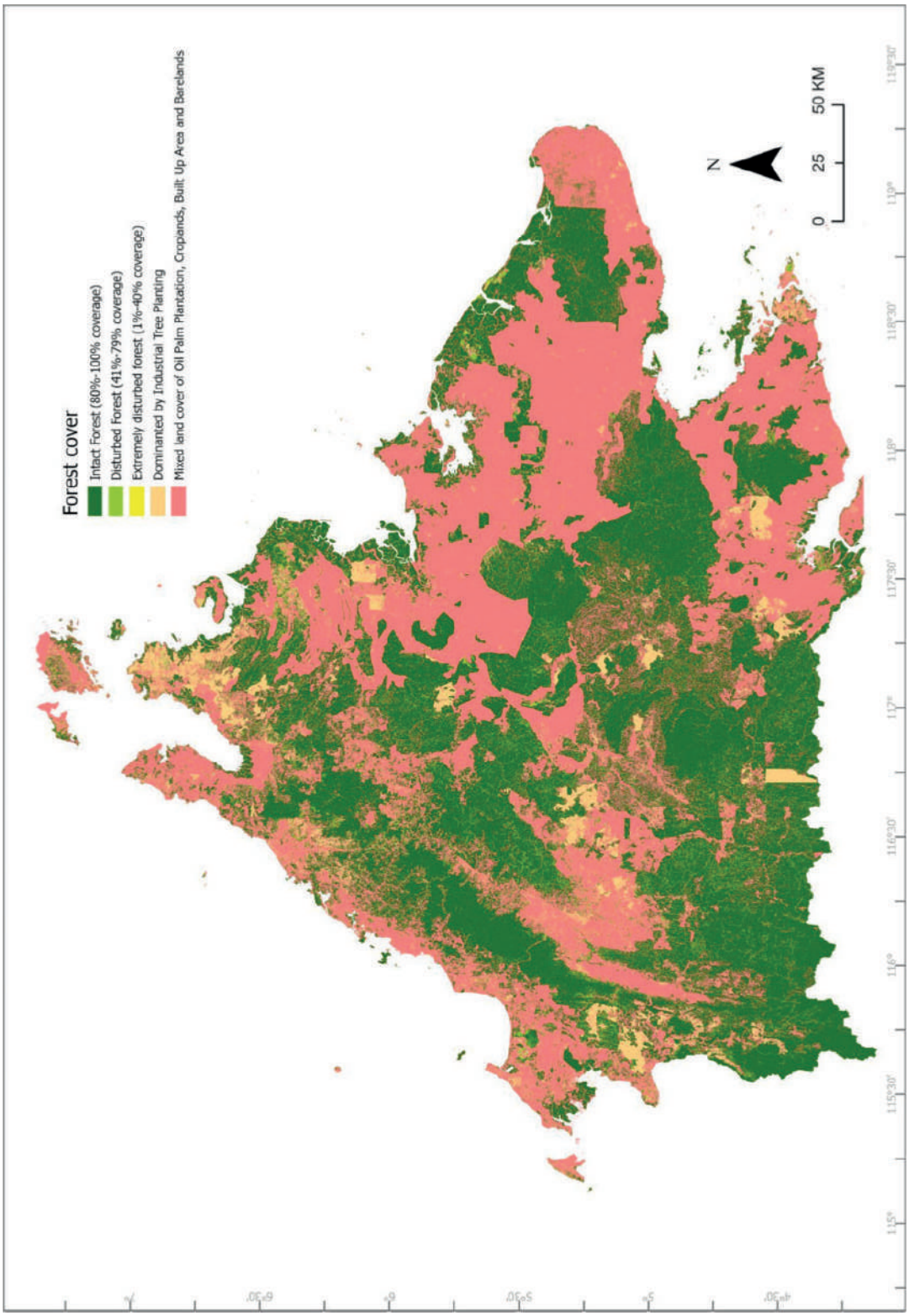


Figure 8. Forest cover as at 2020 (Source: SarVision & Hansen, 2020)

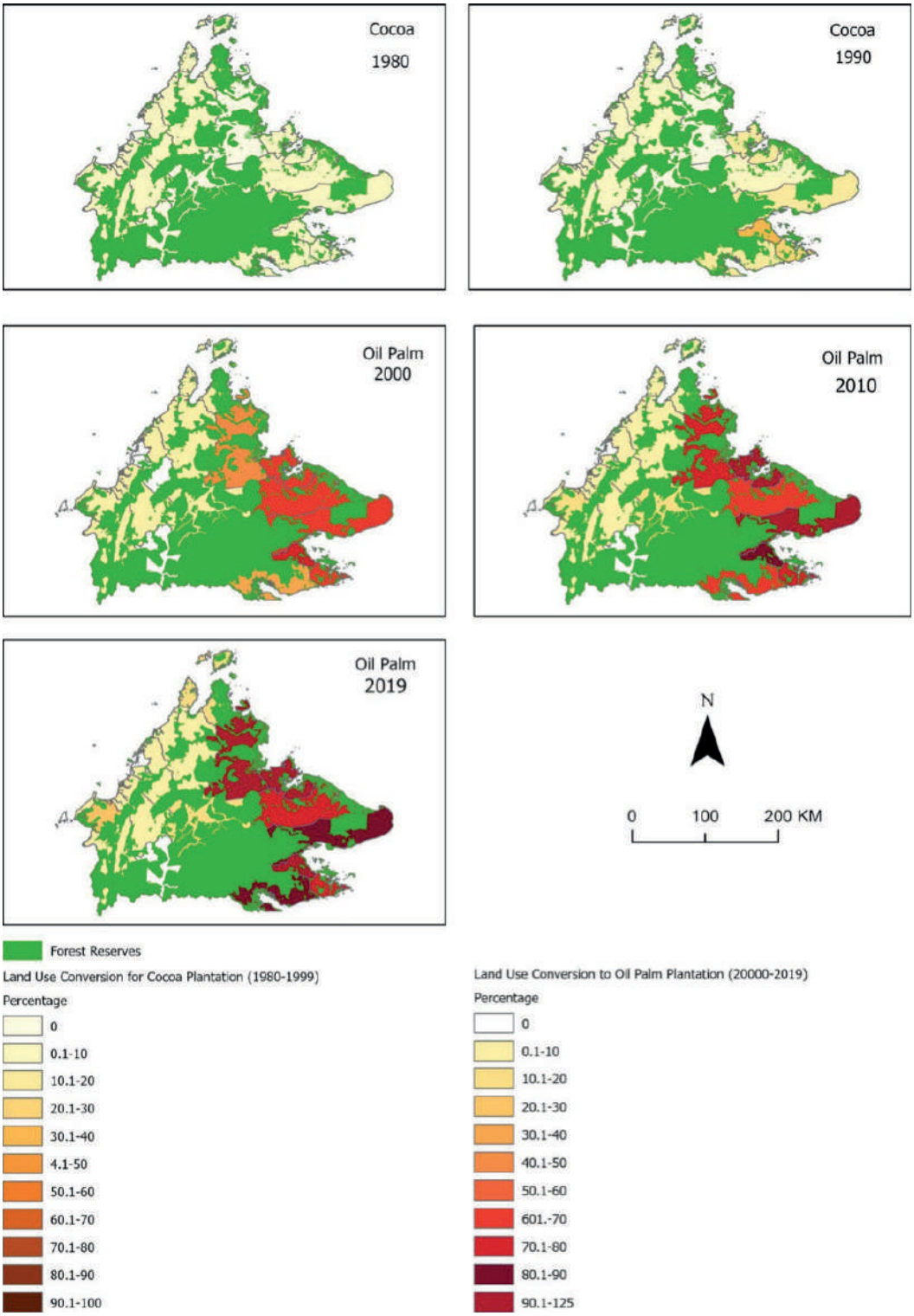


Figure 9. Land use conversion from natural forest/degraded forest to cocoa and oil palm plantations between 1980–2019

world's biggest cocoa producers. Most of these areas were converted at the expense of former rubber plantations and some forest lands. The cocoa boom in Sabah was also short-lived, and was adversely affected due to global price declines, labour shortage and susceptibility to pests and diseases due to the no-shade monocrop system.

The collapse of the cocoa industry in Sabah was a quick process due to its replacement by the oil palm crop (Figure 9). Oil palm expansion on a massive scale started mainly in the Tawau-Kunak and Sandakan-Beluran districts in the early 1980s. Local government linked companies, mainly the Sabah Land Development Board (SLDB), were formed to mobilise and introduce oil palm cultivation to the West Coast mainly in Langkon, Kudat and Kota Marudu, although the sandy soils there were less suitable, and land previously planted with coconut tended to cause Ganoderma disease.

Large companies converted most of their land banks into oil palm plantations, which dominated prime land on the East Coast, such as BAL Plantation and Golden Hope Plantation in Tawau-Kunak landscape; Kretam Holdings and Hap Seng Plantations in Lower Kinabatangan; Unilever Plantation in Pamol on Lower Sugut Landscape; and Kuala Lumpur Kepong (KLK) and FELDA in Tabin, with their associated mills. Almost 90% of crude palm oil mills were established between 1990–2000, corresponding to the 1985–1999 large scale forest land conversion, alongside conversion of former cocoa, coconut and rubber plantations to almost entirely oil palm plantations.

There is not a single crop that can compete with the economic benefits of oil palm. But, without alternative crops, the expansion of the oil palm monocrop is a challenge which is mainly driven by the global market and demand, and competes with local food production. This pattern is spreading quickly to the uplands of mid and western Sabah, and within the interior division, and will lead to continued deforestation if this expansion continues.

Deforestation – Fires

In Southeast Asian tropical rainforests, long drought events are associated with the atmospheric and oceanic anomaly, the ENSO phenomenon (Richards & Walsh, 1996). In Sabah, forest fires were not perceived as a pressing issue prior to the major fires in 1983. But the 1983 incident saw about a million ha of forest area destroyed (SFD, 2017c), and caused a major change in perception toward forest fires and long drought events.

Sabah has experienced three major forest fire incidents in 1983, 1997–8 and 2002–3. The El-Nino in 1983 caused widespread forest fires in Sabah, and a similar catastrophic event occurred in 1998 (SFD, 2015). The El-Nino and drought-related fire events caused damage to about 200,000 ha of forest reserves (Sabah Forestry Department); many of the affected areas were badly damaged while others were completely destroyed (Figure 10). The main causes of fire as identified by the Sabah Forestry Department are related to open burning for clearing land for agriculture in adjacent areas, camping inside forest reserves by poachers, and occasionally arsonists deliberately setting fire to forests. Research into regeneration after forest fires indicates that unlogged forests, where some canopy remains after the burn, have better regeneration of forest trees than logged forest which suffered much greater damage (Woods, 1989).

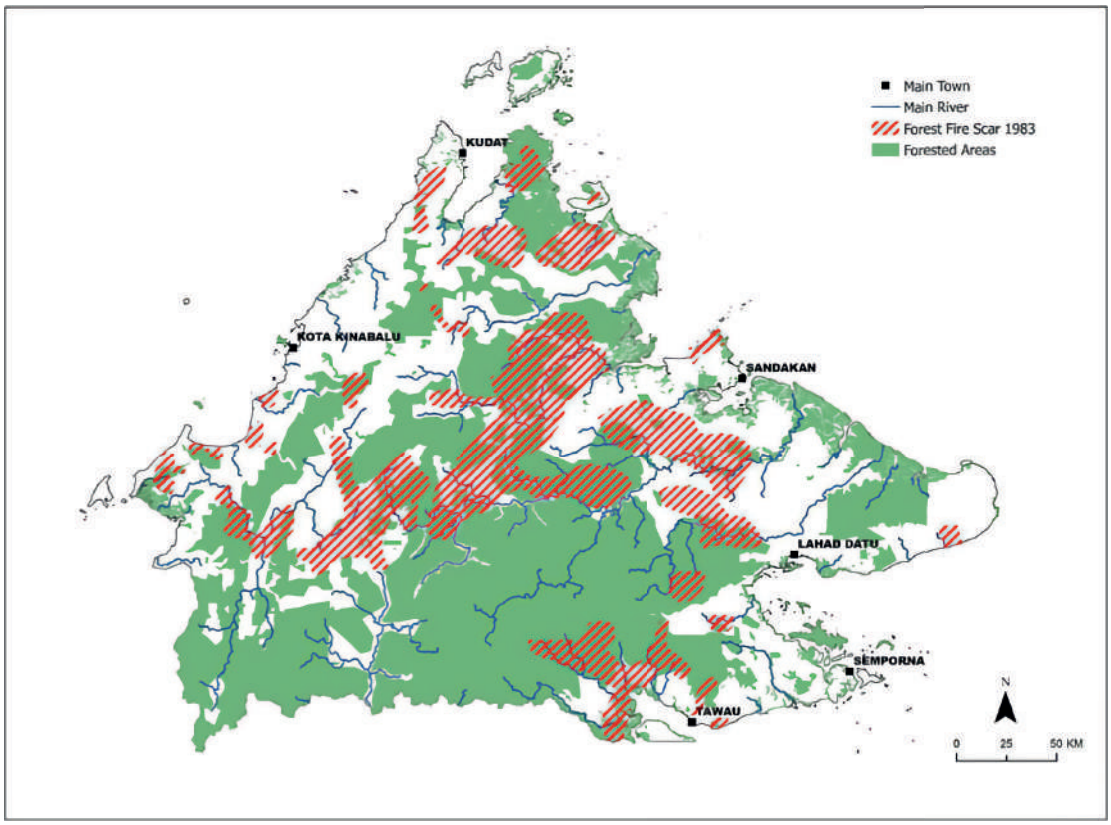


Figure 10. Historical forest fires, 1983 (Source: Sabah Forestry Department Portal)

Acknowledgements

The authors acknowledge the contribution of maps from Sabah Forestry Department, and assistance from WWF-Malaysia colleagues in the GIS and Spatial Planning Units. Editorial assistance was provided by Glyn Davies and Angela Lim, and extensive peer review, especially of the forest formations and early history, was generously given by John Tay and Frederick Sheldon.

Primates

Glyn Davies

Sabah is blessed with 12 species of non-human primates. This taxonomic group includes: great apes, such as the orangutan, and lesser apes, such as the gibbon — both of which lack tails; the monkeys: leaf monkeys, proboscis monkeys and macaques, which all have tails of varying lengths. Sabah also has populations of two diminutive, nocturnal prosimian primates: Tarsier and Slow Loris.

These species can be divided into two communities; those that are mostly found in coastal and riverine habitats, seldom venturing far inland: Proboscis Monkey, Silvered Leaf Monkey, and Long-tailed Macaque, and those that are more commonly found in inland forests, including lowlands and uplands and along smaller rivers and streams. That said, all these species are adaptable and can move away from their preferred habitats, either because they have been driven there by disturbance or threat, or moved there to exploit new opportunities.

They are cryptic, melting into the forest if they are alarmed by human presence. They tend to be very difficult to find and study, with data gathering involving hours of painstaking field work. Where they make loud calls, such as the gibbons, or sleep in conspicuous night trees, like Proboscis Monkeys, then direct counts can be made during surveys to calculate their abundance. But where this is not the case, then indirect methods are often used, such as orangutan nest counts from transect walks or helicopters, and camera trap records to indicate the presence of those species that travel along the ground — especially orangutans and macaques. As a result, our knowledge of their ecology is limited to a few long-term (>12 months) field studies and anecdotal observations, and our knowledge of their populations is limited to broad differences between habitats, and rough estimates of numbers across Sabah. This information is often sufficient to inform conservation policy and guide management, but caution is needed to avoid over-generalisations based on modest amounts of data, and further research efforts are needed to fill the many gaps in our knowledge.

Before looking at the details it is helpful to place Sabah's rich primate diversity in some broader context (Table 1). First, of five subspecies of Red Leaf Monkey in Borneo, one (*P. r. chrysea*) is found entirely within the State; second, Sabah Leaf Monkey populations are almost entirely restricted to the State; and third, about 2/3 of the Bornean Orangutan subspecies *morio* is found in the State. In terms of rarity, the Bornean Orangutan is critically endangered, and the Sabah Leaf Monkey, North Bornean Gibbon, and Proboscis Monkey, are all endangered, with population strongholds in Sabah.

Given this context, and that all the other primates in Sabah are classified as 'Vulnerable', Sabah is very important for primate conservation globally. Details for most are presented in the chapters that follow, and for the Silvered Leaf Monkey and two prosimian species, for which we have little data, maps and photographs have been included in this introduction.

Table 1. Primate species in Sabah

Sabah species/subspecies	Rarity (IUCN Red List)	Endemism	Sabah Status* (1997)	Scientific name (1997 Sabah) Wildlife law
Bornean Orangutan *Pongo pygmaeus morio*	**Critically endangered** (2016)	Borneo Sub-species: north and north-eastern Borneo	Schedule 1	
North Bornean Gibbon *Hylobates funereus*	**Endangered** (2020)	Northern half of Borneo	Schedule 2	*Hylobates muelleri*
Sabah Leaf Monkey *Presbytis sabana*	**Endangered** (2020)	Majority of range in Sabah	Schedule 2	Both treated as single species: *P. hosei*
Hose's Leaf Monkey *Presbytis hosei*	**Vulnerable** (2020)	Northern Borneo	Schedule 2	
Red Leaf Monkey *Presbytis rubicunda ignita*	**Vulnerable** (2020)	North & north-western Borneo	Schedule 2	Only the species noted, not two subspecies
Red Leaf Monkey *Presbytis rubicunda chrysea*	**Not determined** (2020)	Restricted to Sabah	Schedule 2	
Silvered Leaf Monkey *Trachypithecus cristatus*	**Vulnerable** (2020)	Widespread in South-east Asia — coastal & riverine zones	Schedule 2	*Presbytis cristata*
Proboscis Monkey *Nasalis larvatus*	**Endangered** (2021)	Borneo — riverine & coastal habitats	Schedule 1	
Pig-tailed Macaque *Macaca nemestrina*	**Vulnerable** (2020)	Widespread in South-east Asia — forest habitats	Schedule 2	
Long-tailed Macaque *Macaca fascicularis*	**Vulnerable** (2020)	Widespread in South-east Asia — riverine and anthropogenic habitats	Schedule 2	
Slow Loris — 2 spp. *Nycticebus menagensis* (and *N. kayan*)	**Vulnerable** (2020)	North-eastern Borneo (and north central Borneo)	Schedule 2	Single species: *Nycticebus coucang*
Bornean Tarsier *Cephalocanus bancanus borneanus*	**Vulnerable** (2020)	Borneo	Schedule 2	*Tarsier bancanus*

* Based on Sabah Wildlife Conservation Enactment 1997, and the scientific names therein. Recent breakthroughs in taxonomic research have led to a number of scientific and common English name changes; the latest of which are used in the first column (Roos et al., 2014).

Schedule 1 — Totally Protected Animals; Schedule 2 — Protected Species of Animals — Limited hunting and collection under licence.



Silvered Leaf Monkey (*Trachypithecus cristatus*)

Data Sources

Individuals / organizations (Number of records): Gardner, Penny (1); Phillipps, Anthea (1); BORA (1). *Publications (Number of records):* Boonratana, 1997 (2); Boonratana & Sharma, 1993 (2); Davies & Payne, 1982 (6); Kehoe, 2011 (2); Lim, 1996 (2); Matsuda et al., 2014 (1); Prudente et al., 2009 (1); Rajaratnam, 1995 (1); Regip, 2003 (1); Sharma, 1992 (2); Webb, 2016 (1).

Figure 1. Silvered Leaf Monkey, *Trachypithecus cristatus*, adult © Lee Shan Khee/WWF-Malaysia

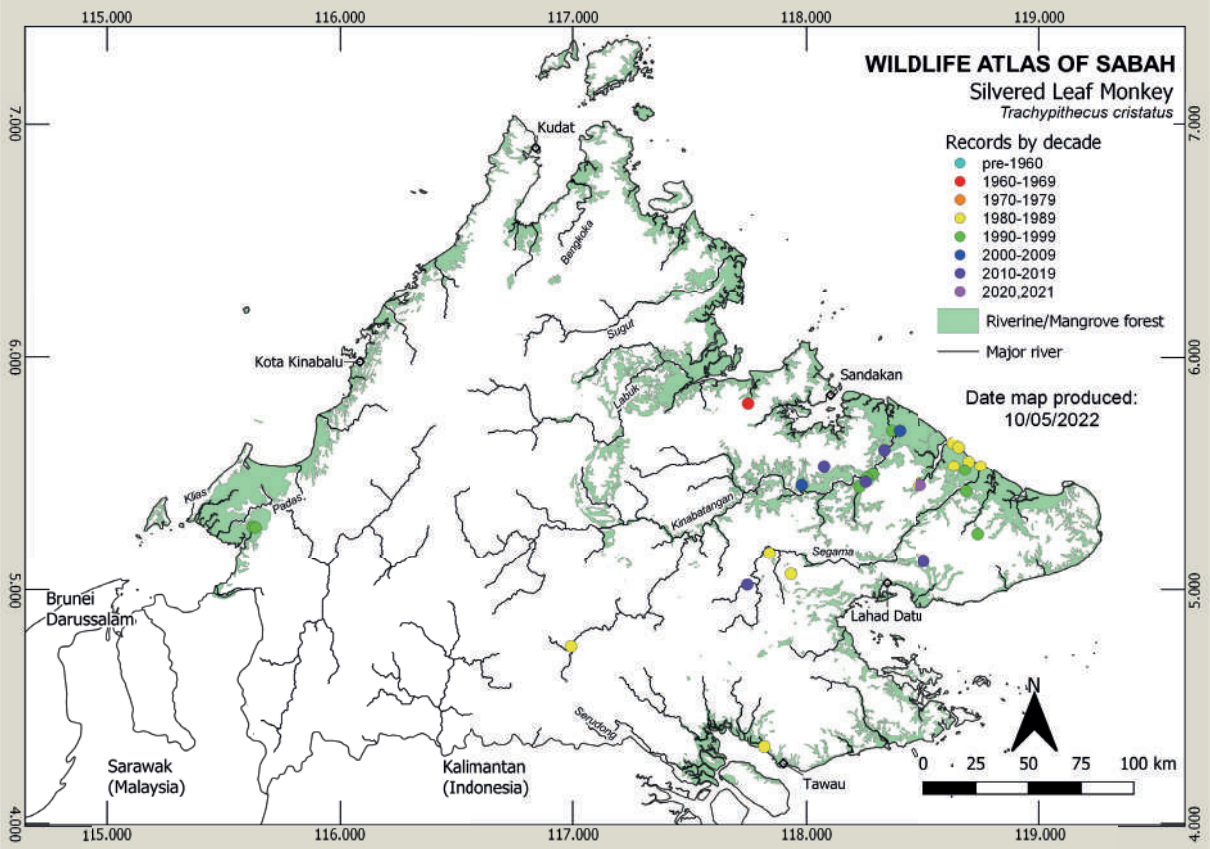


Figure 2. Records of Silvered Leaf Monkey



Slow Loris (*Nycticebus menagensis*)

Data Sources

Individuals / organizations (Number of records): Dee Arnielia (1); Muhammad Edri Nurdin (1); Robert Ong (2); Sabah Museum (12); WWF-Malaysia (3). *Publications (Number of records):* Bernard et al., 1997 (1); Bernard et al., 2014 (4); Bernard et al., 2016 (4); Bili, 2014 (1); Boonratana & Sharma,1993 (1); Chung et al., 2019 (1); Davies & Payne, 1982 (8); Davis, 1962 (2); Kee et al., 2018 (1); Ketol et al., 2009 (1); SFD, 2017 (1); SFD, 2018 (1); SFD, 2019 (1); Tangah et al., 2016 (1); Wilting & Mohamed, 2010 (2).

Figure 3. Slow Loris, *Nycticebus menagensis*, at Sepilok B&B, Sandakan on 1 April 2020 © Andrae Scholz

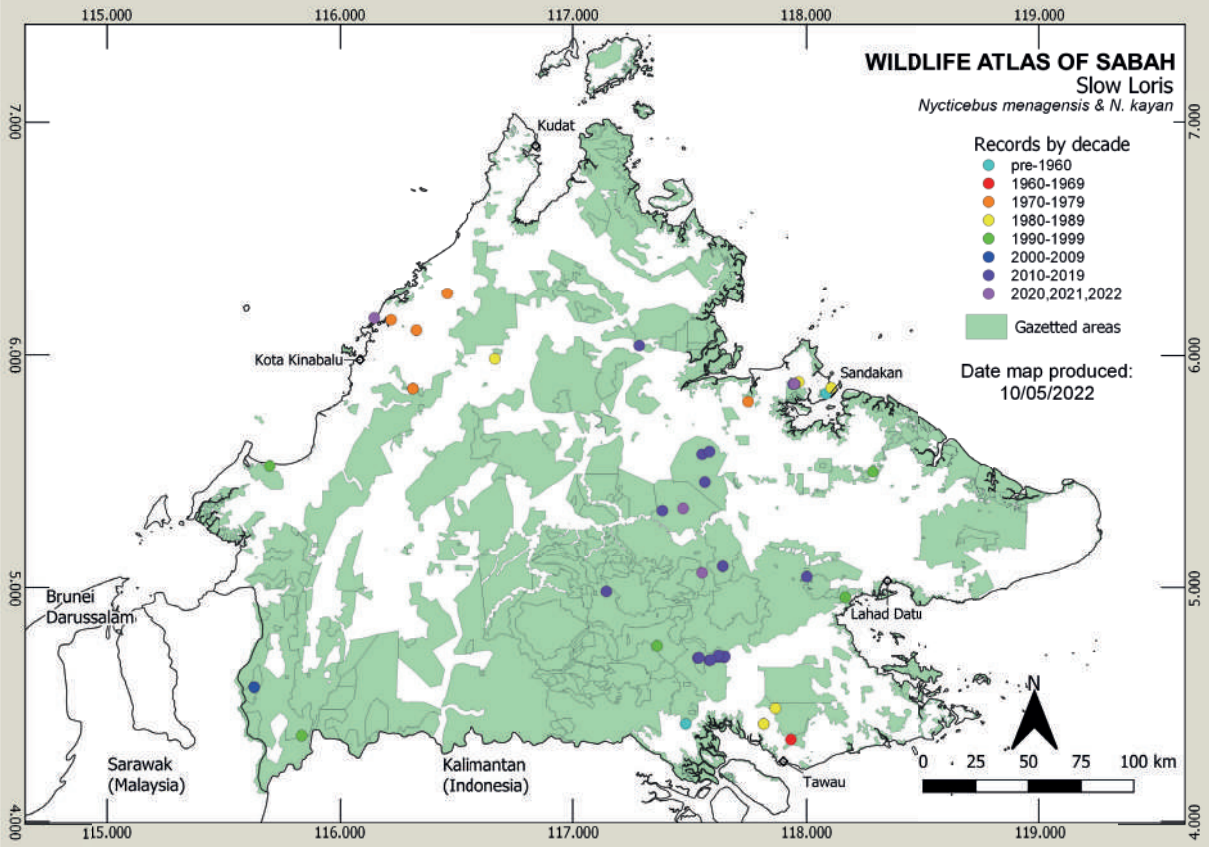


Figure 4. Records of Slow Loris



Bornean Tarsier (*Cephalopachus bancanus*)

Data Sources

Individuals / organizations (Number of records): Guharajan, Roshan (3); Jaity Jumian (4); Jane Wong (1); Sabah Museum (12); Sabah Forestry Department (1); WWF-Malaysia (2). *Publications (Number of records):* Bernard et al., 1997 (1); Bernard et al., 2014 (5); Bernard et al., 2016 (5); Boned et al., 2016 (1); Boonratana & Sharma,1993 (1); Boonratana, 1997 (2); Davies & Payne, 1982 (5); Davis, 1962 (4); Heydon, 1994 (1); Kee et al., 2018 (1); Mullin & Colley, 1972 (1); Onoguchi & Matsubayashi, 2008 (2); Samejima et al., 2012 (1); SFD, 2017 (1); Tangah et al., 2016 (2).

Figure 5. Bornean Tarsier, *Cephalocanus bancanus*, © Jabanus Miun/WWF-Malaysia

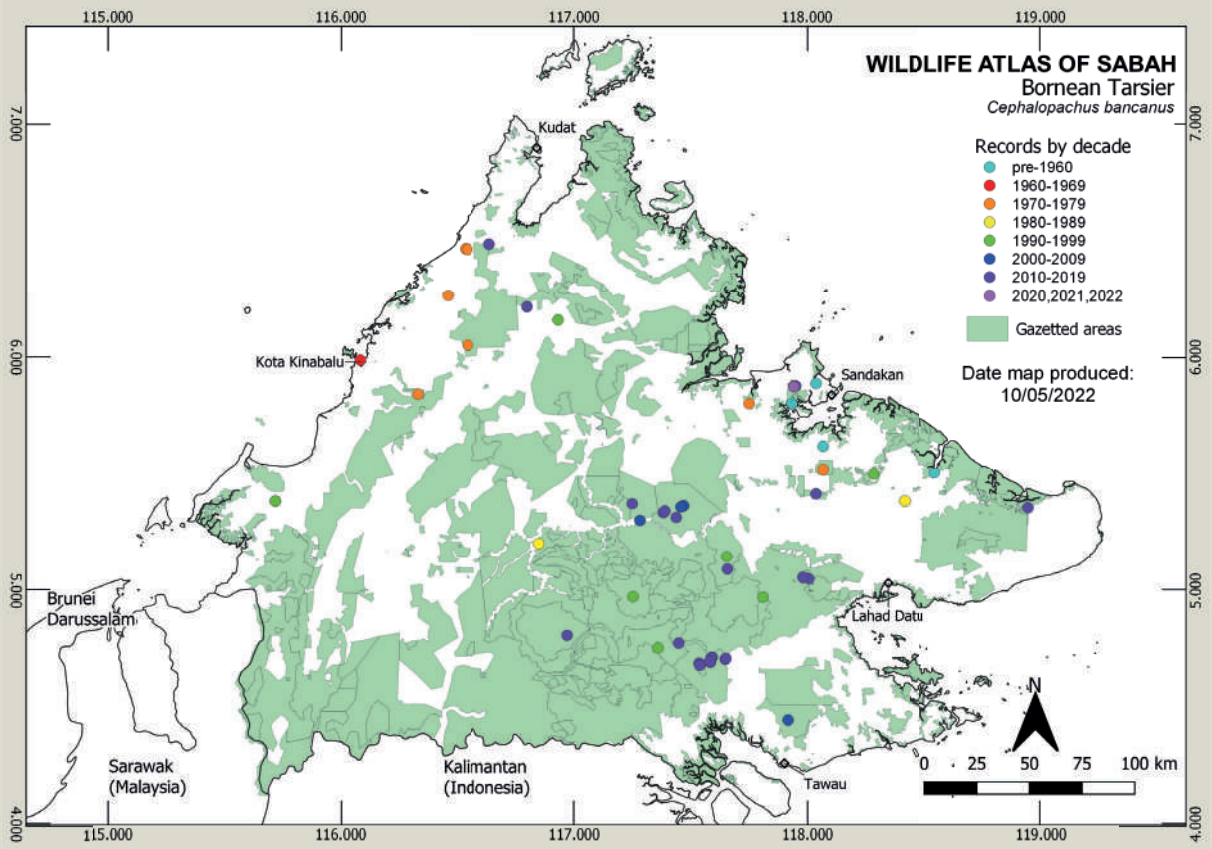


Figure 6. Records of Bornean Tarsier



Fast growing Laran trees planted in Bukit Piton Forest Reserve for orangutan population in a degraded habitat © Mazidi Abd Ghani/WWF-Malaysia

3

Bornean Orangutan *(Pongo pygmaeus morio)*

Donna Simon

Introduction

The orangutan is the only great ape found in Asia, where it is restricted to the islands of Borneo and Sumatra. There are two species in Sumatra: *P. abelli* to the north-west of Lake Toba (Wich et al., 2003) and the newly discovered *P. tapanuliensis* to the south of Lake Toba (Nater et al., 2017). There are three subspecies of Bornean Orangutan (*Pongo pygmaeus*): *P. p. pygmaeus* in Sarawak and West Kalimantan, *P. p. wurmbii* in South-west and Central Kalimantan, and the smallest *P. p. morio* found only in Sabah and East Kalimantan, Indonesia (Figure 1). These Bornean subspecies diverged genetically from a common ancestor about 80,000 years ago (Banes et al., 2016).

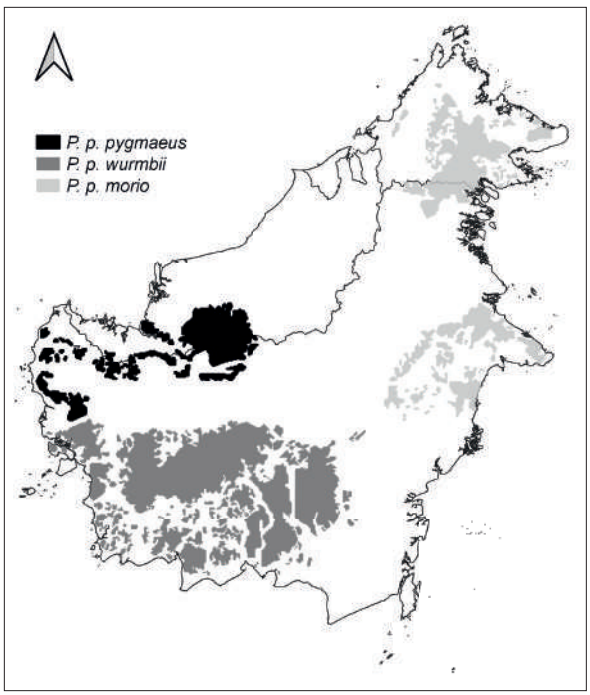


Figure 1. Three Bornean Orangutan subspecies ranges in Borneo Island (adapted from Banes et al., 2016)

The genus *Pongo* originated in South or East Asia around 6–5 million years ago and ranged throughout Southeast Asia around 2–4 million years ago (Spehar et al., 2018; Figure 2). Fossil teeth dating from the Pleistocene epoch indicate a predecessor of the modern orangutan that ranged into southern China. The current species range has substantially reduced over time, based on fossil evidence found in Niah Cave in Sarawak, Java Island and the Padang Highlands in Sumatra (Koenigswald, 1982; Spehar et al., 2018). Habitat loss and fragmentation during the Pleistocene epoch caused a substantial decrease in the overall species' range as a result of climate change and hunting pressure (Spehar et al., 2018), and more recent declines in the Bornean Orangutan, started around 2,000 years ago due to hunting and other anthropogenic pressures (Nater et al., 2015).

The name orangutan is derived from old

Malay words, which mean 'people of the forest', but the orangutan has many other local names in Borneo. The Kadazan-Dusun community representing the largest indigenous group in Sabah calls the orangutan *kogiu*, the Muruts use *kahui* and the Orang Sungai use both terms (Payne & Prudente, 2008). In Sarawak, the most common local name is *mawas* or *maias*, while in Kalimantan it is called *juwud* (Payne & Prudente, 2008).

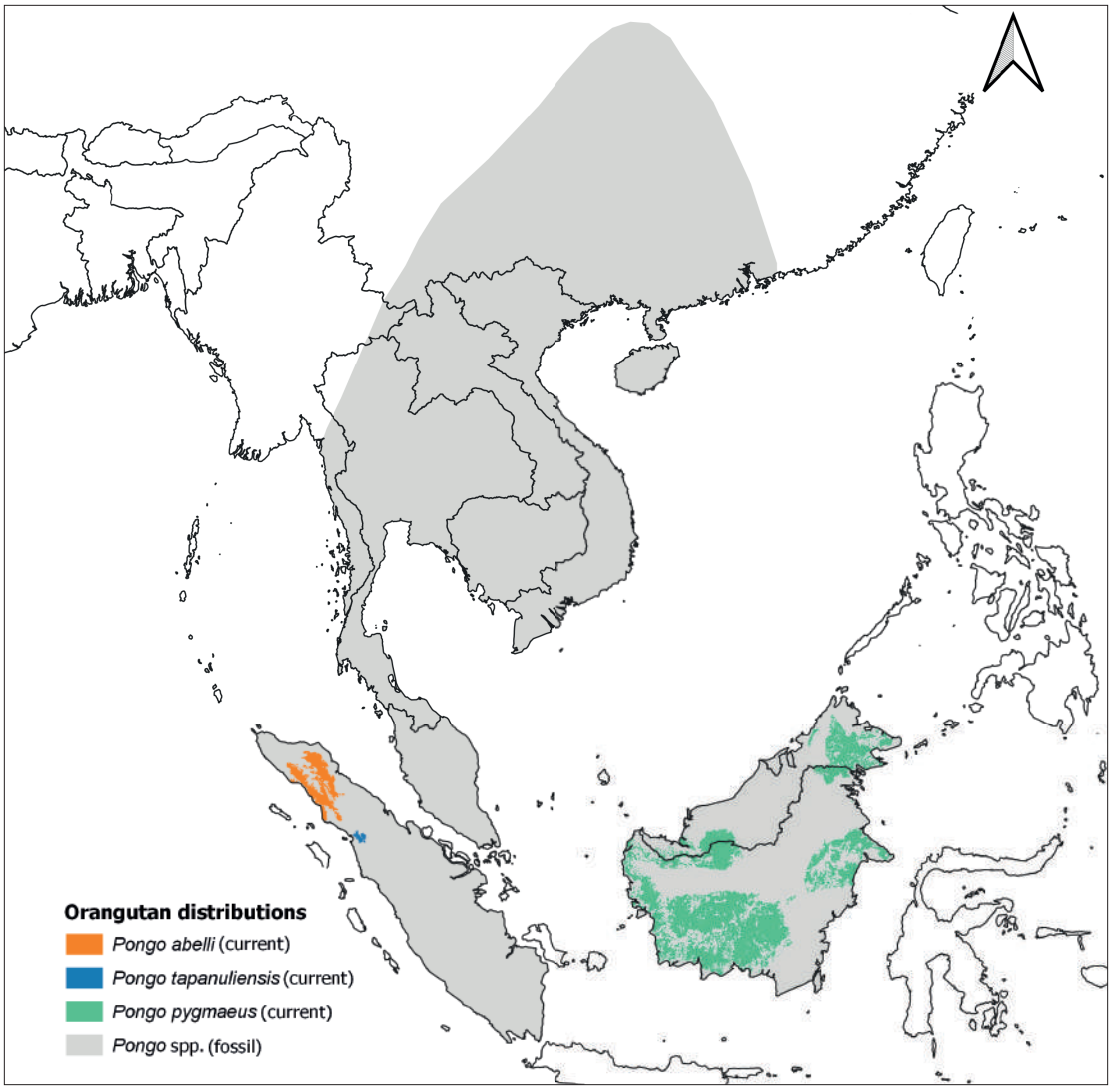


Figure 2. Orangutan species range during the Holocene epoch and current range (adapted from Spehar et al., 2018; IUCN, 2021)

Natural History

Orangutans are the gentle giants of the forest canopy; they are the largest tree-dwelling animal in the world. A baby orangutan weighs about 1.5 kg at birth (all sizes follow MacKinnon, 1974), with sparse erect hair on the head and prominent light coloured skin around the eyes and mouth (Figure

3a). The light skin areas become darker and decrease in size as they age. Infants cling to their mother much of the time until they are about three years old (2–15 kg). While staying close to the mother, juvenile orangutans will learn the necessary skills to survive in the wild, including making nests and foraging until they are about seven years old (10–30 kg) (Figure 3b). They enter the adolescent stage at around 8–15 years for males and 8–10 years for females, when they become independent from the mother. They continue to grow; females reach adulthood much earlier (>10 years; 35–50 kg) than the males (>15 years; 40–55 kg) (Kuze et al., 2005; Figures 3c & 3d). Males exhibit bimaturism, where dominant males will develop cheek flanges after ten years, but the development may be delayed if other flanged males live in the same area (Kuze et al., 2005). A flanged male has a much larger body than other age classes (45–55 kg).

Having no tail, orangutans have strong hands and feet to firmly grip tree trunks and branches for climbing and swinging when foraging and travelling. Adult females and younger orangutans tend to stay on the trees for safety, and have adapted shoulder joints to allow maximum arm rotation. But males, especially large solitary adults, often travel along the ground on all fours — knuckle-walking. The dentition of orangutans with low molar crowns is adapted for fruit-eating, and adult males especially, have large canines for fighting and defense.



Figure 3. a) Infant orangutan holding tight to its mother © Edwin Matulin/WWF-Malaysia; b) Juvenile orangutan © David James/WWF-Malaysia; c) Adult female orangutan on a Bayur tree © David James/WWF-Malaysia d) Adult male orangutan on a Laran tree © William Joseph/WWF-Malaysia

Breeding and Social Behaviour

Orangutans are solitary but social animals. They usually feed alone but live in extended community groups of related females dispersed across vast landscapes. The dominant social relationship is between adult females and dependent young and in their early years. The infant will be taught to build nests, find food and other survival skills. The young orangutans also play with peers and older siblings. Unflanged adult males in particular sometimes travel with them for short distances, increasing the likelihood of conception with the mother for the next offspring (Frohlich et al., 2020).

Juveniles start to move away from their mothers at about seven years, with males moving out of the mother's home range and daughters tending to stay nearby (Ashbury et al., 2020). At approximately 15 years, adult females start producing offspring, after short courtships for mating (Payne & Prudente, 2008). They are more attracted to flanged males because of their significantly larger body size, strength and social dominance (Knott et al., 2010). These flanged males make 'long calls', which can be heard over 1 km away, to attract females. They repel other males that enter their territory. An unflanged male which lacks a territory spends much time travelling and searching for females to mate, while avoiding flanged males.

The vocal repertoire of orangutans includes a 'kiss-squeak', produced by pouting their lips while sucking in air, which they do when alarmed or to ward off other orangutans, animals or humans if they feel disturbed. And from the large throat pouch of adult males comes the 'long call' (see QR Code for calls).

Kiss-squeak behaviour
© Borneo Nature Foundation

Long call behaviour (Tuanan Research Station, Central Kalimantan, Indonesia
© Wendy Erb)

Activity Patterns and Diet

Orangutans spend most of their time feeding, resting and travelling in trees with time allocated differently according to fruiting season and habitat types. For example, in the mixed dipterocarp forests of Kinabatangan and Ulu Segama, orangutans will spend more time resting to conserve energy during low fruiting season (Morrogh-Bernard, 2009).

Orangutans are primarily frugivorous, but have a flexible feeding strategy to account for the seasonal nature of food supplies (Table 1). They prefer soft fruits such as durians (*Durio zibethinus, Durio graveolens*) and wild jackfruits (*Artocarpus rubens*) (Mackinnon, 1974), and not hard fruits (Kanamori et al., 2010). In Danum, they fed on *Ficus*, *Diospyros* and *Spatholobus* during both low fruiting and high fruiting seasons, as these species were commonly available throughout the year. However, *Ficus* and *Spatholobus* are categorised as 'fallback foods' — being abundant but with low nutritional quality (Kanamori et al., 2010), and figs (*Ficus sp.*) are classified as a high quality fallback food (Marshall et al., 2009) with year round availability (Sreekar et al., 2010). This fruit diet is supplemented with young leaves, tree cambium, flowers, tree bark, insects and occasionally small mammals.

Table 1. Time spent on five main food categories (%)

	Sg. Bole	Kinabatangan	Danum
Fruit	51.5 (10–90)	68 (20.2–97.2)	60.9 (11.7–100)
Flowers	-	1.3 (0–7.2)	2.5 (0–17.4)
Leaves	35.6 (8.3–75)	22	22.2 (0–53.3)
Bark	11.2 (0–36.7)	6.7 (0–40)	12.3 (0–29.3)
Others	2.1 (0–8.3) Invertebrate	0.8 (0–11.1) Invertebrate	2.1
Source	Mackinnon, 1974	Morrogh-Bernard, 2009	Kanamori et al., 2010

The Bornean Orangutan has difficulty acquiring a nutritious diet (Wich, 2011). Fertile soils support plant species to produce more nourishing fruits, but due to less fertile soils in Borneo, the Bornean Orangutan is smaller than the Sumatran species, and its mandible is more robust to process tougher foods, such as tree bark and mature leaves (O'Connell et al., 2021). During high fruiting season, orangutans put on weight so that they have fat reserves to tide them over the non-fruiting season when they survive by breaking down muscle protein (Vogel et al., 2012; O'Connell et al., 2021). This strategy is most obvious in obese animals that no longer have to survive a non-fruiting season in zoos.

Ranging / Migration Behaviour

The Bornean Orangutan is more terrestrial, compared to the Sumatran Orangutan, since predators such as tigers and leopards are absent in Borneo (Delgado & Van Schaik, 2000). Flanged males are seen more times on the ground, followed by adult females with dependent young, and animals tend to travel along the ground more in disturbed habitats (Ancrenaz et al., 2014). Terrestrial travel allows movement between forest patches in fragmented habitats for breeding, and access to different food types during low fruiting season. However, this may also increase hunting risk and exposure to predators, parasites and pathogens.

Table 2. Orangutan home range estimates in Borneo (adapted from Campbell-Smith et al., 2011)

Sites	Home range (ha)		Source
	Adult Female	Adult Male	
Tanjung Putting, Kalimantan	350–600	>females	Galdikas, 1988
Lokan, Sabah	65	520	Horr 1975; 1977
Kinabatangan, Sabah	180	>225	Ancrenaz & James, unpublished data
Tuanan, Kalimantan	250–300	>females	Tuanan Orangutan Project, Universitas Nasional Jakarta & University of Zurich, unpublished data
Sebangau, Kalimantan	250–300	>560	Morrogh & Bernard, unpublished data

Orangutan home ranges highly overlap. In general, the male home range is much larger than the female's, so that one male home range may overlap several females', maximising the chances of getting a receptive female for mating.

Orangutan social systems and ranging patterns are quite stable in forests with minimal human disturbance. When conditions change radically, such as after intensive logging or when large areas are converted to oil palm plantations, the animals must adapt their behaviour. Since it is normal for male orangutans to migrate considerable distances following fruiting cycles, they tend to move away from habitat disturbance if possible and females do so less easily. The consequence is that many orangutans can be trapped in forest pockets, a term described as 'refugee crowding' (Husson et al., 2008), but can return to disturbed areas after forest regeneration. Furthermore, the few that do remain in oil palm dominated landscapes must travel between forest patches through oil palms (Ancrenaz et al., 2014; Davies et al., 2017).



Figure 4. A mother and dependent young travelling between forest reserves through an industrial tree plantation in Sabah Softwoods Berhad, Tawau © WWF-Malaysia

Tool Use and Nesting Behaviour

The orangutan is an intelligent animal that exhibits more than 50 types of human-like interactions, such as hiding, playing, tantrums, etc. (Payne & Prudente, 2008). At least 38 tool uses have been documented in the wild (Meulman & Van Schaik, 2013), such as making simple 'straws' to drink water from a tree hole or using sticks as toothpicks, and they can even mimic human activity through careful observation (e.g. paddling a canoe).

Orangutans show great skills in nest-building, which they do daily (Prasetyo et al., 2009) to rest throughout the night, avoiding predation and regulating body heat during cold nights (Casteren et al., 2012). All age groups make nests except for dependent young, which share the nest with the mother. Nest-building by an orangutan demonstrates engineering capacity to produce a sturdy and comfortable bed (Casteren et al., 2012), while also showing preferences for nesting tree species (Prasetyo et al., 2009). Once a nesting tree is selected, the orangutan will fold big tree branches together, forming a sturdy platform to support its weight, padding it with fresh leaves, then locking it together by intertwining branches. It also uses branches for cover when it rains!



Figure 5. a) Orangutan nest in Bukit Piton Forest Reserve © Mazidi Abd Ghani/WWF-Malaysia; b) Closeup of a nest in Tabin © Glyn Davies/WWF-Malaysia

Night nests are important in population surveys, because they show the presence of orangutans, and the number of nests in an area gives an indication of the number of orangutans (Ancrenaz et al., 2004a; Simon et al., 2019). Occasionally, a much simpler day nest for resting is made with leafy vines and woody climbers, which is less visible (Ancrenaz et al., 2004b).

Distribution and Abundance in Sabah

Historical records (Davis, 1962; MacKinnon, 1974; Davies & Payne, 1982; Payne, 1988) show that the species was widespread and most abundant in the eastern lowlands and Segama uplands (Table 3; Figure 6). Following the clearance of approximately 1.6 million hectares of forests for oil palm plantations in the 1980s–90s, the population was fragmented. There are now 16 main orangutan populations recognised (Figures 6 & 7), of which the majority are found in the eastern and central Sabah with some smaller populations in the west (Ancrenaz et al., 2005; Simon et al., 2019).

Some 80% of the orangutan population inhabits the Segama region (Ancrenaz et al., 2010), with the population in Deramakot and Ulu Segama reserves (~5,933 individuals) remaining stable over a decade under Sustainable Forest Management practices, indicating that populations can be sustained in well-managed forests (Simon et al., 2019). On the eastern part of Sabah, fragmented populations in Kulamba and Tabin (ca. 1,200) have declined by 30% and 15%, respectively from 2000–2017 (Ancrenaz et al., 2005), while the small population in Silabukan (~50 individuals) has been maintained (Simon et al., 2019). Unfortunately, due to its small size, it may not be a viable population without an ecological corridor to link Tabin and Silabukan.

Another prominent population of orangutans is in the Lower Kinabatangan (see Box 1), and there are scattered individuals found outside of large forest habitats, often roaming between forest patches in plantation landscapes. Intensive surveys are needed to estimate the population outside of state parks and forest reserves.

Table 3. Population estimates at different sites

Study site	Density (indiv/km^2)	Source
Sg. Bole	1–2	Mackinnon, 1974
Kinabatangan	0.7–6.0	Ancrenaz, 2005
Danum	0.3–4.4	Kanamori et al., 2017
Tuanan (Kalimantan)	4.25–4.5	Van Schaik et al., 2005
Lokan	2.1	Horr, 1975

Looking at population abundance across the State, 30 years ago there was estimated to be about 21,000 orangutans (Payne, 1988), then 15 years later the population was estimated to have halved to around 11,000 (Ancrenaz et al., 2005). Thus, it is estimated that more than 10,000 orangutans have been lost due to unsustainable logging, forest fires, orangutan killing and massive expansion of oil palm plantations in the late 1980s to early 2000s. Sustainable forest management, reduced forest conversion, increased forest regeneration and no major forest fires over a 15-year period have slowed down the loss of orangutans, with a similar estimate of 11,000 orangutans for 2014–2017 (Simon et al., 2019).

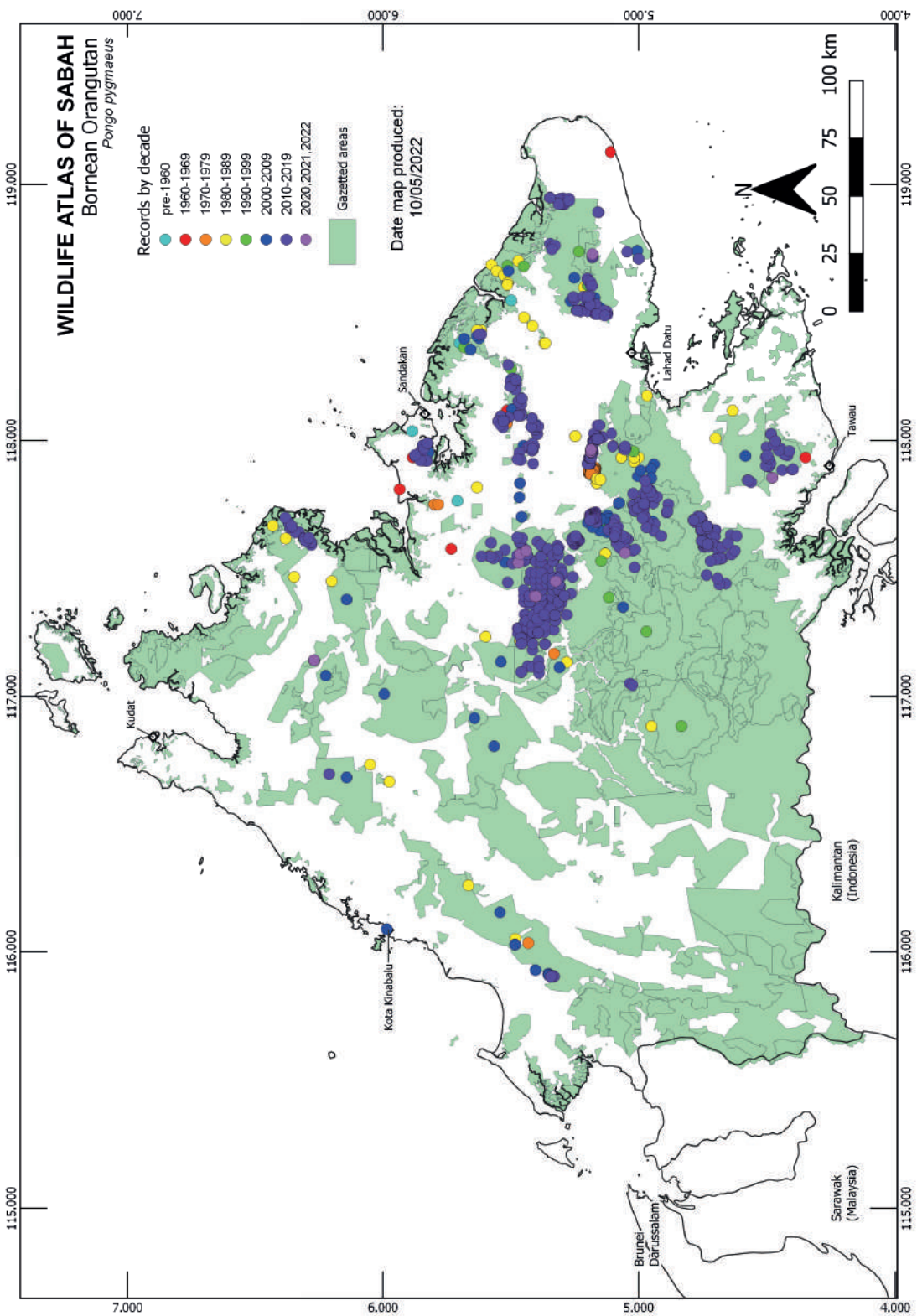


Figure 6. Orangutan and nest sightings based on ground observation, camera traps and museum specimens

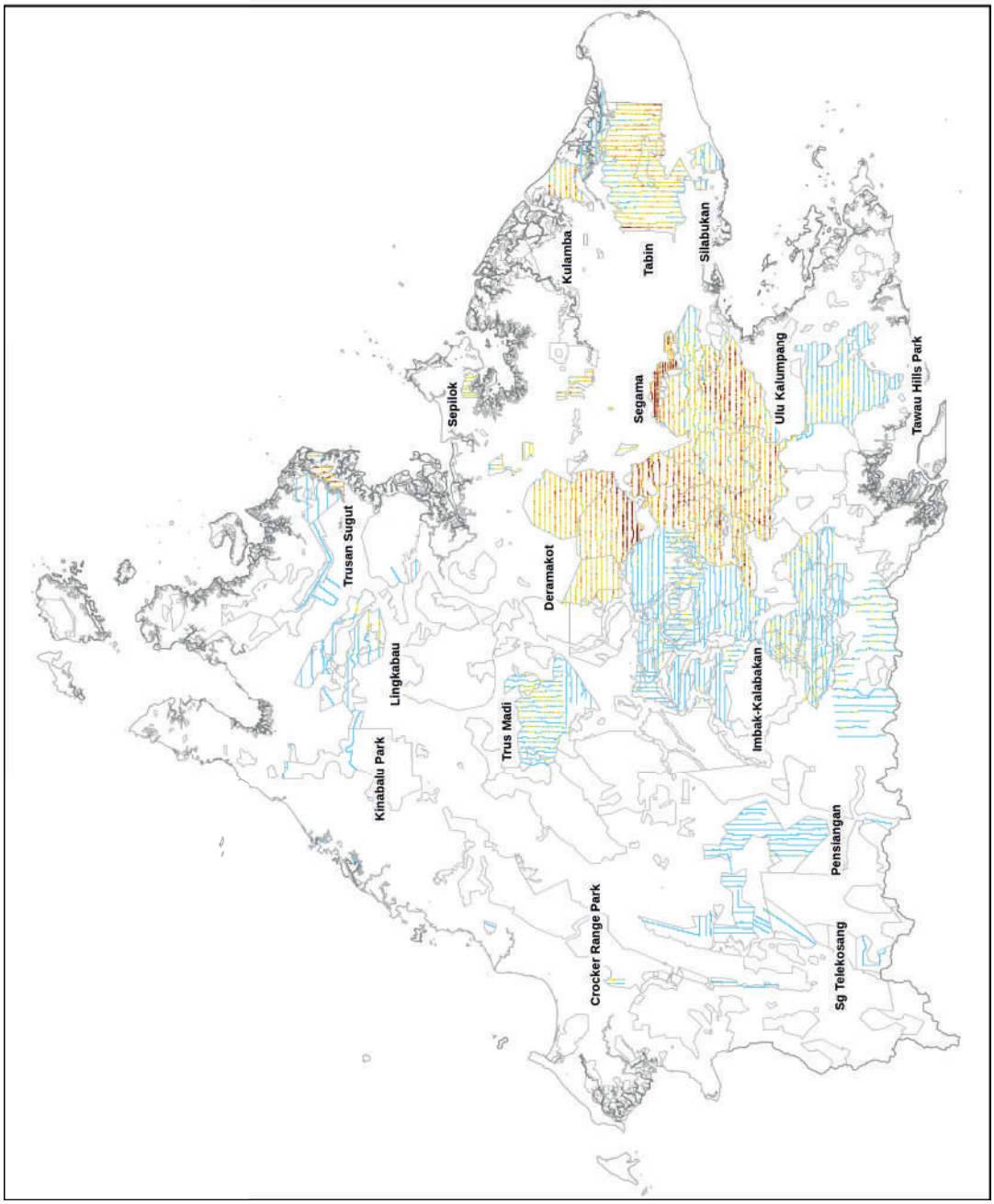


Figure 7. Orangutan distribution map based on aerial nest surveys 2014–2021, Source: WWF-Malaysia

Threats

Orangutans were seriously impacted by habitat degradation due to unsustainable logging in the 1970s–90s, and habitat loss due to massive oil palm expansion, especially in the 1980s to early 2000s (Simon et al., 2019). The loss of forest habitat to oil palm plantations within forest reserves, such as in Benta Wawasan and Bonggaya Forest Reserves, has also contributed to the loss of orangutans, pushing them into smaller forest patches or riparian reserves. Meanwhile in 2017, aerial nest surveys followed by ground surveys in the Sugut Forest Reserve confirmed no recent presence of orangutan, despite records in the 1980s.

In recent years, orangutan killing has dropped tremendously following strengthened legal protection, improved awareness and less expansion of oil palm plantations. However, this does not imply that unreported killings have stopped. Finally, in the last 10–15 years there have been no known reports of orangutans in the pet trade, although there were some records of illegal keeping of orangutan as pets.

Cultural Significance

There are various traditional stories and beliefs involving orangutans. Some forbid looking at the orangutan in the face, as it will invite bad luck. In Sarawak and Kalimantan certain indigenous groups regard orangutans as the reincarnations of humans, so hunting the animals is taboo, thereby protecting and allowing them to eat fruits from their gardens. In Sabah, hunting orangutans was taboo in some areas, while other communities considered them as a desired prey (Payne, 1988).

Conservation

A 10-year Orangutan State Action Plan covering 2020–2029 was developed to list strategies and action plans to protect orangutans in Sabah (Table 4).

Table 4. Legal status of orangutan protection

Legal status	Class	Remarks
CITES (Convention of International Trade in Endangered Species of Flora & Fauna)	Appendix 1	Banned from international trade.
IUCN (World Conservation Union) Red List	Critically endangered	Bornean species being the last one upgraded in 2016 following its decreasing population trend.
Malaysia, Wildlife Conservation Act, 2010	Totally protected species	Hunting and possession without special permit — fines not exceeding RM100,000 and jail not exceeding 3 years.
Sabah Wildlife Conservation Enactment, 1997	Schedule 1 — Totally protected animals	Orangutan cannot be hunted, kept or killed. Fine of minimum RM50,000 and maximum RM250,000 and imprisonment of not less than one year but not exceeding five years.

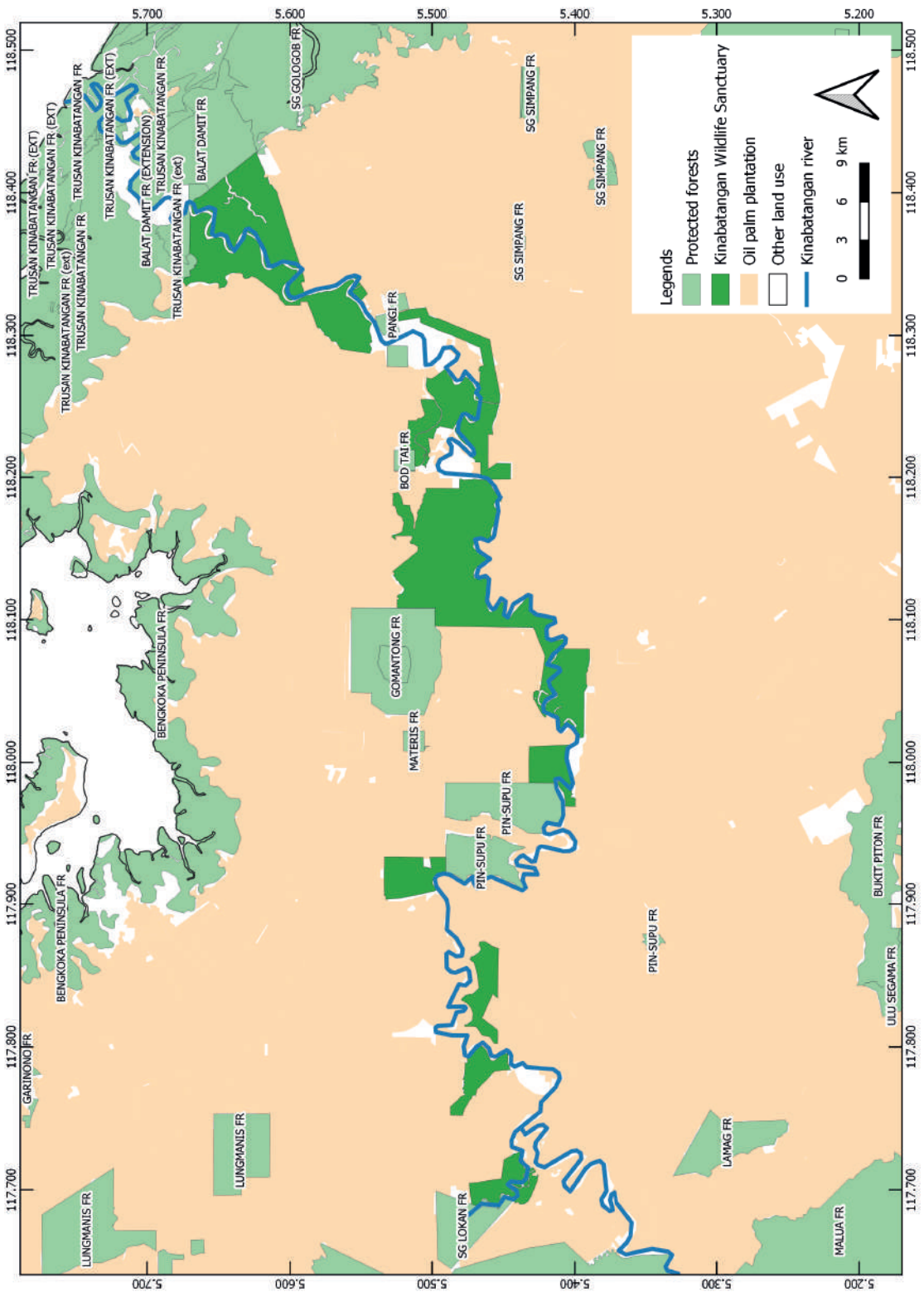


Figure 8. Lower Kinabatangan Floodplain

Box 1. Orangutan in Fragmented Forests in Kinabatangan

Marc Ancrenaz

Today, less than 60,000 ha of forests are left in agricultural landscapes covering more than half a million ha, dominated by monoculture oil palm plantations. Half of these highly fragmented and degraded forests are protected (27,000 ha as the Lower Kinabatangan Wildlife Sanctuary and 15,000 ha as Virgin Jungle Forest Reserves), while the rest is mostly privately owned. In 1998, together with the Sabah Wildlife Department and the local communities, HUTAN, a French NGO, initiated the Kinabatangan Orangutan Conservation Programme.

The Lower Kinabatangan Floodplain is a biodiversity hotspot. In 2001, intensive aerial and ground surveys estimated a population size of 1,125 (95% CI: 691–1807) individuals living in these protected forests (Ancrenaz et al., 2004). The population was about 812 individuals in 2007, and surveys in 2015 estimated the population to be about 785 (414–1467) individuals (Abram & Ancrenaz, 2017). This represents a 30% decline in 15 years, explained primarily by the loss of about 13,000 ha of non-protected forests during the same period (Abram & Ancrenaz, 2017).

However, HUTAN fieldwork also showed an unexpected resilience of the species. Orangutans have survived and bred for decades in small forest patches isolated within the oil palm landscape (Ancrenaz et al., 2015). The future of orangutans in the Lower Kinabatangan Floodplain's extensive agricultural landscape will depend on how forest fragments and corridors are maintained and restored (Ancrenaz et al., 2021). Furthermore, the future of orangutans in the Anthropocene will primarily depend on the collaboration of all land users and government working together to target a peaceful coexistence between people and the great apes inside and outside of protected areas.

Below are the key strategies in the 10-year Orangutan Action Plan:

Better protection of orangutan across its entire habitat

Improve awareness and education about orangutan protection and its critically endangered status while securing long-term viability of orangutan meta-population through effective law enforcement.

Ensure the best ex-situ practices for orangutan management and conservation

A proper guideline on when and how to translocate orangutans, and stronger regulations for tourism need to be developed to minimise contact with orangutans and so mitigate the possible COVID-19 outbreak in orangutans. Care protocols for orangutans in Sepilok Orangutan Rehabilitation Centre should also be improved.

Population monitoring and population trend predictions at 10–15 years

Given that some populations have shown declines over recent times (Abram & Ancrenaz, 2017), and there is a risk of in-breeding depression for small, isolated populations (Bruford et al., 2010), monitoring populations at 10 to 15-year intervals is essential to inform policy and management. This is particularly important as new threats emerge; such as the COVID-19 pandemic as the coronavirus can be transmitted to orangutans, and the impacts of climate change (Struebig et al., 2015).

The biggest challenge for the realisation of the action plan is the high costs associated with some of the strategies; i.e. population monitoring and restoration. Funding will be a challenge, especially with the current slow economic growth following the COVID-19 pandemic.

Halt habitat loss and restore orangutan habitat

Key orangutan habitat should be protected from any threat of conversion and the quality of degraded habitat should be improved through effective forest management, forest rehabilitation and forest fire protection. Forest connectivity should be established to address habitat fragmentation and maintained to link major orangutan habitat and facilitate its movement.

Box 2. Forest Rehabilitation in the Degraded Orangutan Habitat of Bukit Piton Forest Reserve

Bukit Piton Forest Reserve stretches about 12,000 ha in the eastern part of Sabah was heavily degraded due to poor logging practices in the past and combined with drought-induced forest fires in the early 80s and late 90s. Interestingly, aerial nest survey activities carried out in the 2000s resulted in an estimate of 170–300 orangutans (HUTAN, 2007 estimate, Unpublished report; WWF-Malaysia, 2008 estimate, Unpublished report). This population however was separated from the largest Segama orangutan population by the Segama River on the South and on the north, it is surrounded by vast oil palm plantation. In other words, the orangutan's survival depends on the heavily degraded Bukit Piton with low chances of surviving without any management intervention.

In 2008 until 2019, WWF-Malaysia together with the Sabah Forestry Department (SFD) spearheaded the forest rehabilitation project to improve the orangutan habitat in Bukit Piton. Open and exposed areas being planted with fast-growing pioneer species such as Binuang (*Octameles sumatrana*) and Laran (*Neolamarckia cadamba*) to support the orangutan's feeding habits, fruit trees that are edible to orangutans including Sengkuang (*Dracontomelon dao*), Terap (*Arthocarpus sp*) and Figs (*Ficus sp*) were also planted. Dipterocarps were also planted in areas shaded by forest canopies. In 2012, Bukit Piton was given the highest form of protection which is Class-1 Protection which does not permit any form of land conversion, timber exploitation or extraction of any forest products by the Sabah State Government.

After 12 years, about 11,612 ha of the degraded forests in Bukit Piton have been rehabilitated with records of orangutans starting to utilise replanted trees in Bukit Piton for food, nest and travelling observed as early as 3 years after planting (2011). This is only the beginning as long-term maintenance and continuous forest protection are needed to ensure this forest rehabilitation is successful.

Watch WWF video of reforestation for orangutans

Ensure survival of orangutan in agricultural landscapes

Small numbers of orangutan remain within pockets of forest patches or riparian reserves after forest clearance. These pockets of forests tend to be left because they are not suitable for planting, and are often small in size and scattered in oil palm plantations. These pockets may act as 'stepping stones' that allow species movement between forest patches and help maintain populations in altered habitats, and may need larger scale replanting and forest restoration activities to reconnect fragmented forest blocks.

This also means that translocation (see Box 3) is not always necessary, and orangutans should remain in forest patches where they are found, while ensuring they are protected with zero tolerance of orangutan killing, so that a meta-population in scattered parts can be safeguarded.

Box 3. Translocation as a Conservation Tool

The major expansion of oil palm plantations during the 1990s to early 2000s has caused extensive loss of orangutan habitat, stemming the need of orangutan translocation to large forested area. Since the early 90s, hundreds of orangutans were translocated from conversion areas and released in Tabin WR, Deramakot FR, Gomantong FR, Sepilok-Kabili VJR or nearby forests under the management of Sabah Wildlife Department (Andau et al., 1994). However, translocation is known to be very costly and may end up further endangering the animal. It may not be effective in the long run as there are known limits and constraints of this method; such as identifying suitable release sites, unknown impact as no post release monitoring activity was carried out, unknown survival rate and failure to foster co-existence with wildlife where they are released.

Acknowledgements

Special thanks to WWF-Malaysia's Orangutan Conservation Team (William, Bob, Tinrus and Zuraimi) for data collected during aerial nest surveys and ground surveys; Anastacia Amanda and Adi Shabrani and Suzika Juiling for producing maps; Marc Ancrenaz of HUTAN for the Kinabatangan orangutan population write-up; Marc and Felicity Oram of PONGO Alliance/HUTAN and Glyn Davies for commenting on this chapter; and WWF-UK as a major donor for orangutan conservation work in Sabah. We greatly appreciate the permission granted by the Sabah Forestry Department, Sabah Wildlife Department and Sabah Parks in allowing us to conduct surveys in areas under their jurisdiction; and Sabah Biodiversity Centre in approving licenses to conduct research in Sabah.

Data sources

Individuals / organizations (Number of records): Brodie, Jedediah (40); Gardner, Penny (161); Guharajan, Roshan (173); Haysom, Jessica (279); Hearn, Andrew (248); Lim Wing Shen (3); Muhammad Edri Nurdin (1); 1StopBorneo Wildlife (3); Sabah Museum (1); WWF-Malaysia (252). *Publications (Number of records):* Abdullah et al., 1995 (17); Allan & Coolidge, 1940 (1); Ancrenaz et al., 2005 (29); Ancrenaz et al., 2004 (8); Bernard et al., 2013 (1); Bernard et al., 2014 (10); Bernard et al., 2016 (9); Boonratana & Sharma, 1993 (2); Boonratana, 1997 (7); Bunya et al., 2010 (1); Chung et al., 2019 (6); Davies & Tan, 2019 (4); Davies & Payne, 1982 (66); Davis, 1962 (4); Dawson,1992 (4); Deere et al., 2017 (18); Harrison, 1998 (1); Hawkins et al., 2019 (1); Ishige et al., 2017 (1); Kanamori et al., 2010 (1); Kanamori et al., 2012 (1); Kehoe, 2011 (5); KOPEL, 2016 (6); KOPEL, 2019 (2); Mackinnon, 1974 (98); Mojiol et al., 2008 (1); Nakashima et al., 2008 (4); Okano, 1965 (3); Prudente et al., 2009 (1); Rajaratnam, 1995 (1); Regip, 2003 (2); Samejima & Ong, 2012 (27); Samejima et al., 2012 (1); SFD, 2017 (1); SFD, 2018 (3); SFD, 2019 (1); Shukor et al., 2011 (1); Sollmann et al., 2017 (3); Tangah et al., 2016 (10); Webb, 2016 (2); Wilting & Mohamed, 2010 (1); WWF-Malaysia, 1985 (6).



Gibbon calling in Tabin Wildlife Reserve © Mazidi Abd Ghani/WWF-Malaysia

4

North Bornean Gibbon (*Hylobates funereus*)

Glyn Davies

Introduction

"Gibbons are diurnal, and among the most conspicuous inhabitants of the North Bornean forests, and their beautiful morning calls are heard wherever there is old forest" (Davis, 1962). This summary from forest surveys in the 1950s shows how widespread gibbons were in Sabah's unlogged lowland forests at that time, and they remain widespread in the logged forests today (Shabrani et al., 2021).

Taxonomy

Based on sonographic, morphological and genetic analyses, four endemic species of gibbon are now recognised in Borneo (Roos et al., 2014), and the species in Sabah is *Hylobates funereus* (previously named *Hylobates muelleri*), which is coloured with a " ... combination of very dark underparts associated with light coloured hands and feet ... there is a light brow-patch, varying from a small patch above the eyes to a ring completely encircling the face" (Davis, 1962). Adults weigh 5–6.4 kg (Payne et al., 1985). The gibbon in Sabah has been given various common English names, perhaps the most appropriate of which is North Bornean Gibbon — since the species' range extends to cover the northern half of Borneo (Figure 1).

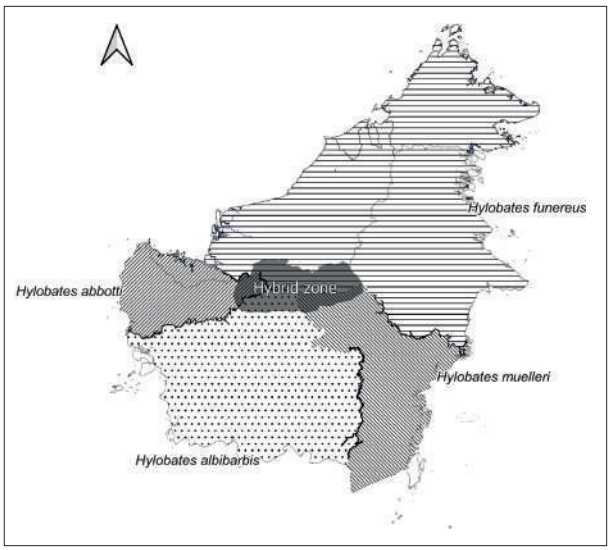


Figure 1. Map showing four species of gibbons on Borneo (after Phillipps & Phillipps, 2018)



Figure 2. a) North Bornean Gibbon photographed at canopy with camera trap in Maliau Basin © Jessica Haysom/ DICE; b) Gibbon in Tabin Wildlife Reserve © Mazidi Abd Ghani/WWF-Malaysia

Natural History

The most conspicuous feature of all gibbons is their tremendously long arms, used to make acrobatic swings between branches, which is known as brachiation. Their long arms catapult them through the air, often covering large distances, in marked contrast to the rather ungainly bipedal locomotion they show when walking along branches with their legs (Figure 2a). They have not evolved adaptations for walking along the ground, like orangutans walk on their knuckles. Indeed, travel along the ground is almost never recorded for gibbons, and they seek safety in the tallest trees.

The species' annual diet has been recorded in both Sabah (Inoue et al., 2016) and Kalimantan (Leighton, 1987), and these show a remarkable similarity with over 60% comprising fruit parts, especially figs which account for a quarter to one third of the annual intake (Figure 3). Gibbons eat young leaves when preferred fruit parts are seasonally unavailable in the forest, and they travel more during periods of fruit abundance (Inoue et al. 2021).

Gibbons pair for life, and live in monogamous groups of an adult male and female with their progeny — giving a group size of 3–4 animals. Births occur around 3 years apart, and the mother carries the infant until it can travel independently (around 2 years old). On one occassion, an adult male was recorded carrying a well-grown 17-month old infant in Danum. Between 8–10 years of age, sub-adult gibbons begin the process of departing

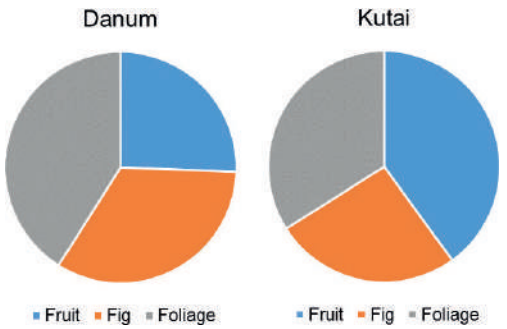


Figure 3. The proportion of different items in the diets of *H. funereus* studied in Danum Valley (Sabah) and Kutai (East Kalimantan).

Gibbon songs

Yoichi Inoue

A very important part of gibbon society is their singing. Gibbons produce species-specific and sex-specific songs (Inoue et al., 2013). In the case of *Hylobates funereus*, males sing solo songs before or at dawn and mated pairs sing duets in a coordinated fashion usually in the morning (Figure 4). Male solo songs in Danum Valley appear to be influenced by environmental factors — rain in the preceding night led to fewer calling events and led to a later start time of male solos (Clink et al., 2020).

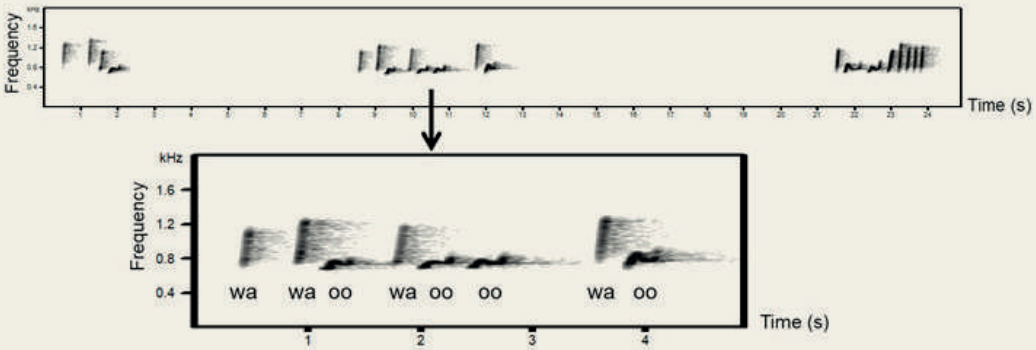


Figure 4. Three phrases of a male song recorded in Danum Valley. In this case, a phrase consists of two notes, "wa" and "oo"

The female great call is the main part of the duet song (Figure 5). The great call begins with relatively long "oo-wa" notes, which become progressively shorter and delivered at a faster pace, until the female produces a rapid repetition of "wa" notes delivered at a rate of about eight notes each second (Haimoff, 1985).

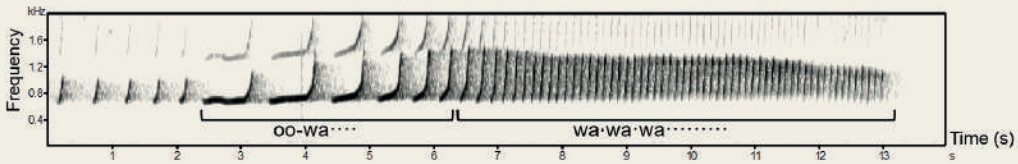


Figure 5. Spectrogram of a female great call recorded in Danum Valley. The female great call shows the slow build up and ending with a rapid crescendo — also referred to as a "bubbling" sound (Hose, 1893)

The loud calls are generally delivered from the tallest trees in the forest, to help the sound travel further. Sub-adult females may join her mothers in the great call sequence, but they do not call again until they have left and formed their own group. There are other calls, such as the soft "hoo" that is heard when surveyors surprise a group in the forest, or the copulation calls which females give — perhaps to increase mate guarding and strengthen the pair bond within the relationship (Inoue et al., 2019). This range of calling behaviour indicates that the vocal interactions of this small ape are quite sophisticated.

(or being chased away by their parents) from their group, and this is a challenging time when non-paired animals are travelling alone and seeking new partners and territories.

The family groups in Danum travelled an average of 1.27 km/day, and in Kutai 0.85 km/day, yet in both places they lived in similar size home ranges: 33–34 ha, with minimum overlap between neighbouring territories (Leighton, 1987; Inoue et al., 2016). This leads us to the importance of song. As an alternative to patrolling territory boundaries, all gibbon species invest considerable time and energy in defending their territory with their loud calls, which can be heard over 1 km away. This has been shown as a mechanism for group spacing (Mitani, 1985).

Gibbon calls from Sabah
© Marc Anderson
(wildambience.com)

Distribution and Abundance in Sabah

In Sabah, from the time of the earliest collections in the 1930s until today, the species has maintained its widespread distribution in all forested areas — whether unlogged (primary) or logged forest (Figure 6).

In terms of population size, records across Sabah from 1979–1981 showed that "Gibbons are common over most of Sabah. They are abundant in the lowland forests and are found up to about 5,000' [1,500 m] asl on Mt. Kinabalu. They occur in logged forests and were seen once in a tree plantation, … " (Davies & Payne, 1982). An important ecological observation was that gibbons were most abundant in forests below 450 m asl (3+ group/km^2), and populations declined by more than half at higher elevations. This corresponds with the change from lowland/upland dipterocarp forest to highland dipterocarp forests (Davies & Payne, 1982).

Threats

Timber extraction has left less than 5% of Sabah unlogged at the present time, and the impact of logging on gibbons in Sabah was first studied in the late 1980s in Danum and Tabin areas. This arboreal species showed a remarkable and unexpected resilience to the impacts of timber extraction, in areas where as many as half the trees were destroyed (Johns, 1988; 1992). This early finding has been supported by primate surveys in Kalabakan forests (Bernard et al., 2016), and reinforced by more recent surveys in Tabin, which show that 20 years after very intensive logging, gibbon numbers are back to levels recorded in previously unlogged forests — about 2–3 group/km^2 (Davies & Tan, 2019).

The good news that gibbons can adapt to live in logged forests following repeated timber extraction needs some caution, however (Table 1). There is evidence that gibbon numbers have declined in logged forests of Deramakot Forest Reserve, despite Reduced Impact Logging (RIL) (Shabrani et al., 2021). Here gibbons persist at roughly half the population density (1–1.5 group/km^2) in forests logged 5 years previously using RIL and followed by silvicultural work (e.g. climber cutting). More detailed research is needed to clarify what long-term impacts timber extraction has on gibbon populations — but populations can certainly recover fully in lowland forests if a 20-year period of regeneration is allowed after the felling has stopped.

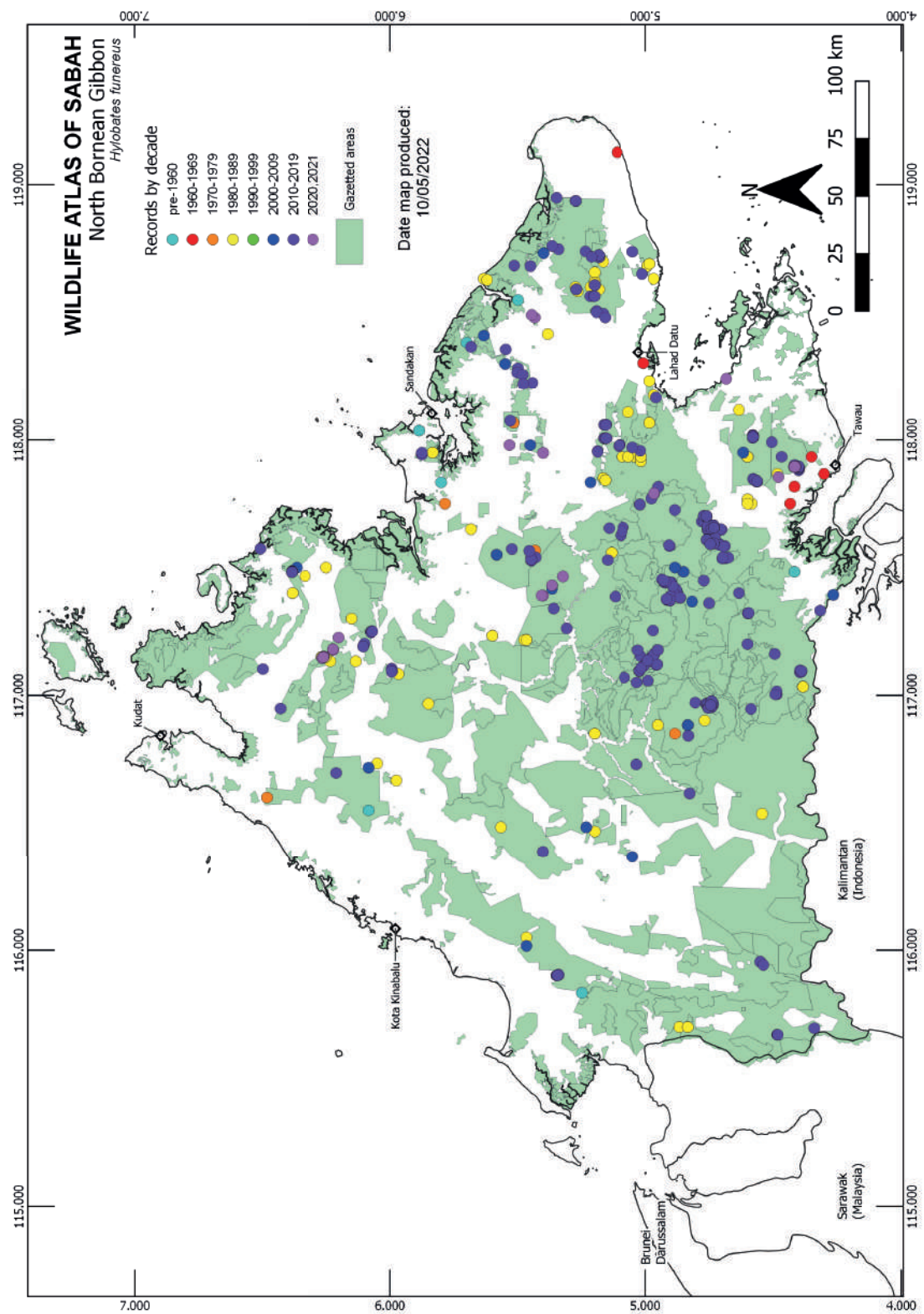


Figure 6. Map of gibbon records by decade, showing the consistent and widespread records within the permanent forest estate

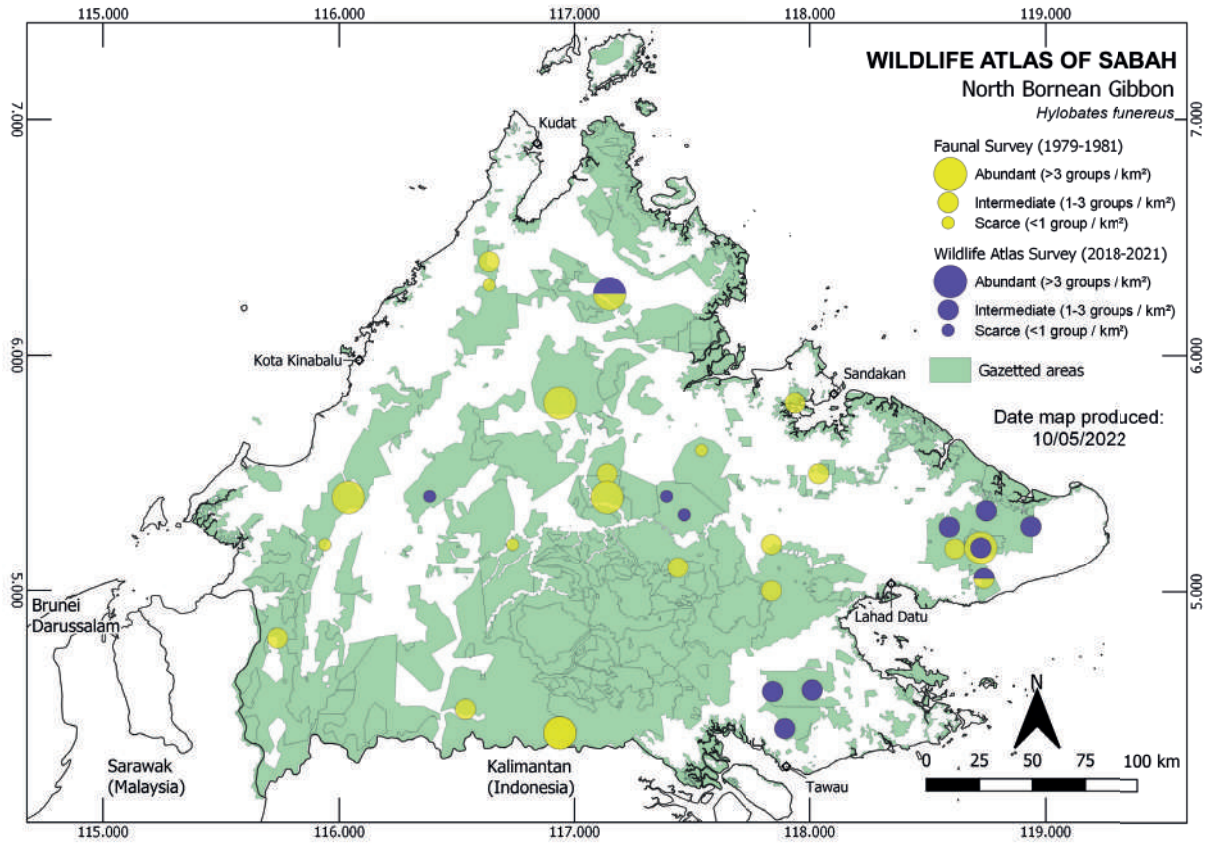


Figure 7. The estimated abundance from 1979–1981, and 2018–2021. Population densities were estimated as high (>3 group/km^2), intermediate (1–3 group/km^2) or low (<1 group/km^2) (Davies & Payne, 1982; WWF-Malaysia survey records).

A second note of caution is on the impacts of hunting, which can increase when logging operations open new roads and the loud gibbon calls attract hunters. Survey results indicate that hunting of gibbons in the highlands of south-western Sabah had negative impact on populations, but this could not be separated from the possible negative influence of habitat change with increasing altitude. Subsequent surveys in 2002 and 2003 confirmed that hunting appeared to reduce gibbon populations in the south-west, and also in some northern areas (e.g. Tungud, Poring and Sugut), but at no survey site had hunting eliminated the gibbons entirely (SWD, unpub. report). By contrast, in the central forests and eastern areas, where most logged forest is found, there is little evidence of hunting of gibbons.

The clearance of forests for agricultural plantations, during the 1980s and 1990s, involved the clear felling, and initially burning, of most forest in the eastern lowlands. This means about 20% of Sabah is no longer suitable gibbon habitat (Figure 7), and at least 100,000 gibbons were lost when these plantations were created.

Gibbons still persist today on the Sandakan Peninsula at Sepilok (4,308 ha), which is a 'forest island', and gibbons have been recorded in smaller forest patches that persist within plantation landscapes, such as Gomantong Virgin Jungle Reserve and forest patches in Lower Kinabatangan and Lower Segama areas. The long-term prospect for these small refuge populations, however, does not look positive.

Table 1. Population estimates in logged forests. In Tabin, after 20 years without logging and without silviculture treatment: ca. 2–3 group/km^2. In Deramakot compartments felled 5–6 years prior to surveys, with Reduced Impact Logging (RIL) and silviculture treatment: 1–1.5 group/km^2. No hunting of gibbons was recorded at any of these sites (after Shabrani et al., 2021).

Survey Site	Altitude	Forest Habitat	Gibbon grps/km^2	Date surveyed
Tabin WR west transect	100–300	Logged (1990s) No silviculture	2.75	Nov 2018
Tabin WR north transect	30–50	Logged (1990s) No silviculture	2.5	Oct 2018
Tabin WR east transect	200–240	Logged (1990s) No silviculture	1.75	July 2018
Tabin WR south transect	150–300	Logged (1990s) No silviculture	1.75	Aug 2018
Silabukan FR	490–550	Logged (1990s) No silviculture	2.5	Nov 2018
Deramakot FR Comp 19 & 20	100–170	Logged 2014, RIL & silviculture liana cutting	1	March 2020
Deramakot FR Comp 77	80–120	Logged 2013, RIL & silviculture liana cutting	1.25	March 2020

Cultural Significance

Gibbons have long been kept as pets (Keith, 1940), often when young are taken after their mothers are killed during forest clearance or hunting (D. Louis, pers. comm.), and licences used to be issued to keep captive gibbons (Burgess, 1961). This pet trade has never been a significant drain on wild populations, but does pose a significant animal welfare concern when the captive animals are kept in poor conditions.

Conservation

Hylobates funereus is listed as 'Endangered' in the 2008 IUCN Red List assessment of 2008 (Geissmann & Nijman, 2008), because the species is declining in numbers across its range as a consequence of forest clearance and hunting. The situation in Sabah confirms that North Bornean Gibbons have been lost through forest clearance, and the vast majority of the population is now only found within the logged forests in the permanent forest estate (Figure 7). It is difficult to estimate the total population of gibbons in Sabah, because so much of the remaining forest is in upland and highland areas less favoured by the species, but using conservative population estimates for the larger forests, there are probably at least 100,000 individuals across the State (Table 2).

Large blocks of forest are important for gibbon conservation, and maintaining connectivity between forest blocks and patches is also important to ensure healthy interbreeding between areas. Ecological connections also keep open options for species dispersal to adapt to future impacts of climate change.

Table 2. Population estimates of North Bornean Gibbons in remaining forests blocks

Forest Habitats	Indiv/km²	Population estimate	Main forest blocks supporting gibbons — population estimates
Lowland (0–500 m asl)	10/km²	57,000	Tabin (10,000); N Kuamut (5,000); Malua (4,500); Danum (4,000); Maliau Buffer (3,500)
Upland (500–1000 m asl)	5/km²	37,000	Kalabakan (5,000)*; Mt. (Gunung) Rara (3,000); Sapulut (3,000);
Highland (>1000 m)	2/km²	6,000	Crocker Range (1,500); Trus Madi (1,000); Mt. Kinabalu (1,000)
		ca. 100,000	

*Upland and highland forests together

The Sabah Wildlife Conservation Enactment 1997 classifies gibbon (*Hylobates muelleri*) as a Schedule II, meaning that North Bornean Gibbons can be hunted with a special licence. This is inconsistent with its current international 'Endangered' status, and efforts should be made to give the species greater legal protection in Sabah, as well as updating the scientific name.

Habitat loss and fragmentation results in a steep decline of the gibbon population in Kinabatangan

Marc Ancrenaz

In the late 1980s to early 1990s, gibbon density was estimated to fluctuate between 2 and 4 group/km² in the Lower Kinabatangan Floodplain (Davies & Payne, 1982), and since 1998 researchers in Lower Kinabatangan have recorded gibbons' morning calls to monitor their populations in the 26,000 ha of protected forests known as the Lower Kinabatangan Wildlife Sanctuary (LKWS).

In 2006–2007, the field surveys estimated an overall gibbon density for the LKWS to be about 1.40 group/km², corresponding to a population size of about 500 groups (or about 1,750 individuals). One decade later, the same surveys showed a further significant decline, with an overall density estimate of 0.84 group/km² across the same area (Hutan, 2017). We estimated the total population size of gibbons for Kinabatangan to be about 357 groups (286/0.8) or 1,250 individuals. These results show a 29% decline in a period of ten years only, and a five- to ten-fold decline in less than thirty years in the forests of the LKWS.

Major threats faced by gibbons in Lower Kinabatangan include forest loss and habitat fragmentation due to conversion to agriculture. Being strictly arboreal animals, gibbons cannot cope well with forest degradation and fragmentation. Unlike orangutans, gibbons do not walk on the ground and their dispersal abilities in the highly fragmented Kinabatangan landscape are greatly jeopardized. Today, the gibbon population found in Kinabatangan is facing extinction. Reconnecting isolated forest fragments is a key management strategy if we want to secure a viable gibbon population in Lower Kinabatangan.

Acknowledgements

Many thanks to Jessica Haysom for gibbon photos and to Marc Anderson of WildAmbience for permitting the inclusion of his weblink containing gibbon calls. WWF-UK gave financial support to conduct orangutan and general wildlife surveys for the Wildlife Atlas of Sabah project. Marc Ancrenaz and Yoichi Inoue provided important 'text boxes', and Yoichi Inoue kindly peer-reviewed the chapter.

Data Sources

Individuals / organizations (Number of records): Deirdre Julius Kulip (1); Donovan Louis (2); Ezra Alim (2); Hearn, Andrew (1), Gardner, Penny (1); Haysom, Jessica (263); Joe Pan (1); Johanis Han Sin Koh (1); 1StopBorneo Wildlife (1); BORA (2); Forest Solution Malaysia (1); Sabah Forestry Department (1); WWF-Malaysia (315). *Publications (Number of records):* Abdullah et al., 1995 (6); Allan & Coolidge, 1940 (2); Ancrenaz, 2020 (15); Bernard et al., 1997 (1); Bernard et al., 2014 (8); Bernard et al., 2016 (8); Bili, 2014 (13); Boonratana & Sharma, 1993 (2); Boonratana, 1997 (10); Bunya et al., 2010 (1); Chasen & Kloss, 1931 (2); Chung et al., 2019 (2); Davies & Tan, 2019 (3); Davies & Payne, 1982 (143); Davis, 1962 (4); Dawson, 1992 (6); Hawkins et al., 2019 (1); Kehoe, 2011 (7); Ketol et al., 2009 (1); Lim, 1993 (1); Mahyudin et al., 2010 (1); Mingueza, 2018 (1); Nakabayashi et al., 2014 (1); Okano, 1965 (2); Payne et al., 1989 (1); Prudente et al., 2009 (1); Rajaratnam, 1995 (1); Regip, 2003 (1); SFD, 2016 (21); SFD, 2017 (16); SFD, 2018 (18); SFD, 2019 (20); Sharma, 1992 (4); Sheldon & Francis, 1985 (1); Shukor et al., 2011 (2); Tangah et al., 2016 (1); Webb, 2016 (2); Wilting & Mohamed, 2010 (1); Wong, 2011 (6); WWF- Malaysia, 1985 (1); York et al., 2013 (1).



Red Leaf Monkey in Sepilok © Brendan Ryan

5

Red Leaf Monkey (*Presbytis rubicunda*)

Glyn Davies and Maklarin Lakim

Introduction

There are five subspecies of Red Leaf Monkey (*Presbytis rubicunda*) found across Borneo (Phillipps & Phillipps, 2018). In Sabah, the subspecies *P. r. ignita* is widespread, with records from the tree line on Mt. Kinabalu (3,272 m asl) to the lowlands on the northern side of the Kinabatangan River. South of the Kinabatangan River there is a paler subspecies, *P. r. chrysea,* and in Tawau Hills Park there are a number of very pale/white coloured individuals of this same subspecies (Davis, 1962; Davies & Payne, 1982; Lakim, 2017; Phillipps & Phillipps, 2018).

The Red Leaf Monkey has been given a number of common English names: Red Langur, Maroon Leaf Monkey, Maroon Langur (Phillipps & Phillipps, 2018). Here we use the term 'leaf monkey' to distinguish the Southeast Asian *Presbytis* species from the South Asian *Semnopithecus* species, which are called 'langur' by local people in India, Sri Lanka etc. A direct translation of 'red monkey' into Malay is *monyet merah*, but the species has a number of local names, such as *maragang* in the Kadazan and *kulesi* in Orang Sungai.

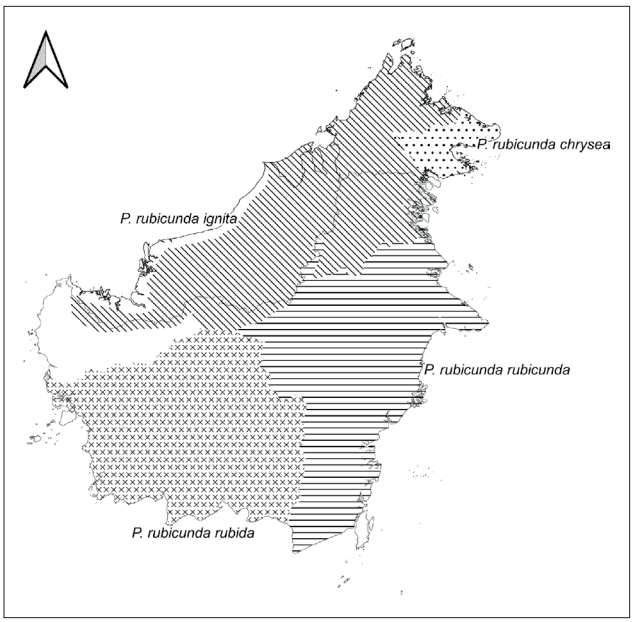


Figure 1. Red Leaf Monkey subspecies boundaries within Borneo (after Phillipps & Phillipps, 2018)

Red Leaf Monkeys have been the subject of detailed ecological studies at three sites in Sabah: Sepilok Forest Reserve (1980–1981); Tawau Hills Park (1996–1998 & 2001–2005); and Danum Valley Conservation Area (2006–2008). These study sites are all in unlogged lowland mixed dipterocarp forests, as distinct from peat swamp forest study sites in Kalimantan (Ehlers-Smith et al., 2013; Supriatna

et al., 1986). However, at both the Danum Valley and Tawau Hills sites there are moderate to large rivers with riverine vegetation running through the study areas, which does not apply in Sepilok where there were only small streams, which often dried up during the dry season.

Taxonomy

According to the most recent taxonomic review, Red Leaf Monkeys branched from an ancestral *Presbytis* stock in Sumatra about 1 million years ago (Roos & Zinner, 2021). This indicates that Red Leaf Monkeys colonised Borneo relatively recently, compared with an estimated date of some 3 million years ago for grey leaf monkeys in Borneo (Roos & Zinner, 2021).

D. Dwight Davis (1962) described Red Leaf Monkeys in Sabah as being distinguished by "maroon to mahogany red … with dark hairs on the feet and tail tip". The paler subspecies are an amber brown (see below). They all have hairs on the forehead forming a radiating fringe that overhangs the



Figure 2. Red Leaf Monkeys in Sabah: a) *P. r. ignita* (darker pelage) adult foraging through mid-storey, Sepilok © Brendan Ryan; b) *P. r. chrysea* (paler pelage) group making a rare trip to the ground to drink water from a stream, Ulu Kalumpang FR © WWF-Malaysia; c) *P. r. ignita* adult male resting in understorey tree, Sepilok © Glyn Davies; d) *P. r. chrysea* — sub-adult foraging, Tawau Hills Park © Aaron Gekoski/WWF-US

eyes. The naked parts of their faces and ears are bluish grey; upper lips and chins are flesh-coloured. The body shape is that of a lithe primate, where " ... the lumbar region is long, the radius long, and the entire hind limb long. These are adaptations for leaping arboreal locomotion". They also have a long tail, and adults weigh 6.2 kg for males and 6.0 kg for females (range: 5.5–7.0 kg; Davis, 1962).

Davis (1962) described a new subspecies of Red Leaf Monkey for Sabah, *P. r. chrysea*, from specimens on the south bank of the Kinabatangan River mouth (Bukit Kretam). He attributed the rest of the specimens in Sabah to the darker *P. r. ignata* (at that time called *P. r. rubicundus*). Subsequent surveys confirmed *P. r. chrysea* subspecies to be found south of the Kinabatangan River and north of the Kalabakan River (Davies & Payne, 1982; Figure 3), and more recent surveys in Tawau Hills Park revealed pure white individuals (Phillipps & Phillipps, 2018). This led to the conclusion that Sabah holds a subspecies of Red Leaf Monkey unique to Borneo, apparently extending as far west as the Imbak Canyon (Lamb et al., 2019).

Davis (1962) did also note "it appears that the colors of *P. rubicundus* are not very stable", and even during surveys in the 1980s there were animals recorded as looking intermediate in colour between the two subspecies (Davies, 1984).

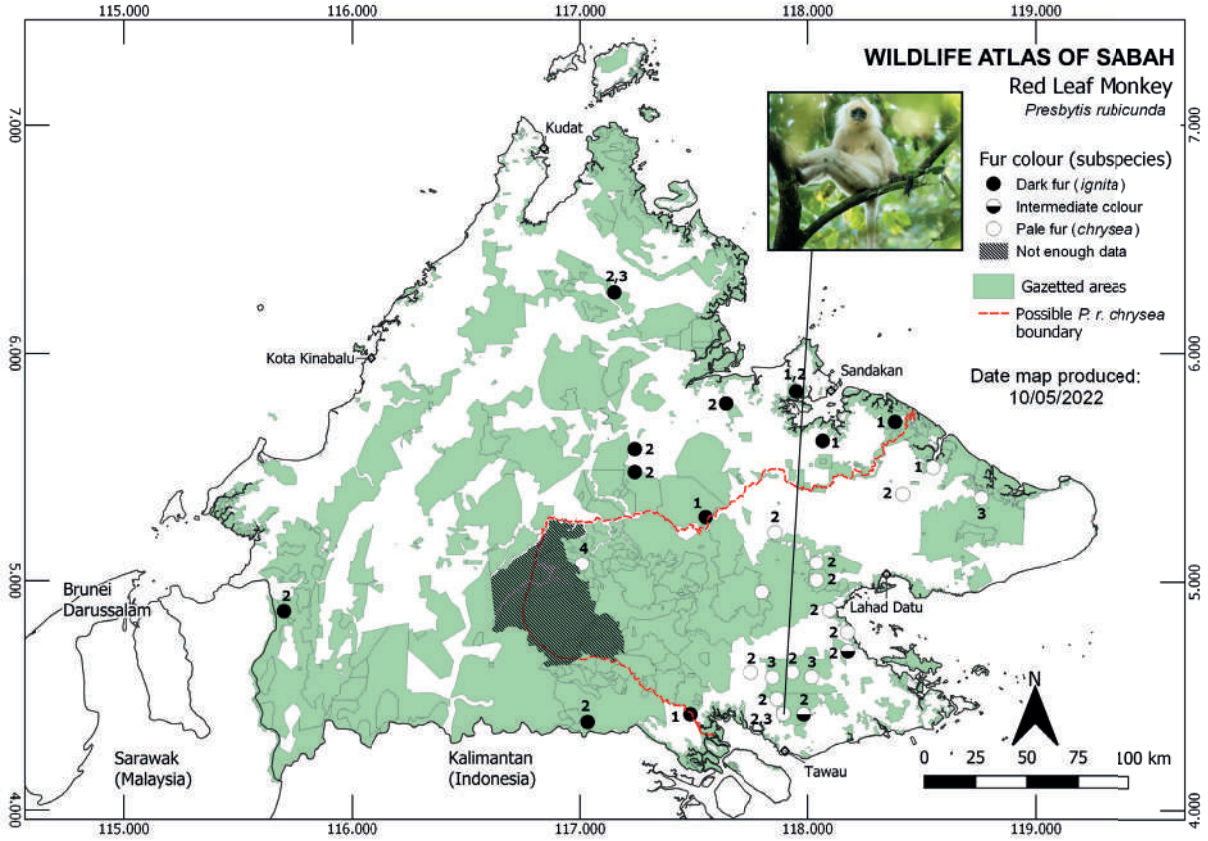


Figure 3. Map showing locations of two Red Leaf Monkey subspecies in Sabah: the darker *P. r. ignita* (black dots), and paler *P. r. chrysea* (white dots). Two 'intermediate coloured animals were seen (half-black dots), and the white individual at Tawau Hills Park (photo inset © Shavez Cheema). References: 1 — Davis, 1962; 2 — Davies & Payne, 1982; 3 — WWF-Malaysia surveys (2018–2020); 4 — Lamb et al., 2019. There is also a report of white leaf monkeys in the Danum area (MacKinnon et al., 1996).

Natural History

One of the most important characteristics of leaf monkeys is their enlarged and multi-chambered stomach (Kay & Davies, 1994). In small-bodied animals like leaf monkeys, food is unlikely to be retained long enough to allow forestomach fermentation to break down cellulose, but it could break open plant cells walls to release their more digestible contents, and may break down toxic plant defence compounds like alkaloids (Davies et al., 1988).

Red Leaf Monkeys are highly selective in their diets (Table 1). They hardly consume the abundant mature leaves of forest trees because they are low quality and less digestible than the young leaves (Waterman et al., 1988). Furthermore, trees in Sepilok that accounted for over 50% of the tree biomass, contributed only 4% to the leaf monkey's annual diet (Davies et al., 1988). This indicates how selective the animals must be, and the limited availability of food resources in Sepilok.

Table 1. The annual diets of Red Leaf Monkeys at three sites in Sabah.

		Sepilok	**Tawau Hills**	**Danum Valley**
Subspecies		***P. r. ignita***	***P. r. chrysea***	***P. r. chrysea***
Study period		June 1980–October 1981	1996–1998; 2001–2005	Dec 2006–Dec 2008
Habitat		Lowland dipterocarp forest	Lowland dipterocarp & riparian forests	Lowland dipterocarp & riparian forests
Diet items Annual intake % (monthly range)	Mature leaf parts	1% (0–7)	4%	0.2%
	Young leaf parts	36% (7–71)	42%	46% *Spatholobus macropterus* (28% of feeding records)
	Seeds only	30% (1–7)	22%	38%
	Fruit parts	19% (20–40) *Neolamarckia cadamba*	18%	12%
	Floral parts	11% (1–30)	8%	2%
	Other	1% (bamboo pith)	5% (stems) 1% (roots)	1% (bark) 1% (pith)
	Species	103++	120+	120+
Sources		Davies et al., 1988	Lakim, 2017	Hanya & Bernard, 2015

Young leaves make up over a third of the leaf monkey's annual diet. They are a very important source of protein (Davies et al., 1988; Hanya & Bernard, 2015) but young leaf production is seasonal; in peak periods as many as 50% of trees produce young leaf flush, and in months of scarcity less than 10% (Davies, 1991). The predominance of young leaf parts from a single species of climber at Danum, *Spatholobus macropterus*, is distinctly different from the diets described in Tawau Hills and Sepilok. This climber was not recorded in Sepilok (DeValt et al., 2006), and it shows the importance of having a highly digestible leaf source which can sustain the animals through all seasons.

Fruit-eating is also very seasonal, and is dominated by consumption of large, non-succulent seeds during a peak fruiting season, with animals shunning or discarding succulent fruit flesh and pulp at this time (Davies, 1991; Hanya & Bernard, 2012; 2015; Lakim, 2017). It is evident that Red Leaf



Figure 4. Red Leaf Monkey foods: a) & b) Large-seeded legume (*Milletia* sp) and other large-seeded fruits with minimum pulpy flesh, Sepilok © Glyn Davies/WWF-Malaysia; c) Young leaves of *Spatholobus macropterus*, the commonest item in the diet, Danum Valley © Goro Hanya

Monkeys are seed predators, generally destroying the seeds that they eat (Figure 4), and especially seeking out nutritious large seeds from the legume (bean/pea) families. Outside the main fruiting season, other types of fruits are eaten, such as the dry, small-seeded fruits of laran (*Neolamarckia cadamba*). Minor items in the diet include pith, and very occasionally soil from termite mounds (Davies & Baillie, 1988). Insects are almost never consumed.

Social Behaviour

The social organisation of leaf monkeys is based on groups which contain a single adult male, two or more adult females and their progeny, such that group size records from Sabah tend to be between 4–8, with a range up to 12 animals (Stott & Selsor, 1962; Davies, 1987; Table 2). The adult male leads, guards and mates with adult females, and excludes sub-adult and adult males from the harem. These males travel alone, or in small bachelor groups, and as a consequence there can be violent exchanges when new males try and displace the incumbent in an attempt to breed with the females. When this happens the group structure can be disrupted, with young females leaving to join the incoming male, and older females with infants preferring to stay with the father to avoid the risk of infanticide by the new male (Davies, 1987).

Much of their time is spent foraging in the middle and lower forest canopy, while sleeping in the safety of very tall trees at night. The average day range length is about 1 km, ranging between 250–2,000 m (Table 2). At Sepilok, the group travelled further when eating seeds (Davies, 1984), but this was not the case in Danum (Hanya & Bernard, 2016). In both Sepilok and Danum the study groups defended their home ranges from neighbouring groups, despite the Sepilok group having a very large home range (84 ha) that was difficult to patrol.

The population in Danum was nearly 5 times more abundant than that reported for Sepilok (Table 2), and other sites in Sabah (Davies & Payne, 1982) and Borneo (Phillipps & Phillipps, 2018). This alerts us to the fact that forests can be very patchy in their distribution of food resources which affects population densities. It is possible that riverine vegetation, such as in the Danum and Tawau study sites, supports higher Red Leaf Monkey populations either because the vegetation is more digestible, or plant part production is more evenly spread across the year.

Table 2. Group size, home range and population at three sites in Sabah

	Sepilok	Tawau Hills	Danum Valley
Study group size range	6–8	(2–15)	8–12
Average home range in ha (min–max)	70–84	80 (35–99)	21–32
Home range overlap with neighbours	<10%	-	<10%
Average day range length in m (min–max)	890 (250–1,670)	-	1160 (550–2,140)
Population estimates	16 indiv/km^2	-	77 indiv/km^2 7.6 group/km^2

Distribution and Abundance in Sabah

Red Leaf Monkeys are found in dipterocarp forests, and in the riverine vegetation along the large rivers in the eastern lowlands. “They can colonise logged forest and are known to enter cultivated smallholdings, cocoa and oil palm plantations, but only remain in such cultivated areas for short periods” (Davies & Payne, 1982). They will also enter industrial tree plantations (*Albizia*) to feed, and sometimes feed on cultivated fruit trees (Lakim, 2017).

Considering the two subspecies, the Kinabatangan River and Darvel Bay set the northern and eastern limits for the *chrysea* subspecies, but the southern and western limits are less clear. Somewhere in the Maliau Basin area is where the *P. r. ignita* subspecies takes over and occupies western and central Sabah, as well as north of the Kinabatangan River (Davies & Payne, 1982; Phillipps & Phillipps, 2018).

A second important feature of their distribution is that although both red and grey leaf monkeys occur all over Sabah, in any given forest only one species predominates and the other is scarce. At the present time, Red Leaf Monkeys are more abundant than greys in forests of the eastern lowland, except Tabin, and greys more abundant in the uplands and hills of central and western Sabah. Given that grey and Red Leaf Monkeys have very similar body weights, digestive systems and diets, and live in harem groups, it is to be expected that, ecologically, they will strongly compete. Indeed there are some rare observations of Red Leaf Monkeys chasing and killing a Sabah Leaf Monkey in Tawau (Lakim, pers. obs.).

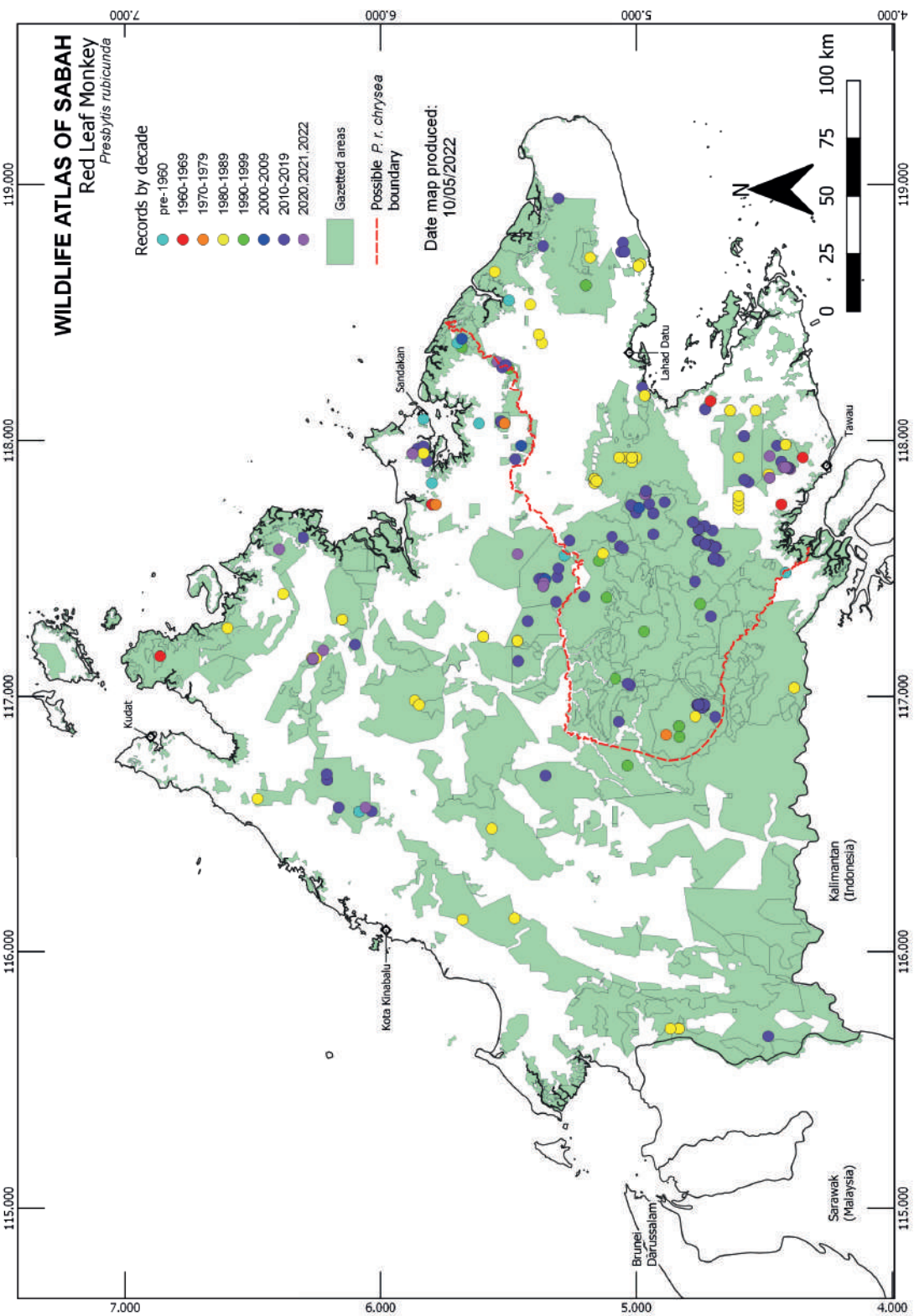


Figure 5. Records of Red Leaf Monkey in Sabah, showing them to be consistent and widespread

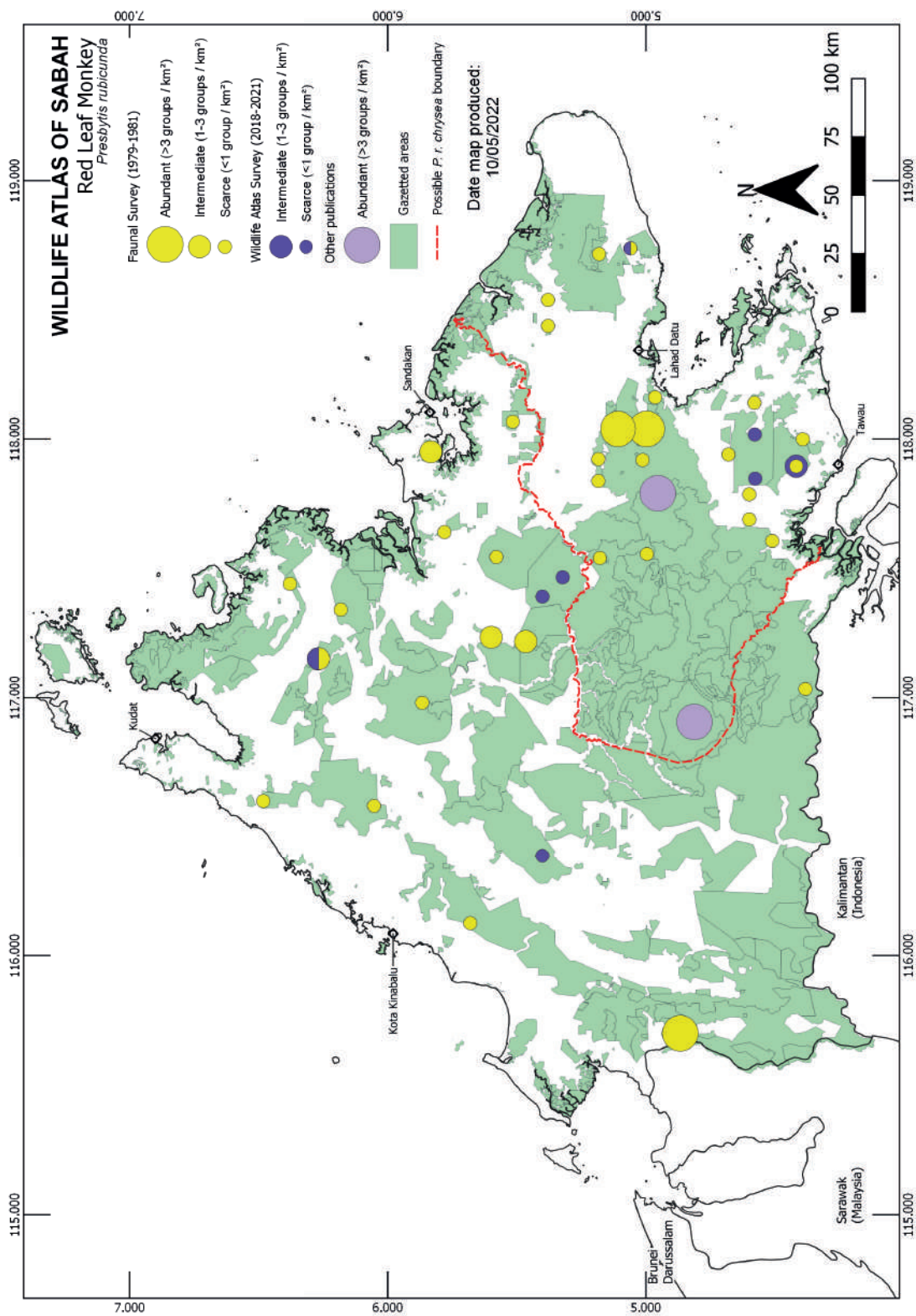


Figure 6. The estimated abundance of Red Leaf Monkey in unlogged forests from 1979–1981 (Davies & Payne, 1982; Phillipps, 2002; Hanya & Bernard, 2016), and logged forests 2018–2020 (WWF unpub. survey reports)

What favours one over the other at any given site, however, remains a mystery, but one factor may be that Red Leaf Monkeys are often found in riverine vegetation, for example along larger rivers in the Kinabatangan, Segama and Tawau watersheds, which is generally not the case for grey leaf monkeys. What features of riverine vegetation may favour Red Leaf Monkeys is therefore an important research question to address. Red Leaf Monkey population density estimates from 1979–81 surveys show 1–3+ group/km^2 (approx. 10–20+ indiv/km^2) in the unlogged forests of the eastern lowlands and Segama uplands (Davies & Payne, 1982; Figure 6). With increasing altitude, populations declined and grey leaf monkeys became more abundant, with one exception of high Red Leaf Monkey population density in a gently sloping valley of Mt. Ibul (1,100 m) in the Crocker Range, and sparce populations in Tabin.

Threats

The impact of timber extraction on Red Leaf Monkeys was researched in the Danum Valley area in the late 1980s (Johns, 1987; 1992), which showed populations reduced to half and a third respectively, 6 and 12 years after logging. However, if groups were adjacent to unlogged forest, then no significant population declines were observed because the animals could maintain their original numbers by making use of both logged and unlogged areas.

During more recent surveys in logged forests of Deramakot, where logging has been going on since the 1960s, most recently Reduced Impact Logging with climber cutting silvicultural (Shabrani et al., 2020), Red Leaf Monkeys were not recorded in two 2-km transect surveys, although they were recorded in riverine forest in the general area (WWF, unpub. reports). They were also recorded at low densities in parts of Ulu Kalumpang Forest Reserve that had been intensively logged a decade previously (WWF, unpub. reports), and seem to be at low densities in Kalabakan forests after logging (Bernard et al., 2016). None of these studies is conclusive, but taking the results together leads to a conclusion that Red Leaf Monkeys adapt poorly to logging, and appear slow to recover numbers after logging has ceased. They are not eliminated from logged forests, however, where hunting pressure is low.

Looking at the impact of agriculture, in particular oil palm plantations, there are no records of Red Leaf Monkeys living in this habitat (e.g. Bernard et al., 2016). There are records of their presence at low numbers in Virgin Jungle Reserves that were left as forested islands in plantation landscapes (Davies & Payne, 1982), and there are reports of Red Leaf Monkeys in the riparian forest patches beside the Kinabatangan and Segama rivers.

The impact of hunting is unknown, in part because of the patchy nature of their numbers in different habitats, and in part because it has not been studied. In general, it is most likely to have a negative impact in western areas where hunting by local communities is more prevalent.

Conservation

Presbytis rubicunda was recorded as 'Least Concern' in the IUCN Red List until 2020, when it was upgraded to 'Vulnerable' (Cheyne et al., 2020). In Sabah the species is probably rarer than North Bornean Gibbon *(H. funereus*), which is recorded as 'Endangered' across northern Borneo, and continuous forest loss in lowland areas over the past 40 years does mean that the leaf monkey population has been declining — possibly halved in numbers over the past 40 years. This species

depends on forest habitats being maintained, especially unlogged forests in the lowlands and Segama uplands where their population densities are greatest. Unlogged lowland forest amounts to only 1% of Sabah at the present time, following decades of logging and forest clearance, and means that remaining unlogged lowland areas are very important.

Looking separately at the two subspecies, the paler *P. r. chrysea* is common in the Danum Valley Conservation Area, and is widespread in the Tawau Hills–Ulu Kalumpang forests of south-east Sabah. The darker *P. r. ignita* occurs in Sepilok, Gomantong and other logged forests north of the Kinabatangan, and at much reduced population densities in Crocker Range and Trus Madi. Overall, this later subspecies has fewer areas of suitable forest (<500 m elevation), and the fragmented population needs monitoring.

The Red Leaf Monkey is classified as a Schedule II under the Sabah Wildlife Conservation Enactment 1997, which means that the species can be hunted with a licence. This should be resisted, however, since there is no evidence that they are crop pests of any significance, and because they can be eliminated from areas by hunting if their population density is already low because of the effects of higher altitude and/or past logging.

Acknowledgements

Many thanks to Goro Hanya and Elizabeth Bennett for their peer review of this chapter. Recent field data were gathered during WWF-Malaysia orangutan/general wildlife surveys, which received WWF-UK financial support. Adi Shabrani and Suzika Juiling provided the maps.

Data Sources

Individuals / organizations (Number of records): 1StopBorneo Wildlife (3); Adriel D.K (2); Brodie, Jedediah (1); Deirdre Julius Kulip (1); Eddy Wong (1); Ezra Alim (2); Frank Faurillo (1); Freddie Jude Juliani (1); Gardner, Penny (9); Geiger, Len (1); Lindsay, Steven (1); Gordon, Mike (3); Guharajan, Roshan (3); Haysom, Jessica (640); Hearn, Andrew (10); Joe Pan (1); Lim Wing Shen (1); Mark Louis Benedict (1); Nderiy Dido (2); Raj Alferri Rulin (1); Sabah Museum (2); Shavez Cheema (3); WWF-Malaysia (35). *Open source database (Number of records):* eMammal, 2021 (3). *Publications (Number of records):* Abdullah et al., 1995 (10); Allan & Coolidge, 1940 (1); Ambu et al., 1984 (1); Bernard et al., 1997 (1); Bernard et al., 2013 (2); Bernard et al., 2014 (6); Bernard et al., 2016 (5); Bili, 2014 (1); Boonratana & Sharma, 1993 (2); Boonratana, 1997 (6); Bornion Timber, 2021 (1); Bunya et al., 2010 (1); Chasen & Kloss, 1931 (1); Davies & Payne, 1982 (92); Davies & Tan, 2019 (1); Davis, 1962 (6); Dawson, 1992 (2); Hawkins et al., 2019 (1); Kehoe, 2011 (5); KOPEL, 2016 (1); Mahyudin et al., 2010 (1); Payne et al., 1989 (1); Prudente et al., 2009 (1); Regip, 2003 (1); Samejima & Ong, 2012 (3); Samejima et al., 2012 (1); Sheldon & Francis, 1985 (1); Shukor et al., 2011 (1); Webb, 2016 (2); Wong, 2011 (1).

6

Grey Leaf Monkeys
Sabah Leaf Monkey (*Presbytis sabana*)
Hose's Leaf Monkey (*Presbytis hosei*)

Glyn Davies

Introduction

Grey leaf monkeys in Borneo have evolved into four distinct species which are closely related and endemic. Two of those species occur in Sabah: Sabah Leaf Monkey (*Presbytis sabana*) and Hose's Leaf Monkey (*Presbytis hosei*). The former occurs across the eastern and central parts of the State, and the latter is restricted to the hilly western region (Nijman, 2010b; Phillipps & Phillipps, 2018). The Sabah Leaf Monkey extends south of the Sabah border into Kalimantan (Figure 2), but the precise location of the species' boundary with Hose's Leaf Monkey is unclear (Nijman, 2010b).



Figure 1. Hose's Leaf Monkey © Joremy Tony

Taxonomy

Sabah Leaf Monkeys are "dark ashy gray on the back, outer side of the limbs and tail, while the belly and inner sides of the limbs are white, and the hands and feet are black" (Davis, 1962; Figure 3). They have a crest running down the centre of the head, being highest in front, and unlike the Hose's Leaf Monkey, they do not have a band of white hairs on the forehead (Davis, 1962; Payne et al., 1985). The face skin is flesh-coloured, with a black triangle stretching across the cheeks. They have "long hind legs and long forearms which are adaptations to arboreal locomotion" (Davis, 1962), and adult females tend to be slightly larger than adult males — body weight range: 6–6.75 kg (Davis, 1962; Nijman, 2010b).

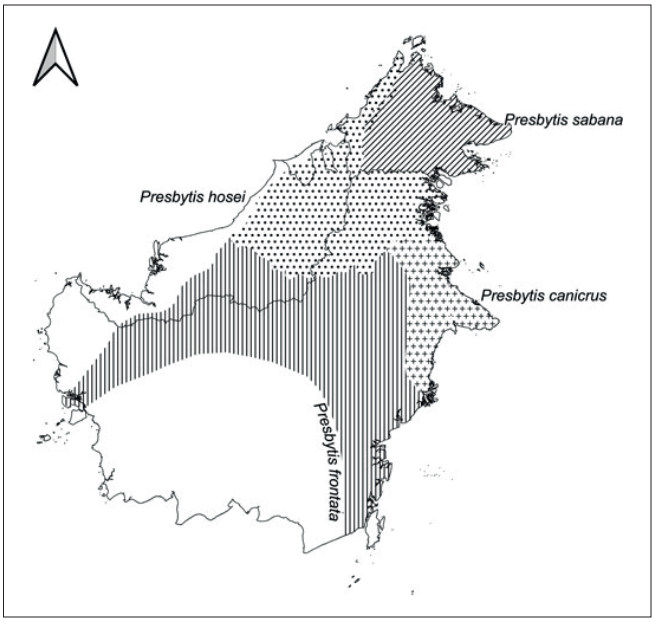


Figure 2. Map of Borneo showing grey leaf monkey species, with Sabah Leaf Monkey (*P. sabana*) and Hose's Leaf Monkey (*P. hosei*) found in Sabah State, and no grey leaf monkey species in the southern arc of Borneo (after Phillipps & Phillipps, 2018)

Only recently was it agreed that the Sabah Leaf Monkey should be a separate species from Hose's Leaf Monkey; before that they were both subspecies of *Presbytis hosei* (Davis, 1962; Medway, 1977). So past records of Hose's Leaf Monkey could refer to either species and care is needed to determine which species may relate to a particular record. The most recent review of genetic material for grey leaf monkeys indicates that they were part of a 'Borneo clade' which separated from ancestral *Presbytis* stock about 3.9 Million years ago (Ma), and further evolved into the species: *P. chrysomelas*, *P. frontata* and *P. hosei* between 3.3–3.0 Ma (Roos & Zinner, 2021). Unfortunately, there is no genetic information on Sabah Leaf Monkeys, but a similar time frame is likely.

In Sabah, both the Sabah Leaf Monkey and Hose's Leaf Monkey are generally referred to as leaf monkeys or langurs in the English language literature (Nijman et al., 2021; Phillipps & Phillipps, 2018). The common Kadazan term is *monosop*, which seems to apply to both species, although six other vernacular names have been recorded (Payne et al., 1985), including *lutong*.

Natural History

The Sabah Leaf Monkey has been subject to one intensive study, in Tabin Wildlife Sanctuary in 1990/91 (Mitchell, 1994), and there are no other detailed studies of either species in Sabah, nor of Hose's Leaf Monkeys in Sarawak, Brunei or Kalimantan, only shorter term surveys (Bennett et al., 1987; Bennett & Dahaban, 1995; Nijman, 2010b).

Both grey leaf monkey species in Sabah show many ecological similarities with Red Leaf Monkeys. Like all colobine monkeys, Sabah Leaf Monkeys have an enlarged and multi-chambered stomach (Kay & Davies, 1994) which allows forestomach fermentation, and in Tabin this is suited



Figure 3. a) Sabah Leaf Monkey male © Cede Prudente; b) female with young, Tabin Wildlife Reserve © Cede Prudente; c) Hose's Leaf Monkey adult with the dark back; d) Hose's Leaf Monkey sub-adult with white underside, both captured on camera trap in FMU 11 © The late Timothy Pan/Bornion Timber Wildlife Unit

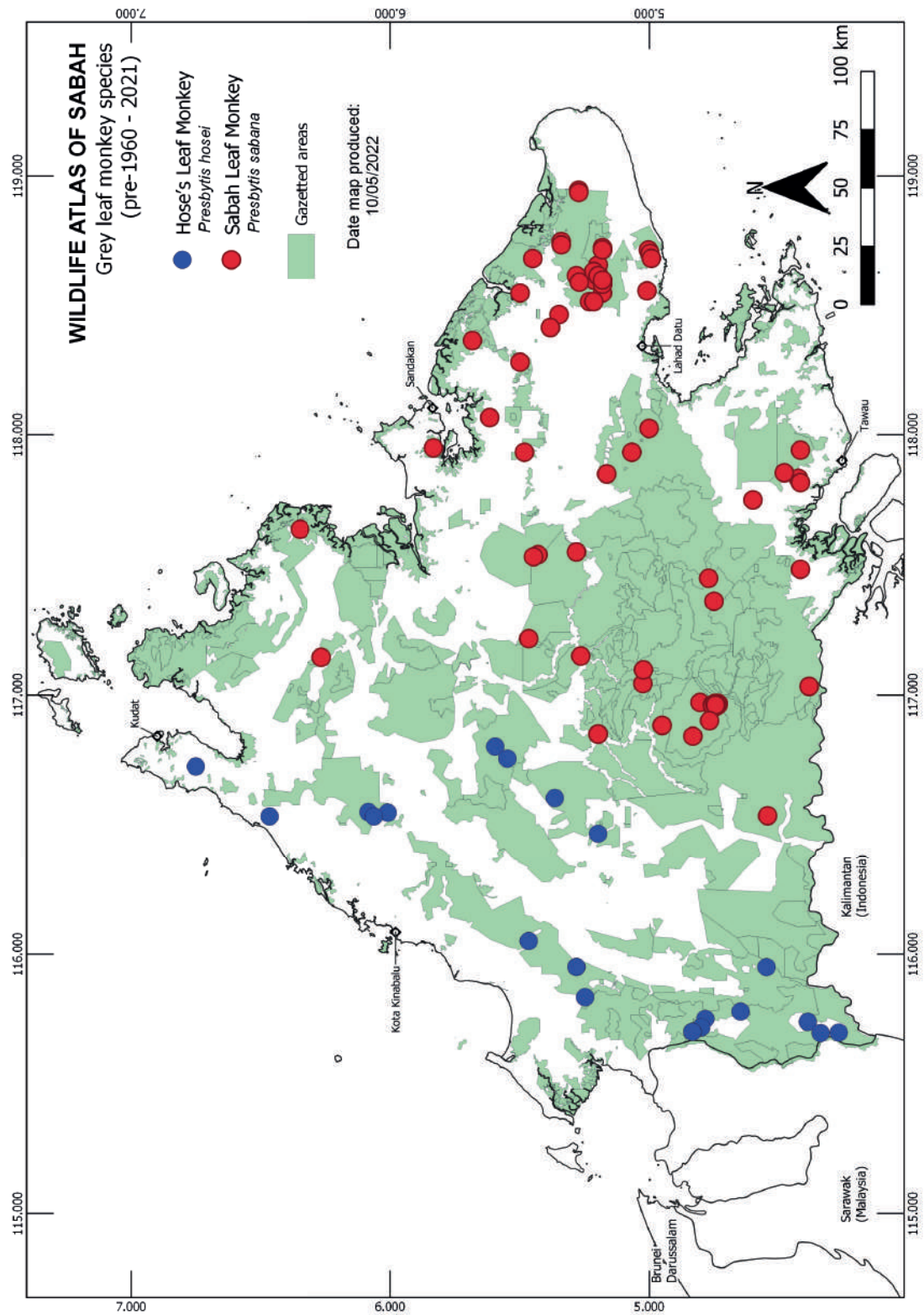


Figure 4. Map showing separation of records for Sabah Leaf Monkey and Hose's Leaf Monkey within the state.

to their mainly folivorous diet, and clear preference for seed-eating during the peak fruiting season. They also consumed large amounts of fruits/young foliage of laran trees (*Neolarmarckia cadamba)* and foliage from *Spatholobus* and other lianas (16 species). The animals were very selective in their diets — taking food from only 36 of the 200+ tree species available in the study area over a 7-month period. There was a preference for foliage with high protein and low fibre, especially from leguminous lianas (Mitchell, 1994).

Table 1. The diets of Sabah Leaf Monkeys in Tabin Wildlife Sanctuary: One group living in unlogged forest, and an adjacent group living in 10–20 year old logged forest, data gathered from May–December 1991 (Mitchell, 1994)

	Tabin — unlogged	**Tabin — logged**
	Lowland dipterocarp forest	Lowland dipterocarp forest
Leaf parts	**78%**	**60%**
Young leaf parts	45% (*Spatholobus hirsutus* + spp. 11%)	42%
Seeds only	16%	23%
Fruit parts	3%	18% (*Neolarmarckia cadamba* 14%)

Sabah Leaf Monkeys in Tabin had family groups that comprised: a single adult male, 2–3 adult females and their progeny, giving group sizes of 7–8 animals, with one group of 10 animals also recorded (Mitchell, 1994; Table 2). Group sizes across Sabah ranged from 3—13, as well as solitary adults recorded on two occasions (Davies & Payne, 1982). What is different to the Red Leaf Monkeys, however, is the calling and territorial behaviour.

The commonest call encountered during surveys is 'staccato grunts', which males give when disturbed and alarmed. They use a quieter 'gargling growl' for group spacing purposes, including during dawn/pre-dawn calling rounds between neighbouring groups (Mitchell, 1994). Indeed the Tabin study group was quite tolerant of neighbouring groups and were never recorded chasing neighbours away (Mitchell, 1994). By contract, Red Leaf Monkeys use a loud call when they are alarmed and during aggressive encounters and chases with neighbouring groups.

Table 2. Sabah Leaf Monkeys in Tabin Wildlife Sanctuary: Group size, home range and population (Mitchell, 1994)

	Tabin — unlogged	**Tabin — logged**
Study group size	7–8	7–8
Home range (ha)	35	45
HR overlap with neighbours	12%	9%
Day range length (m) Average range (m)	690 538–925	794 425–1,088
Distance between food trees (m)	58.8	139
Population estimates	21 indiv/km^2	16 indiv/km^2

Distribution and Abundance in Sabah

Hose's Leaf Monkey is restricted to the south-west and west of the State, including the Witti Range, and the Crocker Range to Mt. Kinabalu. The Sabah Leaf Monkey is found across the rest of the State, from east of the Sapulut River through the central forests into the Dent Peninsula, where they are especially abundant in Tabin (Davies & Payne, 1982). In addition to dwelling in upland and lowland dipterocarp forests, they are found in logged forests and areas of [regenerating] shifting cultivation, and have been recorded feeding in tree plantations (Davies & Payne, 1982).

It is difficult to gather accurate information in dense forests, so only relative estimates were made during 1979–1981 surveys, with populations of 1–3+ groups/ha (approx. 10–20+ indiv/km²) noted in the unlogged forests of Tabin/Silabukan, and central and southern areas (Figure 5). When compared with Red Leaf Monkey populations, grey leaf monkeys are more abundant where Red Leaf Monkeys are scarce, and vice versa, giving an impression that grey leaf monkeys predominate over reds in upland areas. The Sabah Leaf Monkey, however, breaks this pattern by being more abundant in the lowlands of Tabin, and so we do not know what favours red or grey leaf monkeys in a particular forest.

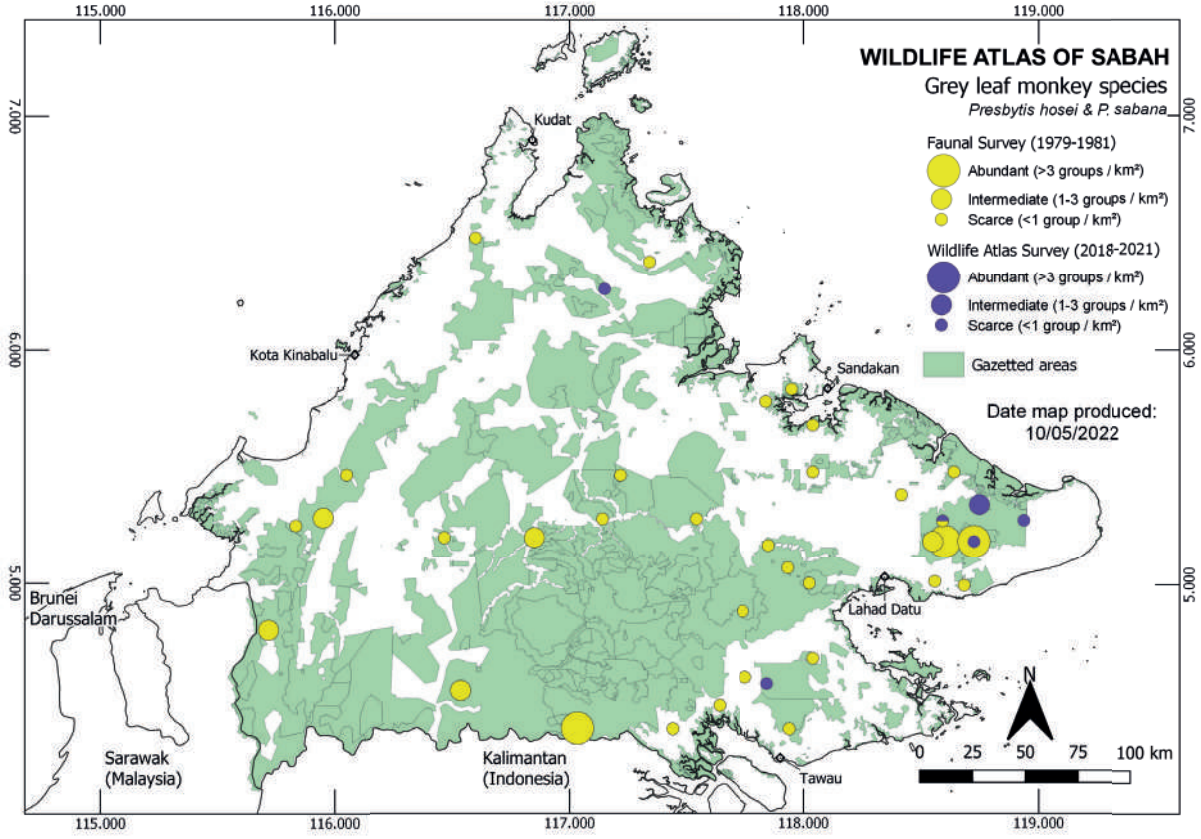


Figure 5. Records of both grey leaf monkey species in Sabah, showing the consistent and widespread records within the permanent forest estate, and abundance over 40 years in the Tabin area.

The combined biomass of grey and red leaf monkey species declines with altitude, especially above 500 m asl (Davies & Payne, 1982).

Looking beyond Sabah, Nijman (2004) shows that Hose's Leaf Monkeys in the Kayan Mentarang National Park (East Kalimantan) had populations of 18.9 indiv/km² in primary hill forests (mostly below 500 m asl), but only half that abundance in unlogged river terrace forests. And in Ulu Temburong (380—685 m asl) in Brunei, there was an unusual combined abundance of both Hose's Leaf Monkeys (28 indiv/km²) and Red Leaf Monkeys (15 indiv/km²) along a transect rising from the eastern flank of the Temburong River (Bennett et al., 1987).

Threats

The impact of logging on Sabah Leaf Monkeys has been assessed in four studies. In 1980, at three sites in Silabukan Forest Reserve, rapid surveys showed the one logged forest held less than one third the population (7.8 indiv/km²) of two unlogged sites (Davies & Payne, 1982). A subsequent more detailed survey in western Tabin, showed Sabah Leaf Monkeys were half as abundant in logged forest (3.6 indiv/km²) as they were in unlogged forest (7.8 indiv/km²) (Johns, 1987). This was reinforced by Mitchell (1994), who showed that unlogged forest held significantly more than an adjacent logged forest, with no groups recorded in a heavily impacted logged forest 2 km away (Table 3). More recent surveys across four logged forest sites in Tabin, following 20 years of natural regeneration, reconfirmed the scarcity of Sabah Leaf Monkeys (Davies & Tan, 2019). They recover poorly from logging, and Hose's Leaf Monkeys in Kalimantan also do not fare well in logged forest (Table 3).

Table 3. Impact of logging on Sabah Leaf Monkey in Tabin and Hose's Leaf Monkey in East Kalimantan (Mitchell, 1994; Njman, 2004)

Area	Unlogged	Logged
Tabin *(P. sabana)*	21 indiv/km²	16.6 indiv/km² (adjacent to unlogged)
		0 indiv (logged forest; 2 km distant from unlogged)
Kayan Mentarang, Kalimantan (*P. hosei*)	18.9 indiv/km² (hill forest)	7.4 indiv/km² (old secondary)
	9.5 indiv/km² (riverine forest)	5.5 indiv/km² (young secondary)

There are no records of Sabah Leaf Monkeys living in oil palm plantations in the Tabin landscape, where they could readily venture from adjacent forest. There are some rare records of them living in a farm-fallow mosaic in central Sabah (Davies & Payne, 1982), and entering tree plantations, but no records from other crop lands. They also appear to be less able to exploit riverine vegetation compared with Red Leaf Monkeys, but more research is needed to examine this question.

Grey leaf monkeys are susceptible to hunting for food by local communities, which in south-west Sabah may combine with the high altitude impacts to account for their low numbers. In Kalimantan populations of Hose's Leaf Monkeys have been wiped out by hunting for the 'bezoar stones' in their digestive tracks (Nijman, 2005; 2010), rather than because of hunting for food, and if the market for bezoar stones were to impact Sabah it could have catastrophic impact.

Conservation

Presbytis sabana is categorised as 'Endangered', because of its limited geographical range and declining population (Setiawan & Traeholt, 2020). This species has undoubtedly declined in recent years due to forest loss within Sabah, and has not adapted well to the effects of timber extraction, although the logged forests of Tabin probably still holds one of the most important populations in the State. *Presbytis hosei* is categorised as 'Vulnerable', and from a Sabah perspective only a small portion of this species occurs within the Witti Range and the Crocker Range/Mt. Kinabalu region. Given the high altitude and often high hunting by indigenous people in west and south-west Sabah, it is unlikely these populations will contribute much towards the species' conservation across Borneo.

Both species of the grey leaf monkey are classified as Schedule II under the Sabah Wildlife Conservation Enactment 1997, which means that the species can be hunted with a licence. This should not be permitted, however, because there is no evidence that they are crop pests of any significance.

They are difficult to keep alive as pets, because of their specialised digestive system, and so there is not a pet trade in this species.

Acknowledgements

The author would like to thank Vincent Nijman and Elizabeth Bennett for peer review comments, and acknowledge the many records contributed by individuals and institutions. WWF-UK gave financial support to conduct orangutan and general wildlife surveys for the Wildlife Atlas of Sabah project.

Data Sources

Sabah Leaf Monkey:
Individuals / organizations (Number of records): Brodie, Jedediah (3); Gardner, Penny (1); Sabah Museum (2). *Publications (Number of records):* Bornion Timber, 2021 (1); Chasen & Kloss, 1931 (1); Davies & Payne,1982 (13); Davis, 1962 (1); Goodman, 1989 (1); Lim, 1993 (1); Nagano, Hidemi (2); Whitehead,1893 (1); Wong, 2011 (1).

Hose's Leaf Monkey:
Individuals / organizations (Number of records): Brodie, Jedediah (3); Gardner, Penny (1); Forest Solution Malaysia (1); Sabah Museum (2). *Publications (Number of records):* Bornion Timber, 2021 (1); Chasen & Kloss, 1931 (1); Davies & Payne,1982 (13); Davis, 1962 (1); Goodman, 1989 (1); Lim, 1993 (1); Whitehead,1893 (1); Wong, 2011 (1).

7

Proboscis Monkey *(Nasalis larvatus)*

Ikki Matsuda, John Chih Mun Sha and Henry Bernard

Introduction

The Proboscis Monkey (*Nasalis larvatus*) is a member of the Afro-Eurasian monkey subfamily Colobinae, which is unique to Borneo (Figure 1). Local names include *bekantan* or *monyet belanda*; although in Sabah *bangkatan* is more commonly used. It is a foregut fermenter (Matsuda et al., 2015b) and has a natural diet generally dominated by leaves, fruits (mostly unripe) and seeds (Bennett & Sebastian, 1988; Bernard et al., 2019; Boonratana 2003; Matsuda et al., 2009a; Salter et al., 1985; Yeager, 1989). They are large, sexually dimorphic and arboreal colobines (Koda et al., 2018; Matsuda et al., 2020b) that can swim well with partially webbed hind feet (Davis, 1962). They live in social groups that typically consist of a single adult male and multiple females, although mixed-sex groups occasionally contain several adult males (Bennett & Gombek, 1993; Bennett & Sebastian, 1988; Boonratana, 2002; Matsuda et al., 2020a; Yeager, 1990), and there are also all-male and sometimes solitary males (Murai, 2004a).

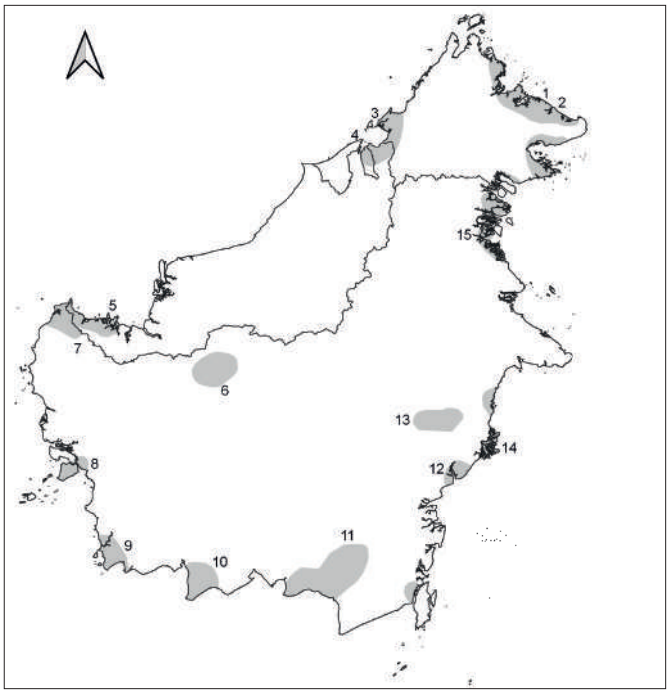


Figure 1. Main populations of Proboscis Monkey in Borneo (after Phillipps & Phillipps, 2018). In Sabah: 1) Kinabatangan, 2) Segama & 3) Klias; 4) Brunei Bay; In Sarawak: 5) Bako; In Kalimantan: 6) Danau Sentarum, 7) Sambas Paloh, 8) Gng Palung, 9) Kendawangan, 10) Tg Putting, 11) Bario River area, 12) Balikpapan Bay, 13) Mahakam lakes, 14) Samarinda Delta & 15) Sebuku area

Natural History

Proboscis Monkeys are diurnal primates, whose activities are strongly associated with waterways (Figure 1). They typically sleep in riverside trees in the evening, but during the day, they travel inland for foraging. Resting is the most common behaviour for Proboscis Monkeys in the Kinabatangan Floodplain and the Klias Peninsula, in part, to allow time for digestion through foregut fermentation (Table 1). The daily rhythm of their activity seems to be influenced by various factors, such as food availability and weather. In particular, the highest peak of feeding activity is generally in the late afternoon (15:00–17:00), just before sleep (Matsuda et al., 2014a). The differences in feeding rhythm between seasons appear to be related to fruit availability and/or food items (Matsuda et al., 2014a).

Table 1. The proportion of time spent by Proboscis Monkeys engaged in different activities, the number of food plant species eaten and the proportion of time spent feeding on different food items. Note that the range from minimum and maximum values of different groups are shown.

	Klias	**Kinabatangan**		***Labuk Bay**
		(riverine)	**(mangrove)**	**(provisioned groups)**
Resting	54%	[1]76.5%		27–39%
Travelling	16%	[1]13.50%		18–25%
Feeding	18%	[1]19.5%		13–21%
DIET	19 plant species	[1]188 plant species	[2]7 and [3]18 plant species	17 plant species
Flowers	3%	[1]8%; [3]8%	[3]16%	4–9%
Fruits	3%	[1]26%; [3]8.3–39%	[3]30%	1–13%
Young leaves	92%	[1,]66%; [3]60–73%	[3]50–73%	59–71%
Mature leaves		[3]0.3%		
Anthropogenic foods				24–30% (pancakes, etc.)
Source	Bernard et al. (2019a)	[1]Matsuda et al. (2009a); [3]Boonratana (2003)	[2]Matsuda et al. (2019); [3]Boonratana (2003)	Tangah (2012)

The total number of plant species consumed by Proboscis Monkeys in the riverine forest in the Kinabatangan Region was up to 188, in seasons when fruits and young leaves were available, but was much lower in the mangrove forests where they fed on 7–18 plant species (Table 1). This was due to the low plant species diversity in mangrove forests compared to that in riverine forests (Boonratana, 2003; Matsuda et al., 2019). In the less diverse forests of the Klias Peninsula, dietary diversity was also reported to be low (19 plant species; Bernard et al., 2019a), similar to the provisioned Labuk Bay population living in mangroves, which consumed 17 plant species and anthropogenic food, such as pancakes and bread (Tangah, 2012).

Over 90% of fruit feeding involved the consumption of unripe fruits, and in most cases, both the fruit flesh and seeds were eaten. In some cases, intact small seeds were found in faecal samples (Matsuda et al., 2013a). Thiry et al. (2019) conducted germination tests and found that *Nauclea* spp.

were the most abundant plant species in faecal samples of Proboscis Monkeys, accounting for 98% of all intact seeds. More importantly, higher germination success was recorded in ingested seeds from both ripe and unripe *N. orientalis* fruits than in control seeds (Thiry et al., 2019), suggesting that Proboscis Monkeys contribute to the dispersal and germination of this plant species.

Nutritional studies have revealed that Proboscis Monkeys living in the riverine forest of the Kinabatangan River generally preferred leaves rich in protein and low in fibre (Boonratana, 2003; Matsuda et al., 2013b). Nonetheless, it should be noted that food abundance was the strongest factor explaining leaf food selection, with more common plant species being selected (Matsuda et al., 2017).

The daily path length was highly variable (Table 2), and it decreased on days when they fed on fruits (Matsuda et al., 2009b), especially fruits of dominant plant species, such as *Mallotus muticus* and *Lophopyxis maingayi*. The monkeys in the Kinabatangan often used areas nearer the riverbank where they had slept, or crossed the river previously (Matsuda et al., 2010b). Anti-predator behaviour may also affect their movement patterns, since they usually cross at locations where the river is narrower and tree crowns on either bank are closer together (Matsuda et al., 2008a; Yeager, 1991a) with shorter branch-to-bank crossing locations that may provide good escape routes from terrestrial predators, such as the Sunda Clouded Leopard (*Neofelis diardi*) that can travel and hunt in trees (Matsuda et al., 2008b; Otani et al., 2012).

Table 2. The daily range length and home range size of Proboscis Monkeys in Sabah. Note that the range from minimum and maximum values of different groups are shown.

	Kinabatangan		**Labuk Bay**
	(riverine)	**(mangrove)**	**(provisioned groups)**
Day range length (m)	[1]220–1734 (mean=799); [2]370–1810 (mean=910)		732–1084
Home range size (ha)	[1]138.3; [2]220; [3]83–108 (lower range: 35–167 to upper range: 41–217)	315	1.5–6
Source	[1]Matsuda et al. (2009b); [2]Boonratana (2000); [3]Stark et al. (2017b)	Boonratana (2000)	Tangah (2012)

Sleeping trees in the Klias Peninsula were more common in the riverine forest — compared with those in mangrove and mixed mangrove-riverine forests (Bernard et al., 2019) — and were taller and had larger trunks, with more and larger branches (Bernard et al., 2021a; Bernard et al., 2011a). In addition, these trees were located near other trees, with overlapping branches, creating good arboreal connectivity. A similar pattern was observed in the Lower Kinabatangan Floodplain, where sleeping trees were also taller and had larger trunks with larger and higher first branches than the surrounding trees (Thiry et al., 2016).



Figure 2. a) Male Proboscis Monkey leaping through the trees © Ikki Matsuda; and b) Female Proboscis Monkey with infant sitting on a mangrove, both photos in the Lower Kinabatangan © Ikki Matsuda

Social Behaviour

Proboscis Monkeys are one of the few non-human primate species shown to have a multilevel society (Bennett and Sebastian, 1988; Boonratana, 2002; Murai, 2004b; Yeager, 1991b). One-male-multi-female groups form the basis of their society, but different-sized groups gather regularly, especially in the late afternoon at their sleeping trees. Such aggregation patterns reflect variations in food availability, and more groups aggregate where the river is narrower, which may be advantageous for predator avoidance (Matsuda et al., 2010a). It also allows groups to see the displays of neighbouring males (Matsuda et al., 2020b).

Social interactions within groups, including agonistic and grooming behaviour, are infrequent (Matsuda et al., 2015a; Matsuda et al., 2012a; Yeager, 1990). Affiliative behaviour, such as grooming among adult females within a group is not affected by any dominance hierarchy and is relatively reciprocal, although grooming between an adult male and adult females is always non-reciprocal (Matsuda et al., 2012a). Social network analysis in the Lower Kinabatangan showed that females are more central and males are generally peripheral to social interaction (Matsuda et al., 2012b). In addition to grooming exchange, infant exchanges among females may be important for establishing social relationships (Matsuda et al., 2015a; Matsuda et al., 2012b).

Female dispersal between groups is typical in a multilevel society, creating the potential for both female choice and male-male competition when groups aggregate at sleeping sites. Under such social circumstances, differences in size and sexual characteristics are likely to evolve — as shown in adult males, where those with the largest noses, testes and body mass have more females within their groups (Koda et al., 2018). However, there is a negative correlation between body size and canine size (Matsuda et al., 2020b) perhaps because larger noses may interfere with the use of canines when fighting, and longer canines may reduce foraging efficiency, particularly with folivorous diets (Matsuda et al., 2020b). Reproduction in free-ranging Proboscis Monkeys appears to be aseasonal (Boonratana, 2011; Heldstab et al., 2021), although it is reported as relatively seasonal in Samunsam, Sarawak (Rajanathan & Bennett, 1990).

They have a repertoire of four common call types: “shrieks”, “honks”, “roars” and “brays”, which are distinguishable based on fundamental frequency variation, call duration and calling frequency. Additionally, Roper et al. (2014) noted that they can give a ‘chorus’, when multiple callers produce a mix of vocalisations.

Distribution and Abundance in Sabah

The most recent information on the distribution and abundance of Proboscis Monkeys was obtained from a Faunal Survey of Sabah conducted in 1979–81 (Davies & Payne, 1982) and a Sabah state-wide census of Proboscis Monkeys conducted in 2004–2005 (Sha et al., 2008). These surveys showed that the Sabah population was sub-divided into seven distinct sub-populations (Figure 3), but with some ‘outlier’ records well into the interior of Sabah, such as Imbak Canyon and Maliau Basin, where they were recorded along rivers during peak fruiting season (June/July) (Hazebroek et al., 2004).

The Sabah population was estimated at approximately 6,000 individuals, found mainly along larger coastal river systems where suitable habitats still exist (Sha et al., 2008). There are seven main populations, which are distinct from each other (Table 3), and four of these account for the

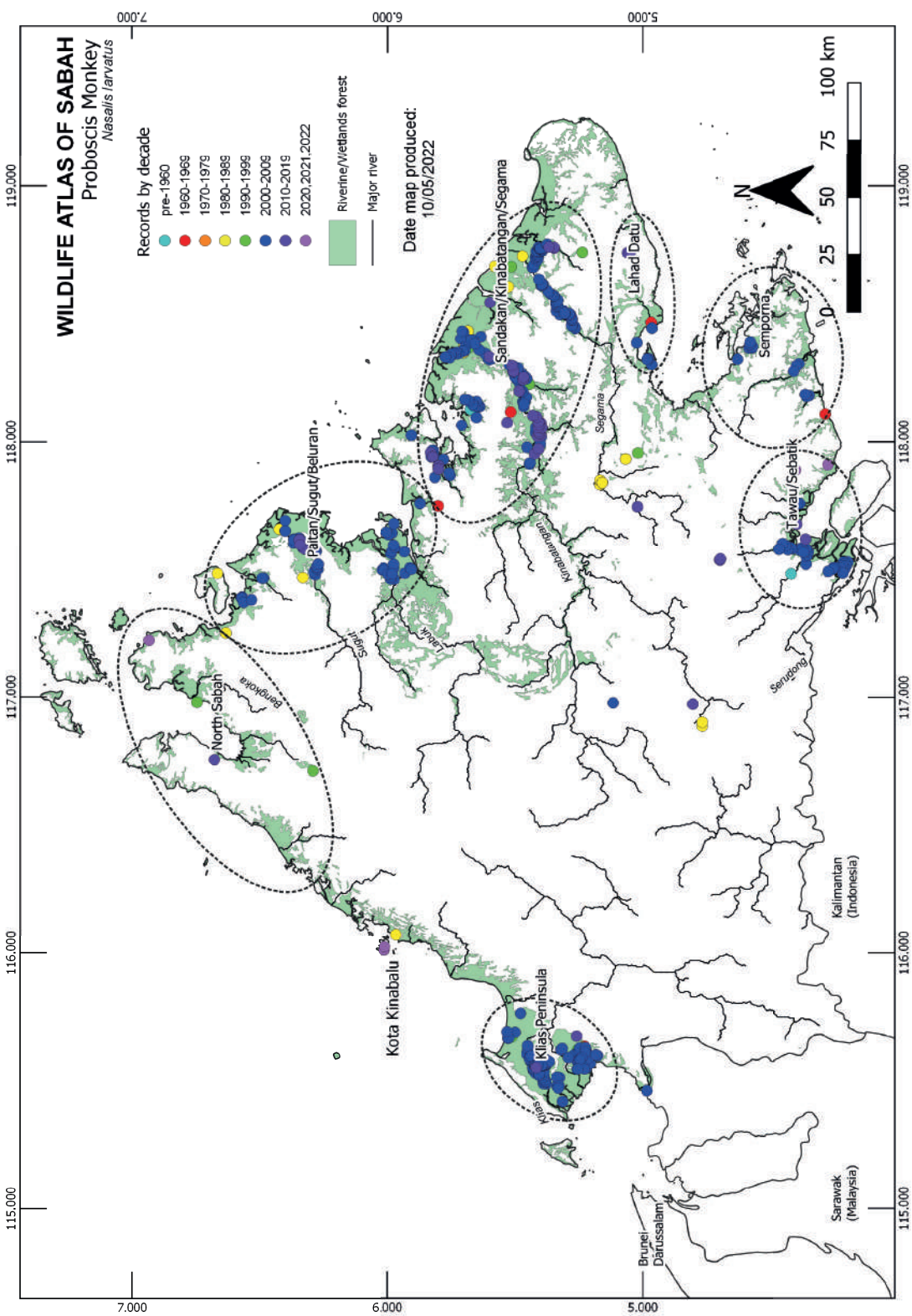


Figure 3. Proboscis Monkeys records (1960–2021) from mangrove, riverine and interior areas. The ovals are sub-populations in 2004–2005 based on Sha et al. (2008).

bulk of the State's Proboscis Monkeys: a) Klias, b) Paitan-Sugut-Labuk; c) Sandakan-Kinabatangan-Segama and d) Tawau-Sebatik.

Studies on population viability predicted that the Lower Kinabatangan Region population would remain fairly stable (Stark et al., 2012). Comparisons of directly counted population sizes over ten years showed significantly reduced group sizes in 2014 compared to 2004, possibly because of the effects of forest fragmentation (Matsuda et al., 2020a), but estimated population densities in three study areas fluctuated, showing no consistent downward trend. Stable Proboscis Monkey population trends from 2004 to 2014 have also been observed in the Klias Peninsula (Bernard et al., 2021a). If forest fragmentation continues, however, downward population trends are to be expected.

Table 3. Estimates of sub-populations of Proboscis Monkey in Sabah

Sub-population		Estimated population	Notes	Threats
Klias		818	Isolated from other populations	Hunting, dog attacks, settlement and plantations, highways, forest fires
Kota Belud-Kudat-Pitas		200	Small & isolated populations	Highway and forest fragmentation
Paitan-Sugut-Labuk		1,194	Inter-connected population	Many oil palms in Sugut
Sandakan-Kinabatangan-Segama		2,280	Inter-connected population in large contiguous wetlands	Bridges and roads, oil palm plantations
Lahad Datu		118	Small & disconnected populations	Highest threat; infra-structure
Semporna		169	Isolated from other populations	50% mangroves lost since 2004
Tawau-Sebatik		811	Inter-connected population	
Others	Sg. Bole	+	Small river headwaters records	
	Imbak Canyon	+		
	Maliau Basin	+		
		ca. 6,000		

Conservation

Proboscis Monkeys are categorised as 'Endangered' under the IUCN Red List (IUCN, 2008) and listed under Appendix I of CITES (UNEP-WCMC, 2003). They are listed as 'Totally Protected' and cannot be hunted, traded or kept under any circumstances under Sabah laws (Sabah Wildlife Conservation Enactment, 1997). Despite these levels of protection, habitat loss and fragmentation continue to be a major threat to this species (Boonratana, 2013; Meijaard & Nijman, 2000a; Meijaard & Nijman, 2000b).

In Sabah, suitable habitats for Proboscis Monkeys have already been lost or fragmented on a large scale. Given that wildlife-based tourism has become of increasing importance to the state's economy in recent years, the Sabah government is now prioritising the protection of important remaining habitats of Proboscis Monkeys, as well as restoration of degraded habitats, including the establishment of forest corridors to connect isolated habitat patches (Lhota et al., 2019). This

approach forms part of the integrated conservation strategy for the Sabah Proboscis Monkey Action Plan, drafted by the Sabah Wildlife Department (SWD) and Danau Girang Field Centre in collaboration with other institutions and experts (SWD, 2019b). Critical to the successful progress of such initiatives is the active participation of wildlife management agencies, such as the SWD, and strong support from the State government, working closely with NGOs and academics towards a common goal of conserving the species.

In areas where Proboscis Monkey populations are commonly found, major proliferation of large- and small-scale tourist establishments has taken place, particularly during the last 15 years, to cater to the increasing visitor volume (Lhota et al., 2019; Sha et al., 2011). A study by Leasor and Macgregor (2014) found a negative correlation between the number of tourists and the abundance of Proboscis Monkey groups in the Lower Kinabatangan Floodplain, suggesting that tourism activities should be better regulated to reduce impacts on populations. The Klias Peninsula is also a key destination for tourism, and Bernard et al. (2021a) proposed that concerted efforts are now urgently needed to safeguard the Proboscis Monkey habitats that are outside of totally protected areas in the Klias Peninsula region so that both wildlife tourism and this endemic, iconic and endangered primate can be sustained in this region.

Acknowledgements

I.M. was supported by the Japan Science and Technology Agency Core Research for Evolutional Science and Technology 17941861 (#JPMJCR17A4), JSPS KAKENHI (#19KK0191, #19H03308) and JSPS Core-to-Core Program, Advanced Research Networks (#JPJSCCA20170005) while writing this article. H.B. was supported in this project by research grant no. FRGS/1/2020/WAB11/UMS/02/1 from the Ministry of Higher Education, Malaysia. The authors appreciate the review comments from Liz Bennett and Glyn Davies.

Data Sources

Individuals / organizations (Number of records): Amanda Wilson & Elsiey Ercy Jomes (3), Donovan Louis (1); Gardner, Penny (4); Gomez, Chrishen (1); Hearn, Andrew (39); Lamb, Anthony (1); Williams, Dale (1); 1StopBorneo Wildlife (2); Forest Solution Malaysia (1); WWF-Malaysia (10). *Publications (Number of records):* Allan & Coolidge, 1940 (1); Ambu et al., 1984 (1); Bernard & Hamzah, 2006 (79); Bernard et al., 2014 (1); Bernard et al., 2016 (2); Bernard et al., 2019 (1); Boonratana, 1997 (3); Boonratana & Sharma, 1993 (2); Davies & Payne, 1982 (22); Davies & Tan, 2019 (1); Davis, 1962 (4); Hamdan et al., 2019 (1); Kehoe, 2011 (3); KOPEL, 2019 (1); Lim, 1996 (4); Matsuda et al., 2014 (1); Okano, 1965 (1); Payne et al., 1989 (1); Prudente et al., 2009 (1); Rajaratnam, 1995 (1); Regip, 2003 (2); Ridzwan et al., 2009 (28); Sarayati et al., 2015 (1); Schulze & Beck, 1999 (1); Sha et al., 2008 (296); Sharma, 1992 (4); Shigeki et al., 2000 (1); Webb, 2016 (1).

8

Long-tailed Macaque (*Macaca fascicularis*)

Henry Bernard, John Chih Mun Sha and Ikki Matsuda

Introduction

Long-tailed Macaques (*Macaca fascicularis*) are one of the most common primate species of the Cercopitheidae family in the Southeast Asian region (Brunei, Bangladesh, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor-Leste and Vietnam), where they are found in their native habitats (Fooden, 1995; Gumert et al., 2011). Humans have introduced this species in several countries, including Hong Kong, Taiwan, Mauritius, Palau, Papua New Guinea and the Solomon Islands (Long, 2003). Despite their wide range, the Long-tailed Macaques are classified under Appendix II of the International Convention for the International Trade of Endangered Species (CITES), and 'Vulnerable' by the IUCN in 2020 because of the declining population resulting from habitat loss, trading, trapping for pharmaceutical research, hunting and conflict with humans (Eudey, 2008; Eudey et al., 2020). Long-tailed Macaques are also listed as "Protected Animals" under local laws in Sabah (Wildlife Conservation Enactment, 1997)

Taxonomy

Long-tailed Macaques are made up of 10 different subspecies (Wilson & Reeder, 2005). Medway (1969) stated that there are three subspecies in Malaysia; namely, *M. f. fascicularis*, *M. f. argentimembris* and *M. f. laeta*. However, Groves (2001) and Brandon-Jones et al. (2004) suggested that in Borneo and Peninsular Malaysia, there exist only one subspecies; i.e. *M. f. fascicularis*. In Malaysia, Long-tailed Macaques are given the common name "kera" or "kra" to represent the sound of this animal's alarm calls. Although they can be found up to 1,300 m asl in the tropical rainforests (Phillipps & Phillipps, 2016), the natural habitats of this monkey are mainly in the lowland areas where they inhabit parts of primary forest areas, disturbed or secondary forests, riparian forests, coastal forests, nipah forests and mangrove forests (Fooden, 1995; Gumert, 2011).

Long-tailed Macaques are sexually dimorphic medium-sized primates, with adult males weighing between 3.4–12 kg and adult females 2.4–5.4 kg (Mittermeier et al., 2013). They are characterized morphologically by their long tails which can range from 310–720 mm, or about the same lengths as their bodies, between 310–710 mm (Fa, 1989; Mittermeier et al., 2013). Their body colour varies from grey to reddish brown, with lighter underparts; face is pinkish; the hair of the crown grows

backward, resulting in a pointed crest and males have cheek whiskers, while females have a beard (Rowe et al., 1996). Females generally become reproductively active at approximately 3.5 years old with an average menstrual cycle of 30.9 days. The gestation period is 162–193 days and females usually give birth to one infant at a time. Lifespan averages 25 years and ranges from 15–30 years, with longer lifespans documented in captivity (Ross, 1991).



Figure 1. a) A solitary Long-tailed Macaque foraging at the river's edge in riverine habitat in Klias Peninsula © John Sha; b) Huddling group of Long-tailed Macaques at sleeping site in Kinabatangan © John Sha

Natural History

Long-tailed Macaques live in social groups consisting of multiple males and females and their offspring, and have a matrilineal social order with a fission-fusion system of subgroups (van Schaik et al., 1983). The group size usually ranges from 5–80 individuals (Phillipps & Phillipps, 2016). In Sabah, according to Davies and Payne (1982), they generally live in groups of ca. 20 individuals with a range from 10–40 individuals. In Sabah's riparian forest of the Lower Kinabatangan region, more recently recorded group size ranges from 10–48 individuals, and can sometimes reach up to 100 individuals (Goosens et al., 2003). Solitary male monkeys are also observed as males migrate out of social groups. The population size in the Lower Kinabatangan is estimated at around 3,170 individuals with a density of 6.34 individuals/km^2, while the home-range size is 25–200 ha (Goosens et al., 2003).

Long-tailed Macaques are typically diurnal animals and do not range very far from rivers (van Schaik et al., 1996). In the primary lowland dipterocarp rainforest of Danum Valley, Sabah, although they have been recorded to move >2 km away from the river, they usually ranged <500 m from the river (Hanya et al., 2020) and exhibit riverine refuging behaviour (Fittinghoff & Lindburg, 1980) as also reported in the secondary riverine forest of the Lower Kinabatangan (Matsuda et al., 2011). Food availability and predation risk may influence their riverine utilisation (Otani et al., 2020). Sunda Clouded Leopard, reticulated python, estuarine crocodiles and large raptors are the main predators of Long-tailed Macaques (van Noordwijk & van Schaik, 1999; Otani et al., 2012). When travelling, they use the lower strata of the canopy, at an average height of 20 m (range:10–45 m) above the ground (Hanya et al., 2020). They also often descend to the ground to forage and are good swimmers (van Schaik et al., 1996).

Long-tailed Macaques are omnivorous and are regarded as generalist feeders with high dietary diversity of a natural diet made up of fruits, but they also feed on flowers, buds, leaves, bark, roots, pith and animal prey (Bonadio, 2000; Richard et al., 1989; Yeager, 1996). They are generally frugivorous in their natural habitats, where their main diets are fruits and seeds (60–90%) (Bonadio, 2000). In the rainforest of Kutai National Park, Central Kalimantan, Long-tailed Macaques consume food sources from 33 plant species. However, more than 60% of their diet is contributed by only five plant species which are the most dominant in the environment (Yeager, 1996). In man-made environments, anthropogenic food sources can contribute to a significant proportion of the monkeys' diets, from 25% and up to 85% (Aggimarangsee, 1992; Fuentes et al., 2005). For example, in the Universiti Kebangsaan Malaysia campus area, Bangi, Selangor, the diet of one group of macaques consists of anthropogenic food (27%), fruits (32%), leaves (15%) and insects (6%) (Ruslin et al., 2019). Long-tailed Macaques show a high level of dietary flexibility where they can change their diet depending on the availability of food sources at different times of the year and in varying environmental conditions (Sha & Hanya, 2013a; 2013b).

Long-tailed Macaques are synanthropic species where they can live in close association with, and benefit from humans and their activities. For example, they are frequently seen on forest periphery near villages and agricultural sites, forest islands in urban or suburban areas, recreational parks, temples and other tourist attractions (Aggimarangsee, 1992; Fooden, 1995; Fuentes, 2006; Fuentes et al., 2005; Md-Zain et al., 2011; Sha et al., 2009a). Their adaptability to living in highly modified environments, coupled with land-use patterns increasingly generating large amounts of forest edge habitats, amongst other human factors, has led to escalating interface and conflicts between this monkey species and humans (Fuentes et al., 2005; Fuentes & Wolfe, 2002; Priston & McLennan 2013; Sha et al., 2009b;). Hence, Long-tailed Macaques are generally considered pests in areas where they interface with humans (Hambali et al., 2012; Lane et al., 2010; Lee & Priston, 2005). There are not many reports of interactions between humans and macaques in Sabah, suggesting that human-macaque conflict is likely not significant. However, human-macaque conflict is an issue of concern in Peninsular Malaysia and the Long-tailed Macaques are the species of wildlife for which people filed the most complaints to the Department of Wildlife and National Parks (DWNP, 2018).

Distribution and Abundance in Sabah

The distribution of Long-tailed Macaques was confirmed in almost all major river basins and some inland areas in Sabah in 1979–81 (Davies & Payne 1982). In recent years, Sha (2006) reported the abundance and distribution of the Long-tailed Macaques as part of the Sabah state-wide Proboscis Monkey survey conducted in 2005 (Sha et al., 2008). Although no population size estimate was given, a relative population density index (as measured by the number of groups and individuals detected per km of river surveyed) was estimated to range between 0.17–0.71 groups/km or 2.21–13.34 individuals/km. The highest relative population density was recorded along the Segama River, followed by the Kinabatangan and Sugut rivers in eastern Sabah. Overall, the species appears to be abundant, and the local communities in Sabah perceived this species to be increasing in number. However, this could be just a perception. The ability of these monkeys to live near and in association with human activities may give the false impression that there are large numbers of these monkeys. Recent surveys and anecdotal evidence elsewhere in various parts of their range suggest that Long-tailed Macaque populations are decreasing (Hansen et al., 2019).

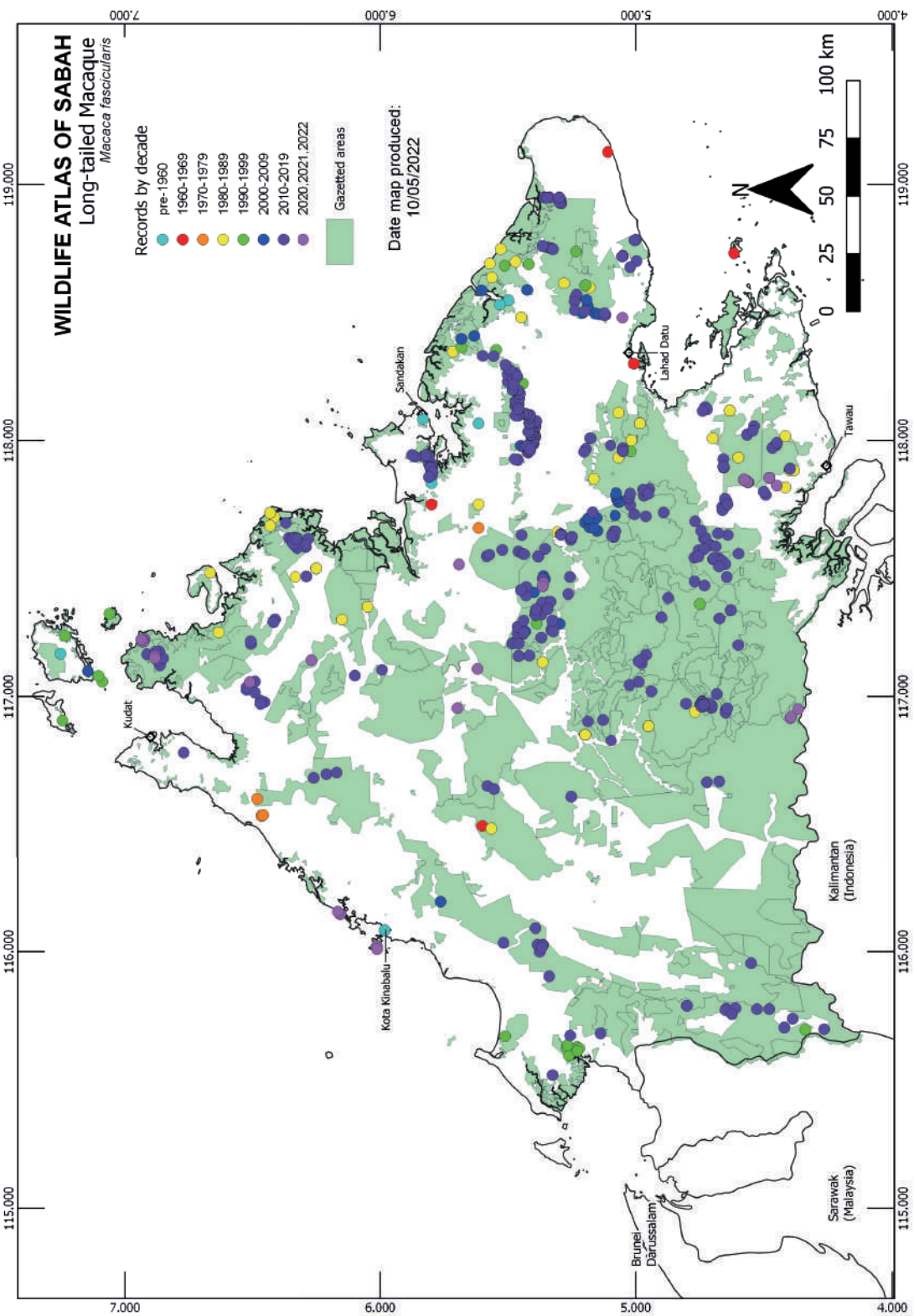


Figure 2. Records of Long-tailed Macaques found along rivers, forests, agricultural lands and open habitats including in urban and suburban areas

Threats

Impacts Of Logging

As might be expected for a species that prefers riverine and 'open-forest' habitats, studies of the effects of logging on Long-tailed Macaques showed mixed results. Populations of Long-tailed Macaques may respond positively or negatively to logging activities irrespective of forest regeneration time after logging (Meijaard et al., 2005). A study conducted in and around Kalabakan Forest Reserve in central Sabah showed that Long-tailed Macaques were found in low numbers in primary dipterocarp forests and they also persisted in variously degraded logged forests, including in heavily degraded forests, although their detection rates were generally low (Bernard et al., 2016). These results indicate that while the primary dipterocarp forest is not their preferred habitat, the Long-tailed Macaques are also generally resilient to logging effects. The most important factor affecting the persistence of this species in logged forests is probably their ability to change the relative proportions of different food types in their diet, specifically to exploit available young leaves in the absence of fruits or by feeding on other fallback foods (e.g. insects) when the availability of their preferred food items are low (Berenstain, 1986; John, 1997).

Impacts of Agriculture

Large-scale expansion of oil palm (*Elaeis guineensis*) monocultures across Southeast Asia has created ecosystems with homogenous habitats. Although Long-tailed Macaques are known to frequent oil palm plantations, a study in Peninsular Malaysia found that the group size of Long-tailed Macaques in large-scale plantations is smaller than in smallholdings, logged forests and unlogged forests (Tee et al., 2018). This may be due to the lower diversity of food resources for Long-tailed Macaques in oil palm plantations. Large forest patches inside oil palm plantations may encourage Long-tailed Macaques to enter plantation areas as these forest patches provide both food resources and sheltering habitat for the macaques.

Conservation

The estimated population size of this species throughout its range in Southeast Asia is not known, although it is generally perceived to be declining (Gumert et al., 2011; Hansen et al., 2021). The previous survey of Long-tailed Macaques in Sabah was conducted more than 40 years ago by Davies and Payne (1982) and there are no recent Sabah state-wide estimates of the population abundance of the species. Therefore, the current conservation status of this primate species in Sabah is generally unknown. In terms of their distribution range in Sabah, this species is widely distributed, including in forest areas in the interior, both in primary and regenerating secondary forest habitats (Bernard et al., 2013; 2014b; 2016), as well as in wetland forests near the coastline, such as in peat swamp forests and mangroves (Bernard et al., 2019; Bernard et al., 2021). Populations of macaques are also found in urban and suburban areas where there are forest fragments remaining (Yong et al., 2021; Figure 2). Because Long-tailed Macaques can live commensally with humans, the perception of the local people is that the population size of these animals has increased.

Often action taken when there is a conflict between macaques and humans is by way of culling or translocating the monkeys because of the belief that the macaques' populations have increased in the conflict area. On the contrary, few studies have focused on Long-tailed Macaque populations in areas where the human population is of high density. Accordingly, it is somewhat premature

to conclude that the human-macaque conflict is due to an increase in the size of the monkey population. Other factors, such as human encroaching into forest areas, and human behaviour towards Long-tailed Macaques, such as food provisioning directly or indirectly through improper disposal of garbage or human refuse, can also result in the occurrence of conflict. It is essential to begin assessing Long-tailed Macaque populations that conflict with humans by uncovering the root cause of these conflicts. A strategic action plan is needed for this species in Sabah not only because conflicts between macaques and humans may potentially escalate in the future here, but also because of the 'Vulnerable' status accorded to this species by the IUCN.



Figure 3. Adult male Long-tailed Macaque, Kinabatangan © John Sha

Acknowledgements

HB was supported by research grant no. FRGS/1/2020/WAB11/UMS/02/1 from the Ministry of Higher Education, Malaysia, while writing this article. We thank Glyn Davies and Angela Lim for editorial review of this manuscript.

Data Sources

Individuals / organizations (Number of records): Alton Jimat Embug (2); Brodie, Jedediah (938); Dee Arnielia Gundeh (21); Gardner, Penny (64); Guharajan, Roshan (64); Haysom, Jessica (291); Hearn, Andrew (938); Jane Wong (1); Yairman Anjingin (1); Forest Solution Malaysia (44); Sabah Museum (6); SFD (5); WWF-Malaysia (151). *Open source database (Number of records):* eMammal, 2021 (5). *Publications (Number of records):* Abdullah et al., 1995 (1); Allan & Coolidge, 1940 (2); Ambu et al., 1984 (2); Bernard et al., 1997 (1); Bernard et al., 2013 (5); Bernard et al., 2014 (6); Bernard et al., 2016 (5); Bernard et al., 2019 (1); Bili, 2014 (1); Boned et al., 2016 (2); Boonratana, 1997 (4); Boonratana & Sharma, 1993 (2); Bornion Timber, 2021 (1); Chasen & Kloss, 1931 (2); Chung et al., 2019 (2); Davies & Payne, 1982 (62); Davis, 1962 (4); Dawson, 1992 (2); Deere et al., 2017 (15); Harrison, 1998 (1); Hawkins et al., 2019 (1); HUTAN KOCP, 2016 (2); Kehoe, 2011 (2); KOPEL, 2016 (3); KOPEL, 2019 (1); Lim, 1993 (1); Lim, 1996 (7); Matsuda et al., 2014 (1); Mingueza, 2018 (1); Mohammad & Wong, 2019 (1); Murphy, 2007 (1); Nakashima et al., 2008 (2); Okano, 1965 (2); Onoguchi & Matsubayashi, 2008 (2); Payne et al., 1989 (1); Prudente et al., 2009 (1); Rahman & Abdullah, 2002 (1); Rajaratnam, 1995 (1); Regip, 2003 (2); Samejima & Ong, 2012 (5); Samejima et al., 2012 (1); SFD, 2016 (3); SFD, 2017 (2); SFD, 2018 (1); Sharma, 1992 (4); Sheldon & Francis, 1985 (1); Shigeki et al., 2000 (1); Shukor, 1996 (5); Sollmann et al., 2017 (3); Stark et al., 2019 (1); Tangah et al., 2016 (1); Webb, 2016 (3); Wilting & Mohamed, 2010 (2); York et al., 2013 (1).

9

Southern Pig-Tailed Macaque (*Macaca nemestrina*)

Yosuke Otani

Introduction

Southern Pig-tailed Macaques (*Macaca nemestrina*) inhabit Malaysia, including Sabah in Borneo, as well as Brunei (Choudhury, 2003; Groves, 2001; Roos et al., 2014), Indonesia (Sumatra and Kalimantan), and southern Thailand. This species has a long history of living closely with humans for the purpose of coconut picking (Bertrand, 1967; Corner, 1993), and is still commonly kept as a companion animal (Malaivijitnond et al., 2007). In addition, this species is used in biomedical research for HIV/AIDS studies (Liao et al., 2007). Despite its close relationship with humans, not many ecological studies have been conducted on this species in the wild.

Detailed ecological studies have been conducted by Caldecott (1986) in Sarawak, Ruppert et al. (2018) and Holzner et al. (2019; 2021) in the Malay Peninsula, Oi (1990) and Robertson (1986) in Sumatra, and Otani et al. (2020a) in Sabah. Recent distribution surveys using techniques, such as camera traps, suggest that this species has experienced a continued population decline of more than 30% over three generations. Because of the likelihood of continuing decline in the future, it is listed as 'Vulnerable' by the IUCN in 2020 (Ang et al., 2020).

Throughout Malaysia the Pig-tailed Macaque is known as *berok*, although in the Kadazan language it is called *gobuk* (also referencing monkeys in general).

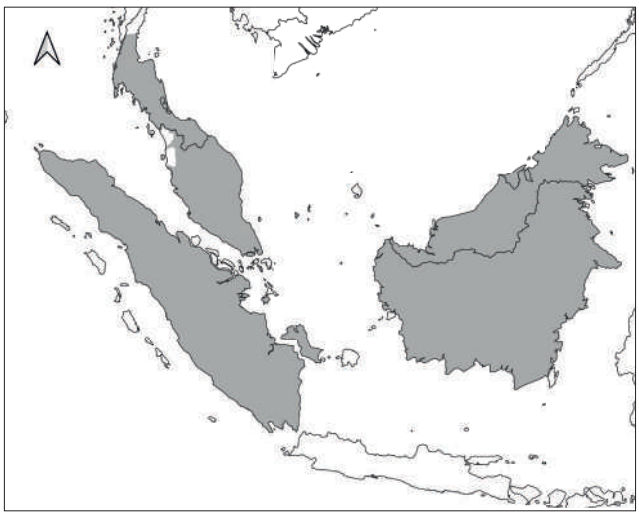


Figure 1. Global distribution of Southern pig-tailed Macaque (IUCN, 2020b)

Taxonomy

Southern Pig-tailed Macaques, Northern Pig-tailed Macaques (*M. leonina*), Pagai Island Macaques (*M. pagensis*), and Siberut Macaques (*M. siberu*) are now treated as separate species, but were

previously considered as subspecies of *Macaca nemestrina* (Groves, 2001). Southern and Northern Pig-tailed Macaques are very similar in morphology, and hybrids exist between the two species at the boundary, which is the Surat Thani-Krabi depression. Both species are kept as companion animals in the surrounding area (Malaivijitnond et al., 2012), and are sometimes released into the wild across the boundary which makes the geographical boundary between the two species ambiguous.

Natural History

There have been very few intensive ecological studies focusing on Pig-tailed Macaques in Sabah (Otani et al., 2020a), and their ecological features and variations within the state are mostly unclear, so what we understand of their ecology mostly comes from studies outside the State.

The Pig-tailed Macaque is one of the most sexually dimorphic species in the genus *Macaca*. Fully mature males weigh about twice as much as adult females (approximately 14 kg for males and 7 kg for females) (Figure 2), and adult males have large canine teeth and broad shoulders (Oi, 1990; Sackett et al., 2002). The species has short olive-coloured hair, black areas from head to back, and a short, curly tail that resembles a pig's tail, as its name suggests. This tropical species mates and gives birth throughout the year (Caldecott, 1986). The average gestation period is 172 days, and captive individuals are fertile from the age of three years, although they probably become fertile later in the wild (Sackett et al., 2002). Females have an average 39-day cycle of estrus; during its peak, the sexual skin on the rump becomes red and swollen (Oi, 1999; Figure 3b).

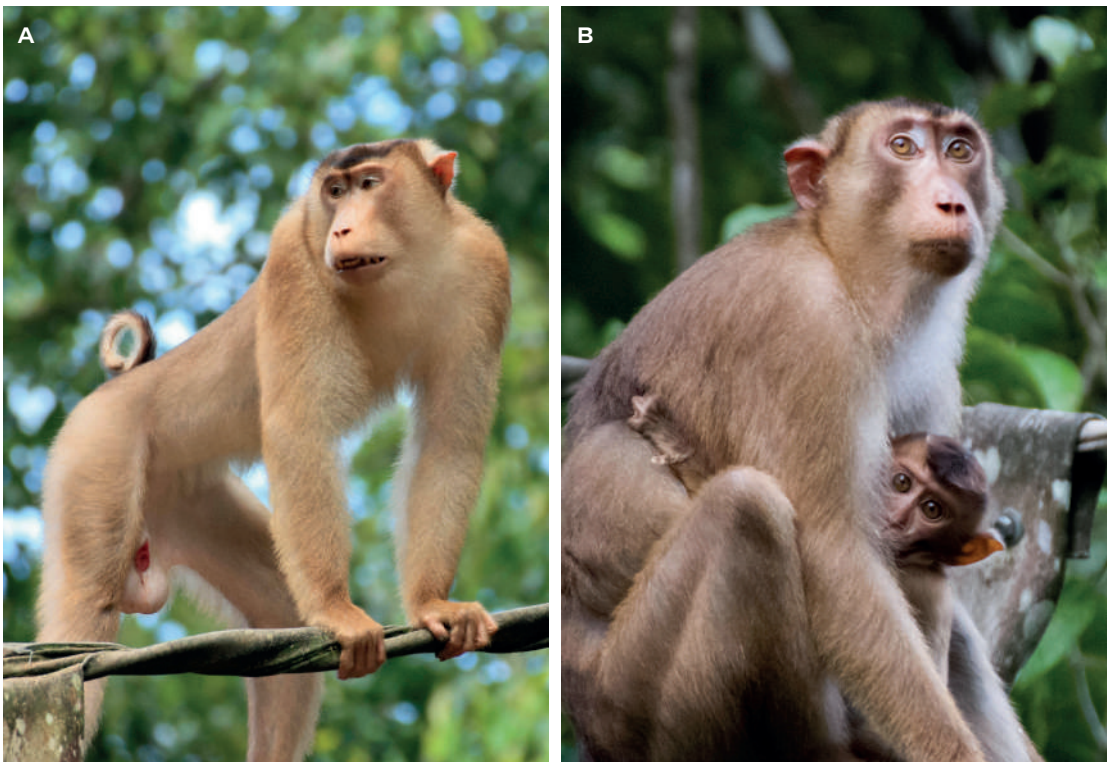


Figure 2. Pig-tailed Macaques a) mature male © Yosuke Otani and b) mature female © Yosuke Otani

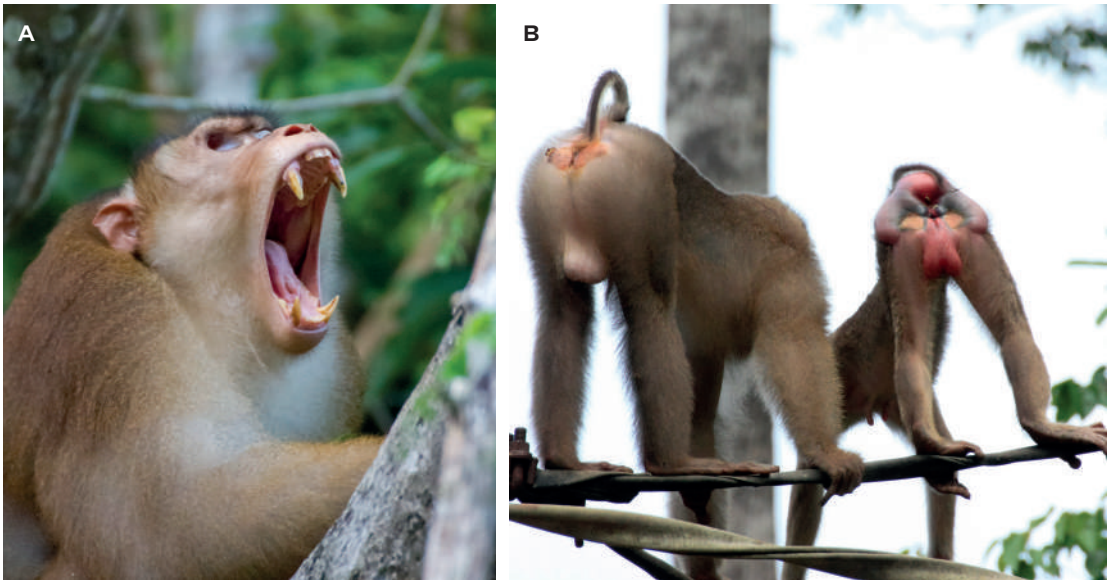


Figure 3. a) Pig-tailed Macaque males have large canine teeth © Yosuke Otani; b) The sexual skin of an estrous female Pig-tailed Macaque © Yosuke Otani

Pig-tailed Macaques form groups of multiple males and females. In contrast to the lifelong affiliation of females to their natal group, males transfer to another group when they mature (Oi, 1999), which maintains genetic exchange. Social group size is estimated to be 40–80 individuals in many habitats (Caldecott, 1986; Oi, 1990), but social group size is difficult to estimate because they frequently split into smaller subgroups of a few to 20 individuals (Otani et al., 2020a; Ruppert et al., 2018; Yanuar et al., 2009). They divide into small groups during the day to forage for food, but at night they often aggregate in tall trees to sleep together because larger groups are generally more vigilant and are capable of detecting predators from longer distances, which potentially reduces predation risk (Otani et al., 2020a; Van Schaik & Van Hooff, 1983).

The Pig-tailed Macaque is classified as having a rather despotic society (Oi, 1999; Thierry et al., 2004). They have a strong hierarchy, with subordinate individuals scarcely ever attacking higher-ranking individuals. Among females, rank is determined by lineage in that rank is inherited by daughters (a matrilineal system). It is not clear how male rank is determined, but in other macaque genera it is determined by the outcome of agonistic interactions and prior group affiliation. The species is promiscuous, with females mating opportunistically with multiple males, but males of higher rank tend to have priority in mating opportunities (Oi, 1999). However, the possibility of high ranking males dominating estrus females in these societies depends on the preference of the females, the ease of hiding in the forest, and the number of females in estrus at one time (Otani et al., 2020b).

This species is omnivorous, with the majority of its diet comprising fruits, and moves along the ground in search of fruits, leaves, flowers, invertebrates, vertebrates and fungi. Their diets vary with habitat type (Table 1). In a study of the macaques' diet, populations inhabiting lowland primary and secondary rainforests consumed a high supply of fruits (Caldecott, 1986), and this was much lower in a population studied in unlogged forest surrounded by oil palm plantations. However, a study of animals with a large coverage of oil palm plantations in their home range had diets consisting of 77%

of oil palm fruits (Ruppert et al., 2018). The species is also adapted to exploiting other anthropogenic foods, including crops such as corn, durian fruit, papaya fruit, and tapioca root in its diet (Ang et al., 2020). The damage caused by this species to farms has led to a decline in profitability for farmers, and extermination of this species as a pest, which is an obstacle to sustainable coexistence.

Table 1. Pig-tailed Macaques (*Macaca nemestrina*) diet (% feeding records).

Study sites	**The Pasoh Forest Reserve, Peninsular Malaysia**	**Segari Melintang Forest Reserve, Peninsular Malaysia and in the oil palm plantations bordering forest reserves**	
HABITAT	lowland dipterocarp (unlogged and secondary)	lowland dipterocarp forests (unlogged and secondary) (N=521)	Oil palm plantations and forest edge (N=196)
Fruit parts	65.9	32	77 (oil palm)
Floral parts	1.5	2	8 (oil palm)
Leaf parts & bark	11.9	28	9
Invertebrates	12.2	32	4 (ants)
Others	0.4 (rats)	6 (fungi)	2 (rats)
Source	Caldecott, 1986	Ruppert et al., 2018	

Pig-tailed Macaques are less arboreal than the sympatric Long-tailed Macaque (*Macaca fascicularis*). The larger adult males spend over 70% of their time on the ground (Ruppert et al., 2018), and groups mainly travel long distances along the ground (Rodman, 1979). These features indicate that this species is vulnerable to forest fragmentation, and in fact incidences of road casualties have increased in recent years (Ang et al., 2020).

Distribution in Sabah

This species is found in a variety of habitats, including lowland primary and secondary rainforests, mangrove forests, hill dipterocarp forests, and montane forests, and has been reported to occur from 0 m to 1,900 m asl (Yanuar et al., 2009). They are most commonly observed in hilly dipterocarp forests and lowland forests, and tend to occur at higher densities at lower elevations, but previous reports differ in survey methods, making simple comparisons difficult (Bernstein, 1967; Crockett & Wilson, 1980; Yanuar et al., 2009). In addition, they are also found in farmland and around urban environments.

A great deal of effort has been devoted to the census of mammals, including primates (e.g. camera traps, line census) in Sabah (e.g. Bernard et al., 2013; Boonratana, 1997; Camacho-Sanchez et al., 2019; Davies & Payne, 1982; Samejima et al., 2012). Since this species travels in groups and is highly terrestrial, monitoring the population by camera traps is an effective method. In addition, populations inhabiting riverine forests sleep on riverbanks, so observation from a boat is an effective survey method (Matsuda et al., 2016). Continuous monitoring using a combination of these methods is recommended to guide conservation interventions.

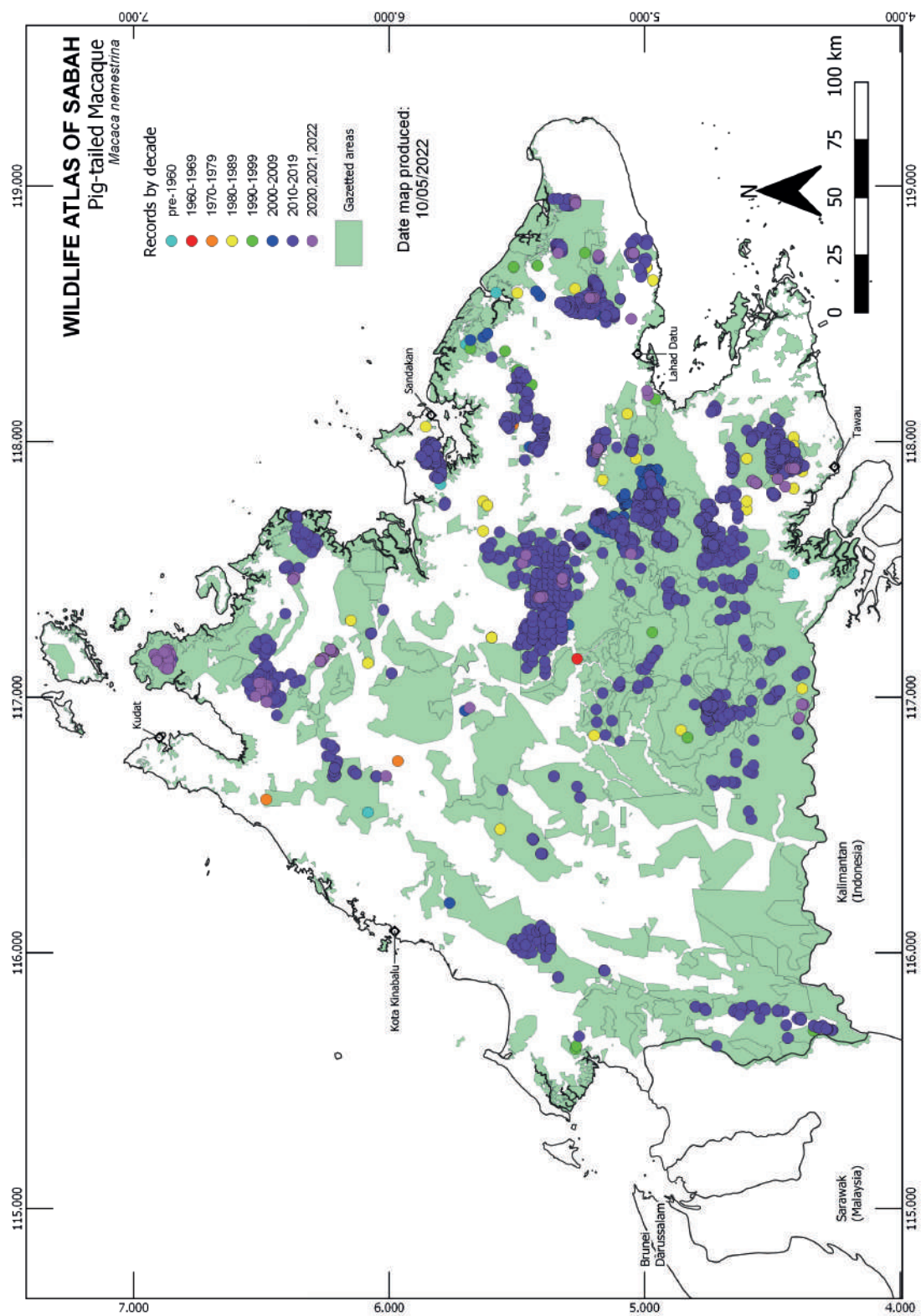


Figure 4. Records of Pig-tailed Macaque, showing a wide range of habitats and adaptation to diverse environments, although agricultural habitats are undersurveyed for the Wildlife Atlas Database.

The results show that Pig-tailed Macaques are very widespread in Sabah, and found in mangrove forests, lowland rainforests, hilly dipterocarp forests, and even higher elevations (Figure 4).

Similar to the Pig-tailed Macaque, the Long-tailed Macaque (*M. fascicularis)* is widely distributed throughout Sabah. This species is smaller (male: 9 kg max, female: 6 kg max) and more arboreal than the Pig-tailed Macaque (Rodman, 1979), but has similar feeding habits and overlapping ecological niches. However, there is microhabitat segregation between them (Rodman, 1991), which allows them to coexist successfully.

Relationships with Humans

Pig-tailed Macaques have been bred and trained to work and pick coconuts and other fruits from high up in the trees. From the time when individuals are immature, breeders teach them their rank relationship with humans, and at the same time teach them how to work in stages (Bertrand, 1967). Because of their tendency to adhere to hierarchical relationships, they are also kept as companion animals in a wide range of their habitats (Malaivijitnond et al., 2012), with a famous example of E. J. H. Corner, a British mycologist and botanist, who bred and trained several individuals in the Malay Peninsula from 1937 to 1941 to collect samples of flowers, leaves, and epiphytes from the canopy of tall trees, some of which were over 60 m tall (Corner, 1993). In recent times, however, licenses to keep Pig-tailed Macaques have only been issued to coconut pickers, but keeping these animals is generally discouraged, to avoid mistreatment of the animals and the risk of attacks on humans.

In addition, this species plays an important role in biomedical research. Species of the genus *Macaca*, such as Long-tailed Macaques and Rhesus Macaques (*M. mulatta*), are important animal models in the study of viral infections, such as measles, polio, and influenza. Conversely, the host range of human immunodeficiency virus type 1 (HIV-1), the causative virus of acquired immunodeficiency syndrome (AIDS), is known to be very narrow, and the animal species in which HIV-1 can infect and multiply are limited to apes such as chimpanzees (*Pan troglodytes*). However, the Pig-tailed Macaque is the only exception that is susceptible to HIV-1 infection (Agy et al., 1992; Liao et al., 2007). Therefore, there is a continuous and active trade in this species in Indonesia for the purpose of providing them for HIV/AIDS study (Ang et al., 2020).

Conflicts between humans and this species have also become a serious concern because of crop raiding. As mentioned above, this species has adapted to exploit various commercial crops, and the regular presence of macaques in some plantations has reduced farmers' tolerance for this species (Linkie et al., 2007). More seriously, direct aggression against people and livestock also occurs. The adult males sometimes behave aggressively towards labourers; for example, stealing their lunch or attacking their dogs (Davies, pers. comm.). The fear of Pig-tailed Macaques, as well as the perceived crop damage, drives intolerance, conflict and retaliation. Conversely, it has been reported that Pig-tailed Macaques on oil palm plantations are offsetting the damage they cause on oil palm fruits by vigorously preying on rats that cause more damage to the crops than the macaques themselves, thus benefiting farmers (Holzner et al., 2019).

Conservation

It has been estimated that the >30% population decline of the Pig-tailed Macaque over three generations has been due to peat land drainage, logging, conversion of habitat to large-scale oil palm monoculture, habitat degradation (due to highway construction and other large-scale development projects), and burning (Ang et al., 2020).

The home range of a single group of this species is large (100–300 ha), making it vulnerable to forest fragmentation, and because it tends to travel long distances on the ground, making it likely to venture onto roads and cause traffic accidents when travelling between forest fragments. This species can also cross roads via power lines, which can result in electrocution and power outages (Otani, pers. obs.).

In addition, macaques choose relatively tall trees (mean ± SD, 20.9 m ± 4.9 m) as sleeping sites to avoid predators (Albert et al., 2011), but this strategy may be spoiled by the reduction of tall trees due to logging. The area of continuous forest required for conservation of this species is very large, as multiple social groups with a large enough home range are required to maintain genetic diversity to ensure the long-term viability of local populations. The installation of ecological corridors may be an effective means of improving the current situation (Pascual-Hortal & Saura, 2006; Holzner et al., 2019). These corridors are designed to connect forests divided by roads and residential areas with animal bridges, underpasses, and greenbelts. Maintaining large areas of logged and unlogged forest is the most important priority for the conservation of this species (Holzner et al., 2021).

Although Pig-tailed Macaques are listed as 'Vulnerable' by the IUCN, they are persecuted as perceived pests because they damage crops (e.g. orchards and oil palm plantations) (Lee & Priston, 2005). Crop raiding reduces farmers' tolerance towards wildlife (Linkie et al., 2007), despite potential benefits these monkeys could bring in reducing rat numbers in oil palm agriculture (Holzner et al., 2019). Without careful planning based on appropriate data, reduced damage to plantations cannot be achieved, as exemplified by situations in which extermination does not reduce the damage to crops (e.g. Hewison et al., 2001; Izumiyama et al., 2003). Plantations with high concentrations of nutrient-rich food are very attractive to wildlife, so even if extermination is carried



Figure 5. Pig-tailed Macaques crossing a wildlife bridge © Yosuke Otani

out on a plantation, individuals will soon flow in from surrounding areas. To solve animal damage, it is necessary to combine protection (e.g. electric fences), modest population control (e.g. selective culling of damaging individuals), and habitat improvement (Honda et al., 2019; Swan et al., 2017). The key is to increase the risk and effort for animals to visit farms, and to create a situation where wildlife will prefer to live in the forest. This is very difficult and costly in the long term, and achieving conservation of wild populations will require such considerable effort.

Acknowledgements

This paper is based on the records in the Wildlife Atlas of Sabah database. I would like to express my sincere gratitude to those who contributed to building the database. The data presented here is the result of the great efforts of many researchers in their field. I thank the Sabah Biodiversity Centre and Sabah Wildlife Department for granting permission to carry out my research and Sabah Forestry Department for support in the field. I appreciate the support of Dr Glyn Davies and Mr Adi Shabrani. Finally, I thank Dr Nadine Ruppert for helpful comments which improved the manuscript.

Data Sources

Individuals / organizations (Number of records): Brodie, Jedediah (631); Gardner, Penny (422); Guharajan, Roshan (439); Haysom, Jessica (8376); Hearn, Andrew (4296); Herman Insob (1); Lim Wing Shen (2); Muhammad Edri Nurdin (1); Suzika Juiling (1); Forest Solution Malaysia (321); Sabah Museum (2); SFD (26); WWF-Malaysia (2101). *Open source database (Number of records):* eMammal, 2021 (460). *Publications (Number of records):* Abdullah et al., 1995 (1); Allan & Coolidge, 1940 (2); Bernard et al., 2013 (8); Bernard et al., 2014 (9); Bernard et al., 2016 (5); Bernard et al., 2019 (1); Bili, 2014 (5); Boonratana & Sharma, 1993 (2); Boonratana, 1997 (6); Bornion Timber, 2021 (9); Chasen & Kloss, 1931 (1); Chung et al., 2019 (7); Davies & Payne, 1982 (41); Davies & Tan, 2019 (2); Davis, 1962 (2); Dawson, 1992 (3); Deere et al., 2017 (67); Granados, 2016 (2); Hawkins et al., 2019 (1); HUTAN KOCP, 2016 (1); Kehoe, 2011 (3); Ketol et al., 2009 (1); KOPEL, 2016 (1); KOPEL, 2019 (1); Lim, 1993 (1); Lim, 1996 (2); Matsubayashi et al., 2011 (1); Matsuda et al., 2014 (1); Mingueza, 2018 (2); Murphy, 2007 (1); Onoguchi & Matsubayashi, 2008 (2); Payne et al., 1989 (1); Prudente et al., 2009 (1); Rajaratnam, 1995 (1); Regip, 2003 (2); Samejima & Ong, 2012 (29); Samejima et al., 2012 (1); SFD, 2016 (9); SFD, 2017 (13); SFD, 2018 (1); Sharma, 1992 (3); Sheldon & Francis, 1985 (1); Sollmann et al., 2017 (3); Wilting & Mohamed, 2010 (2); York et al., 2013 (2).

Elephant and Ungulates

Adi Shabrani

The Bornean subspecies of Asian Elephant (*Elephas maximus borneensis*) is the smallest among all other elephant species, but it is the largest land mammal on the island. Despite its large size and capability for long distance travels, the Bornean Elephant's distribution is restricted to only in the eastern part of Sabah, and this population is widely agreed to represent a distinct genetic unit. It is a land-dwelling animal with migratory behaviour that moves in large groups across the lowland landscape in eastern Sabah. This poses a major conservation challenge because such a large area is needed to maintain matriarchal groups that are reproductively active.

Ungulates is a group of animals that use hoofed toes to support their weight while standing or in motion. The group consists of a diverse species that are typically herbivores, with the exception of some members such as the pig which can be omnivorous. In Sabah, this group is represented by 8 species (Table 1) that seem to sit on two different ends of the conservation spectrum.

On one end of the spectrum are the Sambar Deer, mousedeer (2 species) and muntjac (2 species). These species, having broad distribution and large population size in Sabah, are often associated as wild meats and targeted by hunters for consumption. Sabah natives, in particular the Kadazandusun people, prefer the Bearded Pig for their many local delicacies such as *sinalau* (smoked meat), *bosou* (pickled meat) and *pinongian* (meat with fermented Pangium fruit). The populations of these species appear to be relatively stable even in areas where hunting is still actively practised,



Figure 1. Aerial drone image of Bornean Elephants passing through a Eucalyptus pellita plantation block at SSB, Tawau © Mazidi Abd Ghani/WWF-Malaysia

suggesting that their high birth rates probably can compensate for the number of individuals lost to hunting. However, the emergence of new threats caused by wildlife diseases may change this trend. For instance, the recent outbreak of African Swine Fever in 2021 has wiped out large populations of Bearded Pigs in the north and east of Sabah.

Meanwhile, on the other end of the spectrum are the Bornean Banteng and Sumatran Rhinoceros, both of which have narrow distribution and small population size. Both are large bodied ungulates that have low birth rates compared to the other ungulates species in Sabah, and therefore, are more susceptible to loss of fertile individuals. Banteng is under such tremendous threat of illegal poaching for wild meats that its population is now only restricted to a few localities in Sabah. In the case of the Sumatran Rhinoceros, the Sabah population was already tiny when major conservation efforts started, and the species was largely unknown in terms of its ecology and breeding. Sadly, it was declared locally extinct in 2019.

Elephants and all ungulates in Sabah are protected under its laws, although the provision for protection for Bearded Pig, Sambar Deer, mousedeer and muntjac are more to regulate hunting rather than to prevent or stop it. These animals that are listed in Schedule 3 of Sabah Wildlife Enactment 1997 can be hunted with a licence. The Bornean Elephant and Banteng are listed in Schedule 1 that provides total protection from any form of harvesting or hunting.

Table 1. Ungulate species in Sabah

Sabah species / subspecies	**IUCN Red List categories**	**Endemism**	**Sabah Wildlife Enactment 1997 Protection status***	**Scientific name (1997 Sabah Wildlife Law)**
Bornean Elephant *Elephas maximus borneensis*	Endangered	Eastern Sabah	Schedule 1	
Sumatran Rhinoceros *Dicerorhinus sumatrensis*	Critically Endangered	Locally extinct in Sabah; small population exists in Kalimantan and Sumatra		
Bornean Banteng *Bos javanicus lowi*	Endangered	Subspecies is endemic to Borneo		
Bearded Pig *Sus barbatus*	Vulnerable	Southeast Asia	Schedule 3	
Sambar Deer *Rusa unicolor*		Found throughout southeast and south Asia		*Cervus unicolor*
Bornean Yellow Muntjac *Muntiacus atherodes*	Near Threatened	Borneo		
Red Muntjac *Muntiacus muntjak*	Least Concern	Southeast Asia		
Greater Mousedeer *Tragulus napu*				
Lesser Mousedeer *Tragulus kanchil*				*Tragulus javanicus*

*Schedule 1: Totally Protected, Schedule 3: Protected species of animals for which hunting licence is required

10

Bornean Elephants (*Elephas maximus borneensis*)

Cheryl Cheah, Benoit Goossens, Marc Ancrenaz and Nurzhafarina Othman

Introduction

The Asian Elephant (*Elephas maximus*) occurs in the wild in 13 countries across South and Southeast Asia (Williams et al., 2020a), and the Bornean Elephant is the eastern-most population of the Asian Elephant range, restricted to the north-east region of Borneo. The great majority of the Bornean Elephant population is in Sabah state, with less than ten animals/100 km^2 in north Kalimantan that move between there and Sabah along two narrow river valleys (Sukmantoro et al., 2021).

Prehistoric fossil evidence from only three specimens found in caves in Brunei and Sarawak indicates that the Bornean Elephant may have occurred outside their current range. However, these specimens were not discovered in any controlled excavations and therefore their origin is debatable (Cranbrook et al., 2007; Fernando et al., 2003; Hooijer, 1972).

The Malay name, *gajah,* is applied throughout Malaysia to these magnificent animals, although some migrant communities in Sabah refer to them as *nenek*, which means grandmother, as a sign of respect for their wisdom. The common English name is Bornean Elephant, and it is often referred to as the Bornean Pygmy Elephant, because Bornean Elephants are smaller in stature than Indian and Sri Lankan elephants (Phillipps & Phillipps, 2016). However, these gentle giants are by no means small since adult males have been recorded to reach a height of 3.6 m!

Taxonomy

The Bornean Elephant (*Elephas maximus borneensis*) should be considered as a distinct subspecies, based on recent genetic analyses which strongly suggest that they are an Evolutionary Significant Unit distinct from the mainland Asian Elephants; from which they have been isolated for over 300,000 years (Fernando et al., 2003; Sharma et al., 2018). Furthermore, they are morphologically and behaviourally distinct from their counterparts on mainland Asia (Cranbrook et al., 2007; Williams et al., 2020a). A severe bottleneck was identified between 11,000 and 18,000 years ago — at the end of the Last Glacial Maximum — indicating that elephants colonized Borneo from another part of Sundaland at this time (Sharma et al., 2018). With these recent findings, the IUCN SSC Asian Elephant Specialist Group concur that the formation of a separate subspecies *Elephas maximus*

borneensis is warranted (Menon & Tiwari, 2019) and a definitive subspecific classification awaits a detailed range-wide morphometric and genetic study (Williams et al., 2020a).

Natural History

Elephants are sexually dimorphic with males being larger than females. Adult males range between 1.57–3.64 m with an average height of 2.17 m, while females range between 1.45–2.26 m, with an average height of 1.96 m. A pilot study by Othman et al. (2008) revealed no significant differences in selected morphological measurements between captive Bornean Elephants and elephants from Peninsular Malaysia.



Figure 1. Bornean Elephants drinking and cooling off in a river at the Gunung Rara Forest Reserve © Vicculter Denius/WWF-Malaysia

Asian elephants are a matrilineal social species that form tightly-knit bonds between females and their offspring. Males disperse from the family unit when they reach puberty. Young bulls in India have been observed to disperse from the family between ages 10–15, thereafter ranging solitarily or forming bachelor groups (Sukumar, 2003). Sexual maturity varies across populations depending on diet and environmental factors. Wild female elephants normally reach sexual maturity between 11 and 14 years of age, while males attain sexual maturity between 10 and 18 years of age (Sukumar, 2003). When adult males reach sexual maturity, they undergo a period of intense aggression towards conspecifics in a phenomenon known as *musth*. During this period, the hormone testosterone level in their body is high, fluids are secreted from their temporal gland and they may constantly dribble urine. In southern India, adult males have been observed to come into *musth* from about age 15 years (Sukumar, 2003).



Figure 2. A matriarchal group with young ones spotted at Sabah Softwoods Berhad (SSB), Tawau © Cheryl Cheah/WWF-Malaysia



Figure 3. Bornean Elephants travelling along a road next to mature oil palms at SSB, Tawau © Aaron Gekoski/ WWF-US

In Sabah, matriarchal group size varies from three to seven individuals and it has been observed that elephants tend to congregate in larger groups of 30–35 individuals later in the day (Othman, 2017). The social system is a dynamic fission-fusion arrangement, however, and it is possible to see large herds of more than 100 individuals aggregated together across their range (SWD, 2020b), especially during periods of food abundance.

Elephant activity patterns vary in relation to time of the day, season and group size. In the Lower Kinabatangan, elephants fulfill their ecological needs and requirements predominantly from riparian and seasonal freshwater swamp forests. It is common for them to enter plantations and settlements, especially in the late evening after plantation activities have ceased, and they often stay until dawn. This behaviour is particularly observed in elephants that live in close proximity to people or urbanized areas (Evans et al., 2020a; Othman, 2017). In some areas, however, certain bulls and family herds have increasingly remained in cultivation areas to feed during the day. They may perceive the risk from people to be low, and the potential nutritional rewards to be high, such as during the oil palm replanting stage where mature palm trees are felled and chipped, exposing the 'heart of palm' that the elephants gorge upon (Othman et al., 2019; Figure 4).

Bornean Elephants are known to prefer grasses and bamboos (Poaceae family) in riverine and open-grass areas, as well as palms and gingers (English et al., 2014). The faster growth rates of grasses, palms and bamboos, compared to woody plants, mean they can provide a more regular and stable food resource, but the animals can still switch their diet from grasses to browse depending on seasonal changes in plant quality (English et al., 2014). They are also known to feed on young oil palm shoots, and the pith of felled and chipped mature palms, as well as numerous fruits planted



Figure 4. An elephant feeding on the 'heart of palm' within an oil palm plantation © Chris Ratcliffe/WWF-UK

in orchards: bananas, durian, pineapple, sweet potato, etc., which brings them into conflict with plantations and communities.

Overall an adult can consume up to 150 kg of vegetation/day, and can drink up to 225 l/day (San Diego Zoo, 2019), as well as requiring certain essential minerals, such as sodium, found in salt licks and kaolin clay found in mud volcanoes (Payne et al., 2020).

The availability of food, water, habitat types and seasonal weather patterns (dry versus rainy) influence the home range of elephants. They are forest edge specialists, and favour low-lying terrain, and generally avoid steep elevations above 400 m. Their movements are strongly influenced by access to rivers, valleys and open areas, as well as degraded forests (English et al., 2014; Evans et al., 2018; SWD, 2020b). They like to forage along roads where grasses grow abundantly (Wadey et al., 2018; Yamamoto-Ebina et al., 2016), and travel along ridgelines (Evans et al., 2020a).

Previous estimates report a home range size of 250–400 km² in non-fragmented landscapes and up to 600 km² in disturbed fragmented landscapes, such as the Lower Kinabatangan (Alfred et al., 2012). However, recently Evans et al. (2020a) estimated Bornean Elephants home ranges to average between 150 and 200 km². This may indicate that the remaining forests throughout the elephants' range may not be able to support them over the long-term, especially in fragmented landscapes such as the Lower Kinabatangan (Evans et al., 2020a). Sub-populations occurring in these isolated landscapes had to travel further to fulfil their ecological requirements, which resulted in increased home range sizes compared to sub-populations in less disturbed landscapes, such as the Central Sabah sub-population (Evans et al., 2020a).

Distribution in Sabah

Satellite-collared elephants in Sabah are found to be distributed across three separate Managed Elephant Ranges (MER): Lower Kinabatangan, Tabin and Central Sabah (SWD, 2020b; Figure 5) with the population extending to a small area in the Nunukan District in northern Kalimantan, Indonesia (Alfred et al., 2011; Wulffraat & Greenwood, 2017). The present distribution of elephants in Sabah is a direct result of the expansion of the human population, major changes in land-use and infrastructure development (SWD, 2020b). It is also thought that their distribution is influenced by the presence of certain essential minerals (Payne & Francis, 2007; Payne et al., 2020).

Historic records mention the findings of an elephant skull in the Gomantong Forest Reserve in 1929 and the remains of a molar tooth in 1950 at Bukit Kretam as reported by Davis (1962). In the 1960s, the elephants were documented at Ulu Dusun and present day Kuala Bonggaya Forest Reserve, but their presence there has not been recorded ever since. The elephants used to range as far north as Kg. Belabam Jaya Desa, along Sungai Muanod in the Labuk Sugut District in the 1980s (Davies & Payne, 1982). Similarly, transect surveys in the 1980s also report their presence along Sungai Kretam Besar to the north of Tabin Wildlife Reserve (Davies & Payne, 1982), but the present day sub-populations from the Tabin and Lower Kinabatangan MERs no longer occur there as a result of agriculture development and electric-fence barriers. The distribution of the sub-population in the Central Sabah MER remains mostly intact. However, their occurrence to the west of Sungai Pinangah Forest Reserve, recorded in the 1990s, is thought to be extirpated. Similarly, surveys done by Davies & Payne (1982) indicated that the elephants no longer occurred in Tawau and Semporna, although there were some reports of them in these areas pre-1970s.

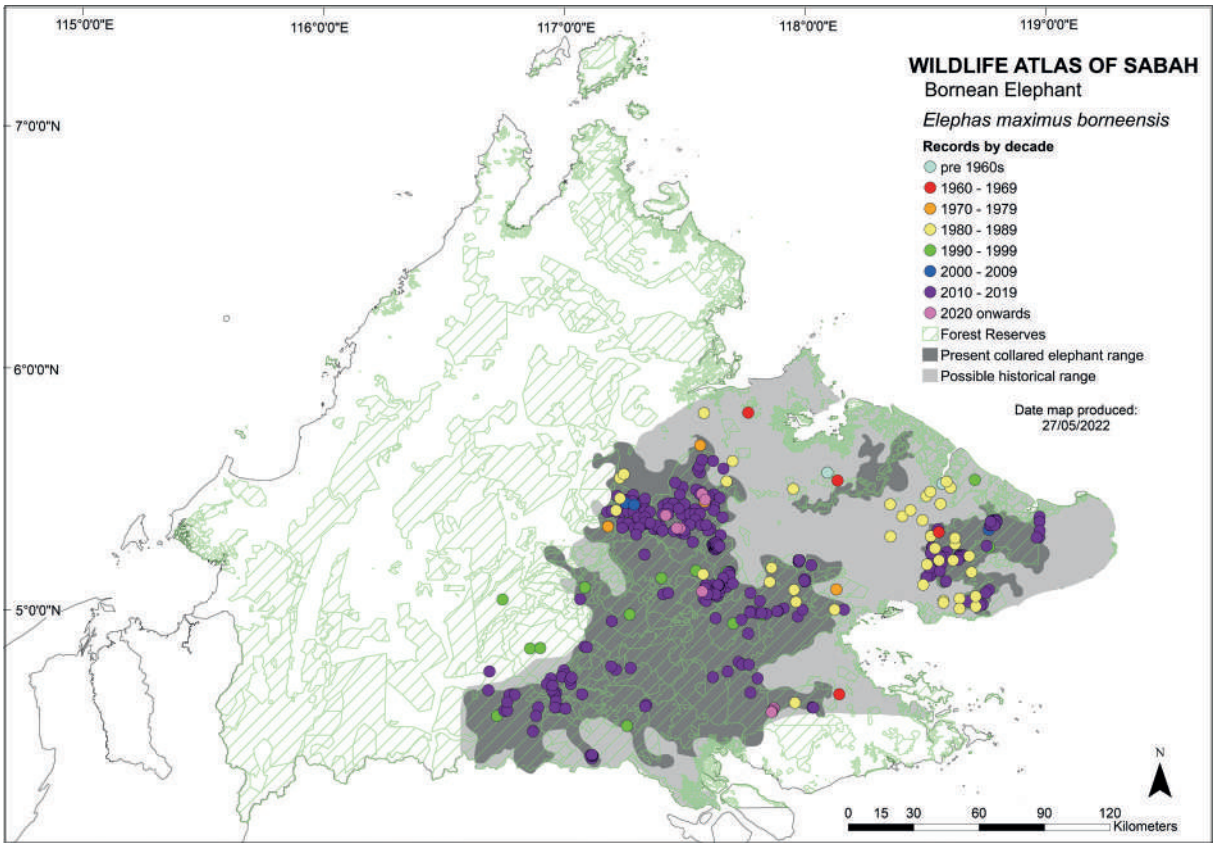


Figure 5. Probable historical range (from Sabah Wildlife Department, 2011) and present range of the Bornean Elephant.

The estimation of elephant population using indirect methods is particularly challenging in tropical forests where biological data essential for population estimation, such as dung decay rates, may vary according to season, weather, habitat and diet (Hedges, 2012; Laing et al., 2003). Using the dung count method, Boonratana (1997) estimated a density of 0.02 elephants per km² for an area of 9,700 km² in Central Sabah, which is roughly equivalent to 195 animals. The author also calculated a density of 0.07 elephants per km² or 85 individuals in Tabin Wildlife Reserve. A Sabah-wide census conducted in 2007–2008, estimated the population size to be 2,040 elephants (Alfred et al., 2010). In 2015, another dung count study was conducted using a stratified random design for the Central Sabah MER (excluding Tangkulap, Deramakot and Segaliud-Lokan forest reserves). This latter study estimated a population size of 387 elephants (Cheah & Yoganand, 2022), where the previous estimate for the equivalent area was 1,132 individuals (Alfred et al., 2010). This discrepancy should not be taken to infer population decline, however, since no drastic land-use change or increase in hunting were found between 2008 and 2015 (Cheah & Yoganand, 2022).

Since then, there has been no recent range-wide surveys carried out in Sabah to estimate the elephant population size, although expert knowledge estimates that there are not more than 1,000–1,500 individuals left in the wild as reported in the Bornean Elephant Action Plan (2020–2029). However, whether or not the population is viable over the long-term is difficult to ascertain because

demographic parameters, such as birth rates, mortality rates and sex ratio, as well as habitat availability and conditions in the wild are still mostly unknown (Sukumar, 1989).

Conservation

The Asian Elephant (*Elephas maximus*) is listed as 'Endangered' on the IUCN Red List of Threatened Species (Williams et al., 2020a) and is therefore facing high risks of extinction if current trend continues. The species is also listed on Appendix 1 of CITES, which prohibits the international trade in specimens of this species except under exceptional cases. The species is totally protected in Sabah under Schedule 1 of the Wildlife Conservation Enactment (WCE) 1997. Section 25 of the WCE1997 provides protection for Bornean Elephant, and the possession of an elephant or its products (skin, bones, tusks, etc.) is an offence under Section 41 of the same enactment. The penalty for both offences, liable on conviction, is a fine of no less than RM50,000 and not exceeding RM250,000, with imprisonment for a term not less than one year and not more than five years.

Threats

The Bornean Elephant Action Plan (2020–2029) identified several major threats for elephants in Sabah. These threats arise primarily from insufficient land-use planning to factor in the requirements of large, far-ranging mammals such as elephants (SWD, 2020b), with a consequence that human-elephant conflicts increase. However, in recent years the poaching of elephants for their ivory is becoming an emerging threat (SWD, 2020b).

a. ***Habitat loss and fragmentation*** including major linear transportation infrastructure development in elephant habitat will further restrict their movement and increase conflicts and elephant deaths. The ongoing development of the Pan Borneo Highway will bisect elephant habitat in the Central Sabah MER, resulting in further isolation of the sub-population there (Othman et al., 2019) and increasing the risks of road kill and hunting pressure (Goossens et al., 2016; Othman et al., 2013). Similarly, the development of the Batu Puteh Bridge in Kinabatangan has isolated and fragmented local elephant population (Estes et al., 2012; Othman et al., 2019). Therefore, there is a need to avoid these sensitive areas where possible, and to incorporate 'wildlife-friendly' sustainable infrastructure designs, such as wildlife crossings (underpasses or overpasses)

b. ***Retaliatory killings*** occur where elephants are raiding crops, especially oil palms, and doing damage to property. These animals may be trapped, shot or poisoned. Furthermore, with the increasing time spent in plantation landscapes where chemicals are used, elephants are potentially exposed to toxic poisoning (SWD, 2020b). This suspected poisoning is emerging as a threat, and may not be related to retaliatory killing but chronic poisoning due to the above.

The lack of coordination between neighbouring plantation owners when installing electric fences has resulted in bottlenecks in some areas (Estes et al., 2012) which has hampered elephant movements (Othman et al., 2019), and even funnelled them towards villages which are vulnerable. In addition, many oil palm plantations in Sabah are currently undergoing the replanting stage, which alters the dynamics of the landscape as newly replanted palm seedlings

are vulnerable to damage (Ancrenaz et al., 2007), and this is expected to further exacerbate the conflict situation.

c. ***Poaching for ivory*** has increased in recent years, including a worrying trend in the smuggling of tusks originating from Sabah across the Kalimantan border. These tusks were meant to be used as wedding dowry by the Indonesian Timorese community. Any increase in trade and poaching will potentially have an adverse impact on the viability of the species (SWD, 2020b).

d. ***Capacity constraints*** limit the efforts to address these threats, which becomes a threat in itself. Lack of management capacity, resources and poor coordination, as well as poor understanding of several key scientific questions, and lack of general awareness in political circles and by the public constrain conservation efforts for wild elephant populations.

The number of orphaned elephants rescued and living in captive facilities across Sabah has increased over the years which is mostly linked to elephant control activities in plantations where some distressed mothers have been observed to leave behind their calves, and attempts to reunite them have proven unsuccessful (Othman et al., 2019). Since all the captive elephant facilities have reached their capacity, Sabah Wildlife Department has to raise funds to cover the expensive costs of the elephants' welfare and upkeep, and they are collaborating with conservation NGOs and international zoos, such as the Oregon Zoo and Houston Zoo, to improve the welfare and husbandry of captive elephants (Othman et al., 2019). Zoos and other captive animal centres are very important for raising awareness on Bornean Elephant conservation to the public.

Conservation Initiatives

a. ***Reduce further habitat loss and fragmentation:*** Planned infrastructure development in elephant habitat should be deliberated and consultation with all stakeholders is necessary to ensure that the development is balanced and sustainable. There have been several initiatives by government, plantation owners and conservation NGOs to establish wildlife corridors in oil palm plantations for elephant movement through fragmented areas. The approximately 182 ha Keruak Wildlife Corridor project in Lower Kinabatangan was established to reconnect two fragmented forests with the aim of reducing human-wildlife conflict, preventing riverbank erosion and protecting local fisheries (see Othman et al., 2019). This multi-stakeholder model highlights the benefits of mutual partnership, which fosters coexistence between human and wildlife (see Case Study 1).

b. ***Reduce poaching and smuggling:*** In order to address the poaching of elephants for their tusks and elephants caught in snares, joint patrol operations have been conducted and task forces, including the Elephant Task Force, have been established by government enforcement agencies, supported by NGOs. The Sabah Wildlife Department has also set up an intelligence unit to further strengthen enforcement and gather intelligence data to boost efforts to tackle wildlife crime. To curb the smuggling of ivory across the border to Kalimantan, bilateral meetings between both governments need to be fostered for better cooperation.

c. **Manage human-elephant conflict (HEC) in plantations:** Working groups involving government enforcement agencies, plantation owners and NGOs have been established with the purpose of jointly implementing HEC mitigation options (Cheah et al., 2021).

The retaliatory killing of elephants due to HEC is one of the main threats, however confining elephants to forest reserves to address the issue is not a viable long-term solution. This is because the installation and maintenance of electric fences along forest boundaries is cost inhibitive and unsustainable over the long-term and this move would further isolate the populations in the three MERs. Considering all this, coexistence is the only way forward. In order to achieve that, partnering with the agricultural industry to inform better land-use planning and engaging with communities to increase their tolerance towards elephants will be crucial. With many oil palm plantations currently undergoing replanting, an integrated electric-fencing system and proper spatial planning at the landscape level is also necessary.

Recently, Bringing Back Our Rare Animals (BORA, previously Borneo Rhino Alliance) has developed a project on habitat enrichment; i.e. to plant grass/pasture in degraded habitats and open areas for elephants. Although still in its infancy, the project hopes to reduce the frequency of elephants entering agricultural lands, by providing alternative food sources apart from crops.

Case Study 1

Coexistence: Balancing elephant needs and oil palm development

Can coexistence be achieved between elephants and the oil palm industry? Sabah Softwoods Berhad (SSB) is a mixed industrial tree and oil palm plantation company located in the Tawau District. The company started experiencing crop damage by elephants in 2004, and had initially planned to install electric fences along their boundary to protect their crops which would incur substantial costs. WWF-Malaysia began to actively engage with them in 2012 to find long-term solutions which included land-use allocations, such as setting aside 1,067 ha of their land as a wildlife corridor to facilitate the movement of wildlife through a fragmented forest. SSB also decided to incorporate strategic electric fencing of only vulnerable areas with young palm trees and settlements, and to allow elephants to access other areas.

This strategy proved to be cost effective over the long-term. SSB's records of costs of oil palm trees damaged from 2004 to 2018 indicated that there was a substantial decline from an average of RM501,393/year between 2004–2011 (the total for seven years amounting to RM3,509,751) to RM5,389 in year 2018, covering an area of 41,500 ha. Coexistence was fostered through regular awareness programmes targeting plantation workers. This model of coexistence brought about a win-win solution: the company is able to save on costs for electric fencing and elephants are able to use certain areas of its plantation. SSB has demonstrated that plantations can play a key role in conservation despite having to bear some costs for allowing elephants on their land.

Case Study 2

Community-based "elephant conservation units" to proactively mitigate HEC

In many areas, HECs have escalated rapidly over the past two decades. It is crucial to harness the support of the local communities to ensure success in mitigating conflicts, particularly in areas where HECs were never recorded before. To achieve this, several community-based "elephant conservation units" have been established by different NGOs with the support of Sabah Wildlife Department since 2000 in Kinabatangan, Telupid and Beluran districts. Members of the "elephant conservation units" are equipped with survey and research techniques, and they have initiated simple and cost-efficient ways to mitigate conflicts. They are responsible to control and divert elephants back to safe zones, organize and train community members to mitigate HECs, and enable better understanding about elephants and promote acceptance of a peaceful coexistence. These members are also appointed as Honorary Wildlife Wardens under the Sabah Wildlife Conservation Enactment 1997, with the power to enforce wildlife laws. A case study in Sukau, Kinabatangan on the impacts of these "elephant conservation units" found that prior to the establishment of the units in 2002, approximately 775 oil palm trees were damaged by elephants. However, regular night patrols in coordination with the crop owners, which included usage of noise cannons, spotlights and herding of elephants back into the forest, had resulted in a substantial decline with only 91 oil palm trees damaged between the period of 2002–2003.



Figure 6. SSB set aside 1,067 ha as a wildlife corridor in 2012 to facilitate movements of elephants and other wildlife from a fragmented forest to a larger forest block © Cheryl Cheah/WWF-Malaysia

Acknowledgements

We would like to thank the Sabah Forestry Department, Sabah Wildlife Department, and Sabah Foundation for permissions to conduct surveys. We value the assistance from the Wildlife Rescue Unit for darting and collaring the elephants. WWF-Malaysia appreciates the support and collaboration of Sabah Softwoods Berhad. We thank our Elephant Conservation Team colleagues: John Japil, Vicculter Denius, Elbatius Sikul, Frederic Kusam and Engelbert Dausip for conducting various field surveys. We are grateful for funding from WWF-Netherlands, WWF-UK, WWF-Germany, and WWF's Asian Rhino and Elephant Action Strategy (AREAS). Danau Girang Field Centre's work on elephants in Sabah has been supported by Columbus Zoo and Aquarium, Elephant Family, Houston Zoo, Mohamed bin Zayed Species Conservation Fund, Ocean Park Conservation Foundation Hong Kong, The Asian Elephant Foundation and US Fish and Wildlife Service's Asian Elephant Conservation Fund. Special thanks go to Wong Ee Phin for reviewing this chapter, and feedback from the Wildlife Atlas of Sabah editors.

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Individuals / organizations (Number of records): Brodie, Jedediah (30); Gardner, Penny (173); Haysom, Jessica (59); Hearn, Andrew (456); Guharajan, Roshan (178); Lim Wing Shen (2); Muhammad Edri Nurdin (1); 1StopBorneo Wildlife (4); Sabah Forest Department (4); WWF-Malaysia (313). *Publications (Number of records):* Abdullah et al., 1995 (11); Alfred et al., 2012 (5); Bernard et al., 1997 (1); Bernard et al., 2014 (1); Bernard & Fjeldsa, 2003 (1); Bili, 2014 (2); Boonratana, 1997 (13); Boonratana & Sharma, 1993 (2); Bunya et al., 2010 (1); Chung et al., 2019 (6); Davies & Tan, 2019 (4); Davis, 1962 (2); Dawson, 1992 (7); Deere et al., 2017 (3); eMammal, 2021 (16); Evans et al., 2018 (24); Ishige et al., 2017 (2); Kee et al., 2018 (1); Kehoe, 2011 (1); KOPEL, 2019 (1); Mingueza, 2018 (14); Prudente et al., 2009 (1); Rajaratnam, 1995 (1); Regip, 2003 (1); Samejima & Ong, 2012 (10); Samejima et al., 2012 (1); SFD, 2016 (2); SFD, 2017 (12); SFD, 2018 (2); SFD, 2019 (3); Shukor et al., 2011 (2); Webb, 2016 (1); Wilting & Mohamed, 2010 (4).



Sumatran Rhinoceros just finished wallowing, a very important activity, showing hairy skin © Raymond Alfred/WWF-Malaysia

11

Sumatran Rhinoceros (*Dicerorhinus sumatrensis*)

John Payne

Introduction

The Sumatran Rhinoceros, *Dicerorhinus sumatrensis* (Gloger, 1841), also known as Hairy Rhinoceros or Asiatic Two-horned Rhinoceros, was formerly widespread in Southeast Asia but is now almost extinct, with the last breeding cluster in Aceh, Sumatra. Local names include *badak* (Malay), *kemancur* (Murut), *latak* (Sungai), *longoun* (Sungai), *tambayungan* (Murut), *tampak* (Sungai) and *temadcur* (Lun Dayeh).

The original range for rhinos was Southeast Asia, extending from what are now north-eastern India and south-western China to the equatorial islands of Borneo and Sumatra. Now, relict non-viable clusters live only in upper Mahakam River, East Kalimantan (fewer than five); Way Kambas National Park (about five), Lampung, Sumatra; and mountains of the Leuser ecosystem in Aceh (about 20), Sumatra, Indonesia (Figure 1).

The formal archaeological record of Southeast Asian rhino fossils is sparse, in some cases with uncertainty over which species are described. At least two artefacts on



Figure 1. Historical (adopted from Havmøller et al., 2015) and current distribution (IUCN, 2020a) of Sumatran Rhinoceros, including breeding population

public display, both bronze wine vessels, appear to be Sumatran Rhinos. One, in the Asian Art Museum of San Francisco, dates from about 3,100 years ago and is believed to originate from Henan province, some 800 km west-north-west of modern-day Shanghai. The other, with gold and silver inlaid cloud designs, dates from about 2,000 years ago and was found at Xingping, near Xi'an in Shaanxi province. *Dicerorhinus* was present in southern China, Myanmar, northern Vietnam and Laos, and western and southern Thailand in the late Pleistocene and Holocene (Antoine, 2012).

Natural History

The diet of wild Sumatran Rhinos that lived in the lowlands and hill ranges consisted almost entirely of the leaves and twigs of a wide variety of species of woody plants, with some species of fallen fruits, eaten ad hoc when found, and extremely small amounts of non-woody plants. The only other type of mammal with such a diet are tapirs. The leaves and twigs are obtained from saplings, small trees and lianas, often by pushing the plants over, twisting them and biting off the terminal leafy twigs. Most of the few remaining wild Sumatran Rhinos, however, live in mountain forest (1,200– 1,900 m asl) where their diet consists mainly of herbaceous plants.

Feeding occurs mainly from late afternoon, through the night, until early morning. Researchers in the 1970s, recorded 147 plant species in 48 families eaten by rhinos in Endau-Rompin (Peninsular Malaysia) and a similar number in the Leuser mountains of Aceh (north Sumatra). The fact that a variety of plant species are eaten is a reflection of two facts: one, that the tropical rainforest consists of a great diversity of plant species and, two, that the leaves of most species contain secondary metabolites that have evolved to dissuade consumption by herbivores. These metabolites are to some degree toxic to mammals, and so only small amounts of any one food plant species can be eaten at any one time.

Observations of captive Sumatran Rhinos in Sabah showed clearly that they prefer fast-growing plant species of forest gaps and secondary growth as their main foods. Plant families with many species preferred by Sumatran Rhinos include Moraceae, Rubiaceae and Euphorbiaceae. Old growth, closed-canopy tropical rainforests are scarce in plant species preferred by Sumatran Rhinos.

After securing enough food, about 30 to 50 kg per day, Sumatran Rhinos rest and sleep in a mud wallow for most or all of the time from around 9 am to 3 pm. This happens daily, and is a means to lose excess body heat in the hottest hours of the day, as well as to help maintain good skin condition and avoid the irritation of biting insects.

Wild Sumatran Rhinos lived a solitary existence. Individuals do not defend a territory, but instead occupied overlapping ranges. During work to capture the last two rhinos in Sabah (2010–2014), camera-trap images along with Borneo Rhino Alliance (BORA) and WWF-Malaysia staff records indicated that the first rhino (Puntung) was occupying a home range of about 1,000 ha and the second (Iman) about 2,000 ha. Nico van Strien's unique and monumental study in Aceh (van Strien, 1985) suggested individual female home ranges of about 1,500 ha each, and males with home ranges of more than twice that size and perhaps up to 6,000 ha or more.

Communication between individuals relies on the sense of smell. The rhinos defecated mainly either in streams (the odour emanating from faeces floating downstream) or, in hilly terrain, on ridge-top long-term rhino trails (breezes passing over ridges will waft scent into the valleys below). It is believed that Sumatran Rhinos detect the gender of other individuals through volatile organic compounds in their faeces and urine, as well as whether a female is in oestrus. The Sumatran

Rhino is the most vocal of all rhino species. Muggenthaler et al. (2003) distinguished three types of vocalizations: eeps (one second duration, 70 Hz–4 kHz frequency), whales (4–7 seconds, similar to humpback whale song, 100 Hz–3.2 kHz) and whistle-blows (a mix of a whistle and loud burst of air, 17 Hz–8 kHz, which includes infrasound).

Based on observations of captive-born animals, the Cincinnati Zoo team estimated that male and female Sumatran Rhinos become sexually mature at 6–6.5 and 5–5.5 years of age, respectively. It is believed that healthy Sumatran Rhinos live to an age of early forties. Female receptivity to mating is limited to about one day at roughly 21-day intervals, with one or two days of aggressive courtship.

Single young are born, probably with an inter-birth interval under optimum conditions in the wild every three to four years, after a gestation period of about 15.5 months, and with a birth weight of 24–39 kg. Calves grow rapidly to a weight of 400 kg at 12 months. Van Strien (1985) observed that wild rhino mothers nurse their calves for 16 to 18 months, and that although they then separate, the young remain in the area where they were nursed for a further two to three years, and gradually extend their range by venturing into adjacent areas. Based on limited anecdotal records, some Sumatran Rhinos seem to move completely and far out of the mother's home range. Kloss (in Chasen, 1940) reported the presence of a wild rhino on 1,500 ha Abang Besar Island, 60 km from the nearest Sumatran mainland. In 2005, a young female Sumatran Rhino named Rosa left the area believed to be her birth site within Bukit Barisan National Park, Sumatra, travelling some 30 km out of the forest into land inhabited by humans. She became tame and was coaxed to walk further, to a site with road access, from where she was then translocated to the Sumatran Rhino Sanctuary (see below). Similarly, a young female Sumatran Rhino was captured on the eastern edge of the main Lahad Datu–Sandakan road in Sabah, some 12 km north-west out of Lahad Datu town in April 1989. She was named Lun Parai and was taken to be part of the captive propagation programme in Sepilok at that time. The nearest candidate for her mother would have lived about 40 km away in the south-western part of Tabin Wildlife Reserve. The only other possible but less likely origin of Lun Parai would be the Kretam area, some 45 km to the north.

Scan for video of the last Sumatran Rhinoceros in Borneo captured on camera trap in Danum Valley, 2007
© WWF-Malaysia

There are only two clues available now as to the likely normal population density of Sumatran Rhinos in equatorial rainforest. The Sungai Dusun Wildlife Reserve (4,330 ha), Selangor, contained about five wild Sumatran Rhinos during the 1970s to early 80s, suggesting a population density of one rhino per 850 ha. Van Strien's 1985 study suggested a population density of one rhino per 700 ha. He thought that hunting had little impact on this particular study area. This suggests a rough order of 14 or 15 rhinos per 100 sq km. However, all observant authors of wild Sumatran Rhino habits from Hubback (1939) onwards agree that natural, concentrated mineral sources (often known as 'salt licks', and in Sabah including 'mud volcanoes' of smectite and illite-rich clays; Davies & Payne, 1982) are an essential resource in Sumatran Rhino home ranges where breeding occurred, implying that regions with no such sources may have been unable to support Sumatran Rhino populations.

Distribution in Sabah

The 1982 estimate of 15–30 rhinos in Sabah (Davies & Payne, 1982) at that time is a reflection of the very end of a long period of loss of the species, with a few scattered individuals presaging subsequent extinction in 2019 (Figure 2).

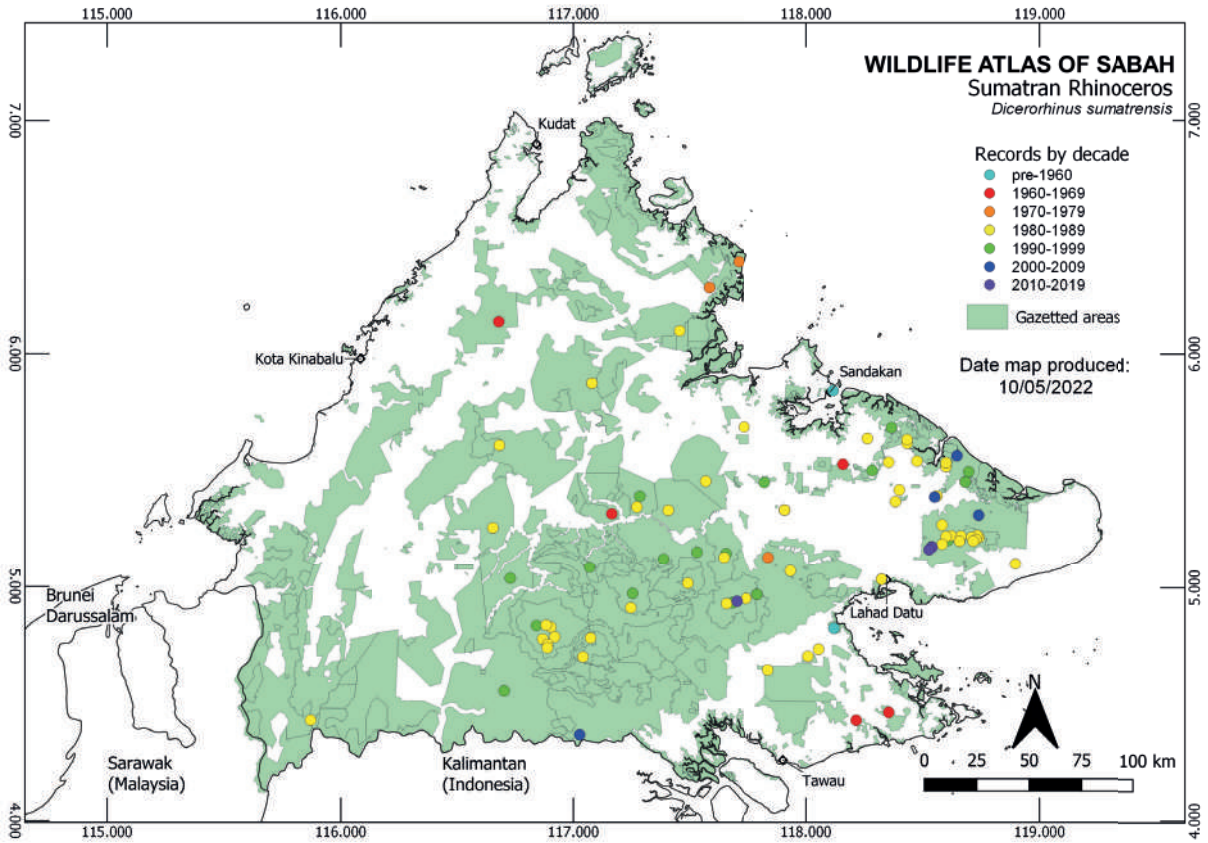


Figure 2. Former distribution of Sumatran Rhinoceros. Last wild record of the species was from Danum Valley in 2014.

Cultural Significance

Rhino nails and horn parts were formerly used for decorative purposes by some interior Borneo people, but no such observation has been made in the case of Orang Asli in Peninsular Malaysia, and in two pages of text on rhinoceros, Burkill (1966) records nothing on cultural significance for the Malay Peninsula. Long-time student of rhinoceroses, host of the Rhino Resource Center and author of *Rhinoceros and Man in Borneo*, Kees Rookmaaker (1976) states "The rhinoceros is curiously absent from Bornean folklore". The first known trade of rhino horn from what is now Malaysia (Peninsular and Borneo) to China came in the Ming period, after 1368 AD.

Conservation

By the 1920s, all literature on the Sumatran Rhino pointed to the existence of many small, isolated clusters in Sumatra, Borneo and mainland Southeast Asia, with no clear evidence of a large breeding population anywhere. Many centuries of hunting to supply the traditional Chinese medicine market was probably the main factor that had led to this situation.

The Sandakan area of eastern Sabah seems to have been excellent Hairy Rhino habitat up to the early years of the twentieth century. Writing in 1881, William Pryer, the British Resident of Sandakan, stated that "Ibrahim, the principal man (of Segaliud village) shot an elephant and a rhinoceros in his little patch of paddy within the course of a fortnight, some short time ago, and since then two more rhinos close to the same patch; and in fact the Segaliud people are continually sending down (to Sandakan) their horns (for sale)". The Handbook of British North Borneo, published as a contribution to the Colonial and Indian Exhibition, 1886, has the following text : "The rhinoceros (Rhinoceros Sumatrensis) is to be found over much the same ground as the elephant, and is rather more often seen than it ... ". The botanist Henry Ridley claimed to have passed four rhinos during a collecting trip near Sandakan in December 1897. A local newspaper in England, Rugby Advertiser, contained a short article on 21 April 1903, stating that "The wife of the Governor of North Borneo has a pet ... The Governor's house is near a jungle and out of this there strayed one morning a baby rhinoceros ... ". The specimen of Bornean Rhino used by Colin Groves as the 'type' when he described Bornean Rhinos as a separate subspecies was acquired by the Natural History Museum, London, in 1901 from Henry Rowe, a manager of the Straits Trading Company who resided in Sandakan at the end of the nineteenth century. The rhino was killed at Suan Lamba, on the south side of Sandakan Bay.

It is hard to escape the conclusion that hunting/trapping was a main driver of the species loss up to the 1960s, since females with young were still being recorded in this period. Then reproductive limitations finished the job once population densities were low.

By 1982, 'poaching' ('hunting' until the introduction of twentieth century wildlife laws) was no longer the only or even main driver towards extinction. Instead, the non-existence of any large populations, wide scatter of the survivors and insufficient reproduction would have been the issues to address. With the exception of Malaysia during the past decade, all institutions involved with the species have spuriously continued to blame poaching and habitat loss, thereby ensuring the extinction of the genus because wrong prescriptions have been made and inappropriate actions taken repeatedly.

Van Strien's 1985 study in Leuser had shown that there were at least several tens of rhinos in his study area, with a good breeding rate. Unfortunately, this finding tended to provide false hope to Hairy Rhino aficionados — then and even now — that there might be similar sites elsewhere and that, even in sites with fewer rhinos, protection from poaching might allow a recovery in numbers at those other sites. In fact, it is now evident that van Strien's study area contained the only remaining cluster of Hairy Rhinos that was potentially viable at that time.

Captive Breeding in Malaysia

The Sumatran Rhino represents a case of the baneful influence of two human traits that threaten critically endangered species (Payne, 2022). Firstly, shifting baseline syndrome is perhaps the

greatest human bias affecting wildlife conservation. In the absence of past information or personal experience of historical conditions, people of each new generation accept the situation in which they were raised as being normal. At a special IUCN-convened meeting in 1984, to discuss and resolve a proposal from the American Association of Zoo Parks and Aquariums to form a globally managed captive meta-population of the Sumatran Rhino, many present were aware that there were only few, scattered rhinos left, but had lulled themselves into thinking that this was normal, and some even insisted that all Sumatran Rhinos must remain in their natural habitat. The meeting turned out to be fatal because it was decided that rhinos known to be breeding would remain in the forest, and the only individuals to be captured were those that were 'doomed' — mainly solitary, infertile, old or sub-fertile. Of the forty Sumatran Rhinos captured between 1984 and 1994, in Sumatra, Peninsular Malaysia and Sabah under the IUCN-endorsed programme, only one pair produced offspring. As it turned out, all the promising breeding animals left in the wild and their offspring are now dead except for a very few in Aceh.

Secondly, up to around 1970 captive breeding was considered by wildlife biologists to be the most urgent intervention when a species reaches very low numbers, and this view was supported by proven success in preventing the extinction of European bison, Arabian oryx and other species. After the 1970s, fashion turned against captive breeding. Common arguments against a managed meta-population approach are that there will not be enough habitat to support released captive-bred animals in the future, and that captive-bred animals cannot adjust to life in the wild. This



Figure 3. Tam, the Sumatran Rhino named after Kretam Plantation where it was found in eastern Sabah, 2008
© Albert Sitawin/WWF-Malaysia

ignores the cases of European bison and Arabian oryx, in which zoo-born calves were released into the wild and populations increased thereafter.

The lack of success in captive breeding of Sumatran Rhinos following the 1984 IUCN-endorsed decision, coupled with a constant strong body of opinion that favoured leaving rhinos 'in the wild' meant that by year 2000 captive breeding was close to being abandoned. However, the first captive births then occurred in Cincinnati Zoo, in 2001 and 2004, while in 2005, two young female Sumatran Rhinos which had walked out of two separate protected areas into village gardens in southern Sumatra were captured and brought to the 'Sumatran Rhino Sanctuary' in Way Kambas National Park, Lampung province. The Sanctuary consists of a circular arrangement of adjacent fenced paddocks under natural forest cover, with individual night stalls that allow for regular close contact with the rhinos for feeding, examination, blood sampling and application of medication and hormones if needed.

The rhinos are cared for by a full-time veterinarian and at least two keepers per rhino. The births and captures of 2001 to 2005 revived some interest in the need for a captive meta-population recovery programme. In 2009, and following the capture of a male Sumatran Rhino, named Tam, in an oil palm plantation in eastern Sabah in 2008 (Figure 4), a similar sanctuary was initiated in Tabin Wildlife Reserve, Sabah. However, it turned out that, after 2009 only two additional rhinos were located in the wild in Sabah, both females. Puntung, the last wild rhino in Tabin Wildlife Reserve was captured in 2011 (Figure 5), and Iman, the last in Danum Valley, in 2014.



Figure 4. Puntung, two days after her capture, missing front left foot © Azrie Alliamat/Institute for Tropical Biology and Conservation, UMS

The fact that female Sumatran Rhinos are susceptible to reproductive pathology was raised in the 1990s. The first sign of the problem in this species had emerged in 1986, when the second female captured in Sumatra under the IUCN-endorsed programme died four months later and was found to have uterine tumours, a pathology that could not possibly have developed in captivity over such a short time. It is now known that, over the past four decades, at least 70% of all females of the species have pathology so severe that they are unable to bear a pregnancy. The pathology is linked to high levels of oestrogens and insufficient levels of the progesterone-like hormones, which occurs in tandem with periods of no breeding. Some Sumatran Rhino advisers still seem reluctant to believe that since the 1980s, well over half of all remaining wild females are probably not breeding as a result of fertility problems.

Application of assisted reproductive technology was initiated in 2005 with semen collection from a male rhino held at Sepilok, under the Leibniz Institute for Zoo and Wildlife Research (Leibniz-IZW Berlin). The underlying idea was that the genomes of all remaining Sumatran Rhinos in captivity could be used to create embryos, both through in vitro fertilization and cell culture. The work was intensified from 2011 onwards both in Sabah and in Indonesia (the last captive Sumatran Rhinos in Peninsular Malaysia had died in 2003), although collaboration between the two was essentially disallowed by the Indonesian authorities. The assisted reproductive technology work in Sabah was pioneered by the IZW team and Professor Cesare Galli, who in December 2020 successfully created two northern white rhino embryos using oocytes harvested from the last living fertile female in Kenya and thawed sperm taken from the last male before his death. In 2022, induced pluripotent



Figure 5. Collecting semen from Tam, the last male Sumatran Rhinoceros in Malaysia, by an all-Malaysian veterinary team, 24 August 2015 © John Payne/Borneo Rhino Alliance

stem cells were created from skin tissue taken from Tam before his death, allowing the possibility to create spermatozoa (Zywitza et al., 2022).

In 2015, the National Biodiversity Council of Malaysia endorsed a proposal by Sabah Wildlife Department that advanced reproductive technology will be used to prevent the extinction of the Sumatran Rhino and that Malaysia will invite Indonesia to collaborate. The first in vitro fertilization attempt in Malaysia was performed by Professor Arief Boediono of Institut Pertanian Bogor (IPB) University, at the Agro-biotechnology Institute (ABI) Malaysia near Kuala Lumpur, using three oocytes and sperm from the captive rhinos held in the Borneo Rhino Sanctuary in Tabin Wildlife Reserve, Sabah. In early 2016, the Malaysian government launched an application of advanced reproductive technology programme for rhino and other endangered species through establishment of a dedicated laboratory in the Faculty of Sustainable Agriculture in the Sandakan campus of Universiti Malaysia Sabah. Despite repeated attempts to engage with Indonesia from Malaysia, at national and state level, governmental and NGO, there was no interest from Indonesia to share information, expertise or rhino gametes, up to and after the deaths of Tam and Iman in 2019.

Acknowledgements

Very many people and institutions have contributed to knowledge of what needs to be done to prevent the extinction of the genus *Dicerorhinus* over the past four decades. Special mention goes to the chairman (Prof Dr Abdul Hamid Ahmad) and veterinarian (Dr Zainal Zahari Zainuddin), along with the staff of Borneo Rhino Alliance; Sime Darby Foundation for generous sponsorship between 2009–2016; Government of Malaysia and Government of Sabah; the persons mentioned in the text above who saw the opportunities presented by application of assisted reproductive technology; Dr Nan Schaffer and Karen Dixon for their valiant attempts to get sensible decisions made in Indonesia and globally.

Data Sources

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Bearded Pig © WWF-Malaysia

12

Bearded Pig (*Sus barbatus*)

David J. Kurz, Peter Malim and Benoit Goossens

Introduction

The Bearded Pig, *Sus barbatus*, is a large, nomadic species of wild pig found in Borneo, Peninsular Malaysia, and Sumatra. In English, the species is commonly known as the "Bearded Pig" or, sometimes, as "wild boar" ("wild boar" can also refer to the Eurasian Wild Boar, *Sus scrofa*). In Malay, the species is referred to as *babi hutan* (literal translation: "forest pig"), or sometimes *babi*

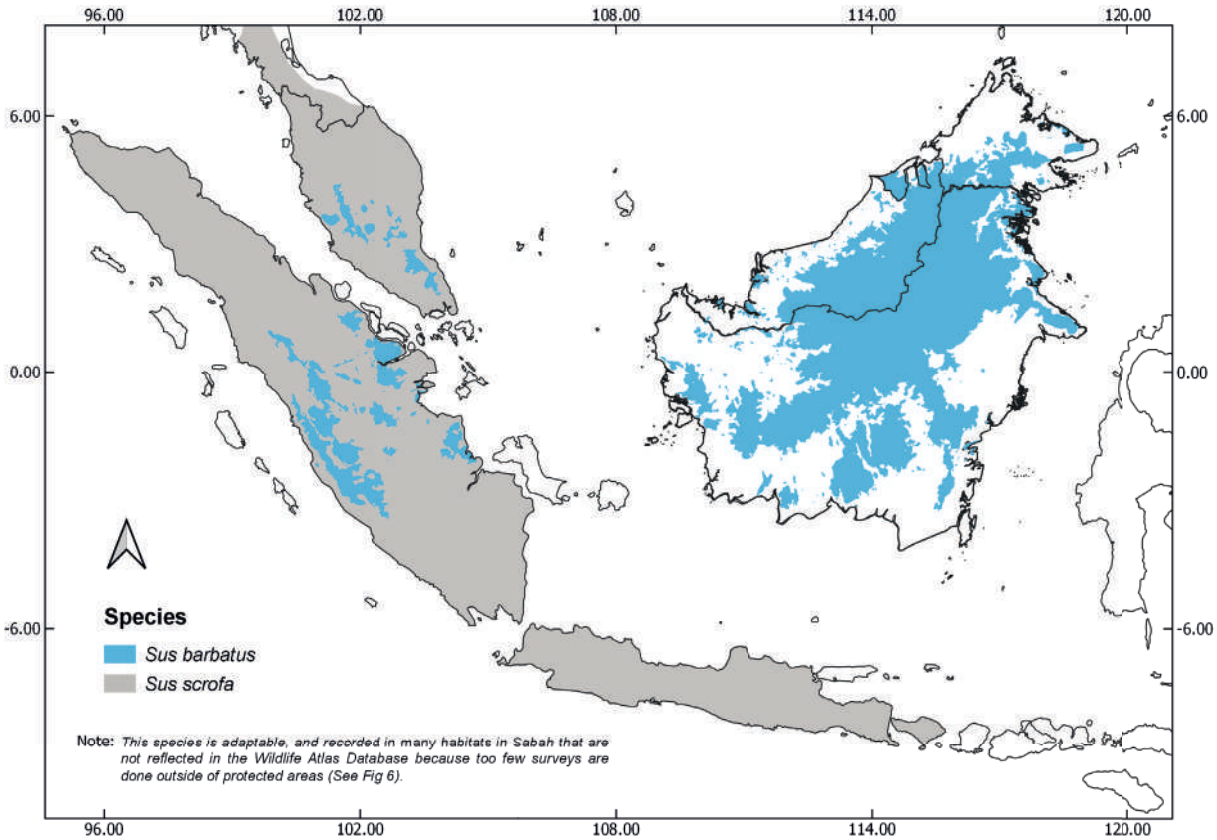


Figure 1. Bearded Pig distribution across its range (IUCN, 2017) prior to mass die-offs due to African Swine Fever in 2020 and 2021 (see Figure 6 for more accurate pre-ASF Sabah distribution)

for short (which can also be used for domestic pigs). Both wild Bearded Pigs and domesticated pigs have suffered dramatic declines as a result of the recent African Swine Fever (ASF) epidemic, which swept through Sabah in 2020 and 2021 (see Box 1).

Taxonomy

The species consists of two subspecies, *Sus barbatus barbatus* and *S. b. oi*; the former inhabits Borneo and Peninsular Malaysia, and the latter Sumatra (Lucchini et al., 2005). Bearded Pigs originated in island Southeast Asia (Larson et al., 2005), and their evolution has been shaped by changes in sea level that likely connected Borneo with Sumatra and Peninsular Malaysia as recently as 50,000–30,000 years ago (Crandall et al., 2012). Today, Bearded Pigs are the only established wild pig species throughout Borneo, but in Peninsular Malaysia and Sumatra, Bearded Pig ranges overlap in some areas with the Eurasian Wild Boar. In certain contexts, the two species are thought to both compete and to inter-breed, which raises conservation concerns for the 'Vulnerable' Bearded Pig (Luskin et al., 2017).

Natural History

Bearded Pigs are large-bodied, long-legged Suids with a distinctive shaggy "beard" (and sometimes a "moustache" as well). They have sparse hairs that range in colour from pale, whitish brown to deep brown (almost black). Limited hair helps them keep cool in a warm, humid rainforest environment, and they need to wallow frequently in small pools of water to avoid overheating. Average height at shoulder is 0.9 m and length from nose to anus is 1.2–1.5 m (Francis, 2008). Adult individuals typically reach 50–120 kg, with much heavier weights (>200 kg) possible in well-fed adult males with large fat reserves (Francis, 2008; Luskin & Ke, 2018). Both sexes store fat reserves when food



Figure 2. A large male Bearded Pig in the Lower Kinabatangan Wildlife Sanctuary in Sabah. Male Bearded Pigs can exceed 200 kg in size © Rudi Delvaux

is abundant, and an individual with significant fat stores is considered to be in "very good" condition (Wong et al., 2005). Like other pig species, Bearded Pigs have a highly attuned sense of smell, on which they rely heavily when foraging and avoiding predation. If they detect danger, they typically flee rapidly into cover or undergrowth.

In Sabah, the Bearded Pig is found in a variety of habitats, including lowland rainforest, hill and montane rainforest, mangroves, and forest-oil palm mixed landscapes; of these, lowland and hill rainforest account for the bulk of core Bearded Pig habitat. Bearded Pig populations are able to persist in logged forests (Granados et al., 2016; Ross et al., 2013), with estimated local abundance not significantly different between logged and primary forest (Brodie et al., 2015). From adjacent logged forest, Bearded Pigs often forage in industrial oil palm plantations (Davison et al., 2019; Love et al., 2018), as well as within oil palm smallholdings and village gardens (Kurz et al., 2021). Even within mixed forest-agriculture landscapes, however, pig nesting, wallowing and tree rubbing behaviors seem to happen almost exclusively within forest habitats (Love et al., 2018). Bearded Pig nests are large piles of freshly snapped saplings, roughly 2 m long and 2 m wide (Figure 4), and dried nests leave a print on the landscape for months after their creation (DJK, pers. obs.). Presumably Bearded Pig nests provide protection from predators and weather for the vulnerable mother and newborn piglets, but more research is needed on nesting behaviour and other aspects of Bearded Pig ecology.



Figure 3. Bearded Pigs are found in a variety of habitats, including a) lowland rainforest and b) mangrove environments © Jessica Suarez

Bearded Pigs are omnivores, consuming fruit, nuts, seeds, roots, small animals, and carrion, among other food sources (Luskin & Ke, 2018). In Sabah, Bearded Pig foraging differs considerably depending on the environment. In secondary forest-oil palm mixed landscapes (e.g. the Lower Kinabatangan), in which most dipterocarp trees have been logged and mast fruiting episodes are largely absent, Bearded Pigs feed heavily on year-round oil palm fruit from adjacent oil palm plantations (Love et al., 2018). However, in large, continuous protected areas of primary forest (e.g. Danum Valley), Bearded Pig diet is regulated by natural forest fruiting cycles (Granados et al., 2019; Wong et al., 2005), especially during mast fruiting when as many as one third of all tree species in a given area of rainforest produce flowers followed by fruits (Appanah, 1985).

During the dipterocarp mast fruiting events that occur in Borneo approximately every 3–8 years (Brearley et al., 2007), Bearded Pigs are known to form large herds that can travel long distances to

seek out the sudden bounty of food resources (Caldecott et al., 1993; Curran & Webb, 2000). Bearded Pigs also locally track fruit during masting events (Granados et al., 2019). Pulses of dipterocarp fruits allow Bearded Pigs to store fat and reproduce readily, leading to rapid population growth (Caldecott et al., 1993; Luskin & Ke, 2018). During these times of fruit abundance, females are able to give birth to 1–2 litters per year with up to 12 piglets in each litter. When food is scarce, however, reproduction is less frequent (Luskin & Ke, 2018), and Bearded Pigs can starve to death during the lean periods between mast fruiting events (Curran & Leighton, 2000; Wong et al., 2005).



Figure 4. a) Fresh Bearded Pig nest formed of snapped saplings © Glyn Davies/WWF-Malaysia; b) Old Bearded Pig nest consisting of dried saplings, with the circular entrance to the nest still visible © David Kurz/DGFC; c) Male Bearded Pig wallowing at night © David Kurz/DGFC; d) Active Bearded Pig wallow © Glyn Davies/WWF-Malaysia

Bearded Pigs are known to form huge herds of hundreds or even thousands of individuals roaming widely in search of large quantities of seeds from dipterocarps, as well as from oaks and chestnuts in montane areas (Caldecott & Caldecott, 1985; Pfeffer, 1959). In Sabah, large herds have been reported by older hunters: “There are so many pigs that all you can do is just stand and stare until they run away” (Kurz et al., 2021). Large Bearded Pig herds are only known to form in the context of nomadic movements (Caldecott et al., 1993; Curran & Leighton, 2000; Mohd-Azlan et al., 2016b). These mass movements are seemingly becoming rarer in Sabah, likely due to deforestation, habitat fragmentation, oil palm plantation expansion, logging for dipterocarps, and the recent ASF outbreak (Box 1). Indigenous Knowledge in Sabah supports this idea: in one study, older pig hunters

had observed large herds of Bearded Pigs in their lifetimes, whereas younger pig hunters typically had not observed this phenomenon (Kurz et al., 2021).

Cultural Significance

For millennia, Bearded Pigs and human communities in Borneo have shared a close relationship. Humans have hunted Bearded Pigs in Borneo for at least 35,000 years (Medway, 1958), and continue to do so in Sabah and throughout Borneo today (Meijaard, 2015). Meat provision is the primary reason for hunting Bearded Pigs (Bennett et al., 2000; Kurz et al., 2021), with Bearded Pigs accounting for 54–97% of wild meat consumed by some communities in Borneo (Bennett et al., 2000; Chin, 2001; Puri, 2005). Additionally, gift giving, cultural celebrations, pest control, sport, and sale are also motivations for hunting Bearded Pigs (Kurz et al., 2021). Bennett et al. (2000) reported that hunting in villages across Sabah and Sarawak occurred regardless of alternative livelihood sources, pointing to a rich cultural connection to Bearded Pig hunting and consumption that continues in modern-day Sabah.

Religion is a major force shaping patterns of Bearded Pig hunting and consumption in Sabah. Sabah is roughly 2/3 Muslim, and roughly 1/3 Christian (Malaysia Dept. of Statistics, 2011). Within Muslim communities, Bearded Pigs are avoided for religious reasons but other wildlife species are sometimes consumed, as has been reported in Sumatra (Luskin et al., 2014). However, within predominantly Christian communities such as the Indigenous Kadazandusun-Murut (KDM) group, Bearded Pig is frequently consumed and often regarded as the strongly preferred type of meat (Bennett et al., 2000). As one KDM Bearded Pig hunter said, “We cannot stop eating the [bearded] pig” (Kurz et al., 2021). Among Malaysian Chinese communities, pork is also regularly consumed (Neo, 2011), including Bearded Pigs in Sabah. Ethnic and religious inclinations to the Bearded



Figure 5. A Bearded Pig mother with two piglets. When food is abundant, it is common to see female Bearded Pigs followed by one or more piglets or sub-adults © Jessica Suarez

Pig are so strong that a "pig line" has been recorded between coastal Muslim fishing communities and interior Christian pig-hunting communities (Bolton et al., 1972). Bearded Pigs in Sabah, therefore, continue to walk a line as both a major cultural touchpoint for some communities and an objectionable species to others (Yusof, 2012).

While Bearded Pig hunting traditions endure in Sabah, some hunting methods and techniques have changed. Pig hunting with guns (on foot or in a car) is popular in modern Sabah, and a number of Bearded Pig hunters reported that hunting in oil palm plantations is easier and more predictable than hunting in forests (Kurz et al., 2021). Another factor changing pig hunting practices is urbanization. Some pig hunters in urban areas hunt and consume Bearded Pig meat less frequently than in rural areas (Kurz et al., 2021). However, barbequed Bearded Pig meat (*sinalau bakas*) remains popular in urban areas. More research is needed on the effects of commercial markets and urbanization on social-ecological links in Sabah.

Distribution in Sabah

Bearded Pigs are distributed throughout many primary and logged forests and forest-agriculture matrices in Sabah. Factors including elevation, protected area status, slope, proportion of Indigenous pig-hunting population, and hunting accessibility have all been associated with estimated Bearded Pig presence across sites (Kurz, 2021). In Sabah, prior to the ASF outbreak, Bearded Pigs were widespread and distributed throughout most forests across the state (Figure 6). However, during 2020 and 2021, the ASF outbreak caused the collapse of numerous local Bearded Pig populations throughout Sabah (Box 1).

Based on ecological and social parameters, estimated Bearded Pig presence (occupancy) is predicted to be highest in the central, eastern, and far western parts of Sabah, and lowest across parts of western and northern Sabah (Kurz, 2021). Areas of high Bearded Pig predicted occupancies are generally characterized by lowland or hill forests and forest-agriculture mosaics, and areas of lower predicted occupancies are sometimes characterized by montane forests or urbanizing areas. However, it is important to note the limitations of occupancy modeling for a nomadic, group-associated species such as the Bearded Pig. Because occupancy model assumptions include static occupancy and independent detections (MacKenzie et al., 2002), occupancy estimates for Bearded Pigs must be considered alongside these important caveats. Given the devastating impact of the ASF outbreak in Sabah, new assessments and ongoing monitoring programs of Bearded Pig population recovery are needed.

Conservation

Bearded Pigs are classified as 'Vulnerable' under the IUCN Red List (Luskin et al., 2017), despite their wide distribution (pre-ASF) across much of Sabah. A major threat to Bearded Pig populations is habitat loss, including habitat destruction, habitat fragmentation, and loss of ecological connectivity. Bearded Pigs have experienced widespread habitat reductions throughout their range, with Sabah estimated to have had a massive loss of 39.5% of forest area between 1973 and 2010 (Gaveau et al., 2014). In addition to habitat loss, habitat fragmentation has led to relative isolation of protected areas within Sabah, particularly in lowland parts of the State (Ocampo-Peñuela et al., 2020; Proctor et al., 2011).

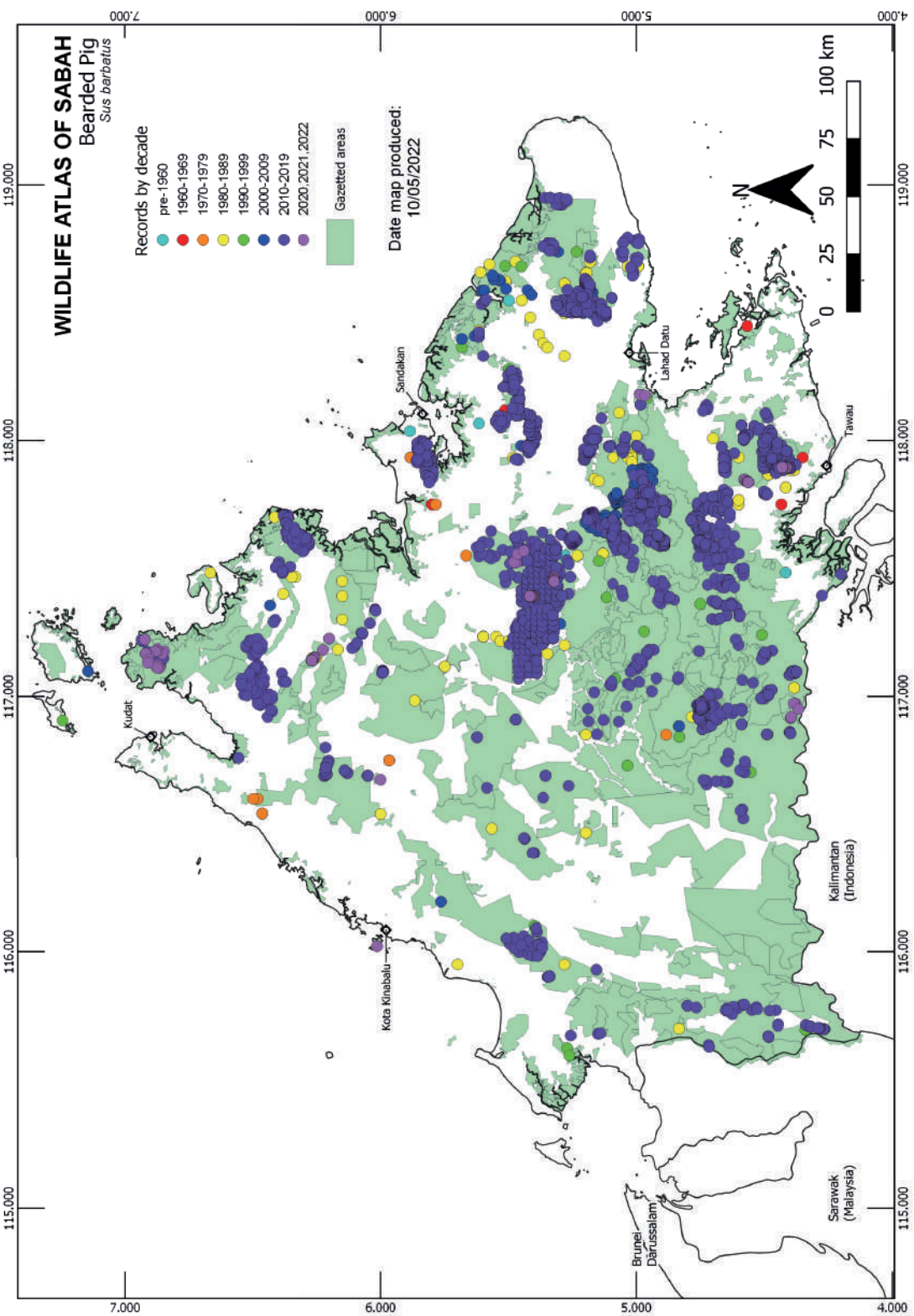


Figure 6. Records of Bearded Pig, which can adapt to agricultural habitats that are under-surveyed for the Wildlife Atlas database.

African Swine Fever (ASF) outbreak

ASF is a virus that can cause 47.7% to 100% case fatalities in domestic and wild pigs (Liu et al., 2020; FAO, 2021a). Widespread deaths of Bearded Pigs were first reported in the Kinabatangan in December 2020 (DGFC, pers. comm.). By October 2021, ASF had been detected in a total of 20 districts within Sabah (Miwil, 2021) and was accompanied by widespread Bearded Pig deaths in most of these areas (The Borneo Post, 2021). In many forests, ASF reduced Bearded Pig populations to few or no individuals remaining (SE Asian Wildlife Research Group, pers. comm.). However, by October 2021, seven districts in Sabah had been downgraded from red to yellow status as a result of no new ASF detections over 60 days (Miwil, 2021).

ASF presents a critical threat to Bearded Pig populations (Luskin et al., 2020), as well as to human communities who rely on them for dietary provision and cultural traditions (Ewers et al., 2021; Kurz et al., 2021). However, humans cannot contract ASF (FAO, 2021a). In response to the ASF outbreak in Sabah, and in connection with movement control orders already in place due to the COVID-19 pandemic, the government of Sabah froze hunting licences in Sabah in early 2021 (Berau Post, 2021; Chan, 2021; The Borneo Post, 2021; The Star, 2021). Additionally, the Department of Veterinary Services continues to actively monitor and test for ASF in Sabah, and to limit the spread of pork products between districts. ASF has also been confirmed in other areas across the Bearded Pig range, including Sarawak (Edward, 2022), Kalimantan (Berau Post, 2021), West Malaysia (Malay Mail, 2022), and Sumatra (Dharmayanti et al., 2021). Continued, diligent practice of ASF protocols, as well as close monitoring of Bearded Pig recoveries, will be critical to restoring Bearded Pig populations in Sabah.



Figure 7. Stagnant pig wallow located in Tabin Wildlife Reserve. The leaves indicate that the wallow had not been used recently © Glyn Davies/WWF-Malaysia

Another emerging threat is climate change, through potentially altered links between climatic cues and fruiting cycles (Ascoli et al., 2021; Numata et al., 2021), but the precise impacts are difficult to predict for this adaptable and migratory species.

Over-hunting is another major threat to Bearded Pigs in parts of its range. As with many mammal species in Sabah, high levels of hunting have threatened Bearded Pigs for decades, due to human population growth and increased use of shotguns (Bennett et al., 2000; Harrisson, 1965; Luskin & Ke, 2018). Additionally, greater access to forests (e.g. using logging roads and outboard motors) has increased hunting accessibility in some areas, and is compounded by Bearded Pig meat sales in some markets (Bennett et al., 2000; Kurz et al., 2021).

There are legal provisions in Sabah to hunt the species and sell the meat with licences from the Sabah Wildlife Department (Wildlife Conservation Enactment, 1997). Moreover, given the prominence of pig hunting for Indigenous KDM communities in Sabah, fair and sustainable access to Bearded Pig hunting is an important equity issue (Kurz et al., 2021). Promising conservation measures that provide for people and for Bearded Pigs could include local decision-making empowerment, location-specific management, harvest quotas, take and no-take zones, reduced hunting in protected areas, elimination of commercial sale of wild meat, and alternative income sources for rural communities (Bennett et al., 2000; Kurz et al., 2021; Luskin & Ke, 2018).

Finally, the recent threat of ASF dramatically alters the outlook for Bearded Pig conservation. Numerous Bearded Pig population collapses were reported across much of Sabah in 2021, with seemingly very high fatality rates. In the short term, continued management to prevent the spread of ASF is of the utmost importance, supported by testing of wild and domestic pig populations, proper carcass disposal, swine movement restrictions, and short-term hunting licence suspensions (FAO, 2021b; Miwil, 2021). Over the medium-term, close monitoring of Bearded Pig populations is needed to evaluate population recovery and assess whether translocations or other management efforts are needed. In the long-term, after population rebound, Bearded Pigs in large, primary forest areas, e.g. Danum Valley and Maliau Basin, may have different management needs than pigs in fragmented forests near oil palm, although more research in this area is needed. Inclusion of local leaders and location-specific management strategies will be key components of successful long-term management of Bearded Pig populations, for the health of Sabah's forests and human communities.

Acknowledgements

This book chapter is dedicated to two extraordinary people. The first is Darrell C. Kilburn, the grandfather of DJK and a steadfast man who served in World War II, earned a Purple Heart for his wounds, built a home, raised 10 kids, marked 70 years of marriage to his wife, hunted game for survival, and loved wildlife. He lived a full life and passed away while DJK was working on this chapter. DJK and BG also dedicate this chapter to Mr. Peter Malim, who worked for many years on behalf of Sabah's wildlife and people through his public service at the Sabah Wildlife Department. Mr. Malim was integral to important research on Bearded Pigs in Sabah, and this chapter represents the fruit of his labors.

We would also like to thank Dr. Glyn Davies, Mr. Adi Shabrani, Ms. Angela Lim, Ms. Jane Wong, and Ms. Suzika Juiling for their vision for this atlas, and for their diligent efforts to bring this chapter and the exciting larger book to completion. Thank you to Prof. Jedediah Brodie for helpful peer-review comments that improved the manuscript. We thank the Sabah Biodiversity

Centre for permissions over the years to conduct research on Bearded Pigs in Sabah (including Access Licence Ref. No. JKM/MBS.1000-2/2 JLD.7 (157)). Many funders have contributed to our work on Bearded Pigs; we would like to thank the Ocean Park Conservation Foundation Hong Kong, the Houston Zoo, Yayasan Sime Darby, the National Science Foundation, the Mustard Seed Foundation, the National Geographic Society, the Waitt Foundation, the Fulbright U.S. Student Program, the American Philosophical Society, the Columbus Zoo and Aquarium, the UC Berkeley College of Natural Resources, the Institute of East Asian Studies, the SJ Hall Fellowship, the Oliver Lyman Fund, the Hannah M. and Frank Schwabacher Memorial Scholarship Fund, the Howard William Siggins Fellowship, the Philomathia Graduate Student Fellowship in the Environmental Sciences, and the Thomas McKenna Meredith ’48 Postdoctoral Fellowship in Environmental Science at Trinity College.

Data sources

Individuals / organizations (Number of records): Amanda Wilson & Elsiey Ercy Jomes (2); Brodie, Jedediah (2117); Gardner, Penny (522); Guharajan, Roshan (2304); Haysom, Jessica (12933); Hearn, Andrew (7617); Lim Wing Shen (4); Forest Solution Malaysia (188); Sabah Forestry Department (26); Sabah Museum (6); WWF-Malaysia (5166). *Open source database (Number of records):* eMammal, 2021 (993). *Publications (Number of records):* Abdullah et al., 1995 (13); Bernard et al., 1997 (1); Bernard et al., 2013 (11); Bernard et al., 2014 (4); Bernard et al., 2019 (1); Bernard & Fjeldsa, 2003 (1); Bili, 2014 (25); Boonratana, 1997 (13); Boonratana & Sharma, 1993 (2); Bornion Timber, 2021 (6); Bunya et al., 2010 (1); Chung et al., 2019 (11); Davies & Payne, 1982 (1); Davies & Tan, 2019 (5); Davis, 1962 (6); Davison et al., 2019 (427); Dawson, 1992 (7); Deere et al., 2017 (68); Harrison, 1998 (1); Hawkins et al., 2019 (1); Heydon, 1994 (1); Ishige et al., 2017 (4); Kee et al., 2018 (1); Kehoe, 2011 (1); Ketol et al., 2009 (1); KOPEL, 2016 (4); KOPEL, 2019 (1); Lim, 1996 (2); Lim, 1993 (3); Mahyudin et al., 2010 (1); Matsuda et al., 2014 (1); Mingueza, 2018 (2); Murphy, 2007 (1); Nakabayashi et al., 2014 (2); Onoguchi & Matsubayashi, 2008 (2); Payne et al., 1989 (2); Prudente et al., 2009 (1); Rahman & Abdullah, 2002 (1); Rajaratnam, 1995 (1); Regip, 2003 (2); Ross et al., 2013 (6); Samejima & Ong, 2012 (30); Samejima et al., 2012 (1); SFD, 2016 (17); SFD, 2017 (22); SFD, 2018 (5); SFD, 2019 (2); Sheldon & Francis, 1985 (1); Shukor, 1996 (1); Shukor et al., 1989 (1); Shukor et al., 2011 (2); Tuen et al., 2002 (1); Twining et al., 2015 (1); Webb, 2016 (2); Wilting & Mohamed, 2010 (3); Wong, 2011 (6); Wong et al., 2005 (1); Wong et al., 2012 (1); WWF-Malaysia, 1985 (5); York et al., 2013 (1); Zakaria & Rajpar, 2015 (1).

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Bornean Banteng *(Bos javanicus lowi)*

Penny C. Gardner, Hong Ye Lim, Soffian Bin Abu Bakar and Benoit Goossens



Figure 1. A pair of male and female bantengs in Deramakot FR © WWF-Malaysia

Introduction

In an early review of the ecology and distribution of the wild cattle species in Asia, Wharton (1968) showed that they did not prefer 'closed canopy' habitats, but preferred open forest glades with good pastures and some shade. This is found along riverbanks and stream valleys, as well as tree fall gaps, and areas where forest has been cleared through shifting cultivation. He noted also that human hunting pressure further influenced their distribution, in some cases 'forcing' animals to live in the refuge of closed canopy forests areas. In present day Sabah, the Bornean Banteng conforms to this ecological model of travelling between, and living in open areas in forested regions, and seeking refuge in forests to avoid hunters. They are locally known as *tembadau*, and are very rare.

Natural History

The Bornean Banteng (*Bos javanicus lowi;* Lydekker, 1912) is a large-bodied bovid that ranges in weight between 400–900 kg (Phillipps & Phillipps, 2016); however, relative to the other two subspecies of bantengs (Burmese and Javan), it has the smallest body size (Hoogerwerf, 1970). The Bornean Banteng is sexually-dimorphic in both pelage and body shape and size; mature bulls are black with white-buttocks, white stockings and a white muzzle, and are the larger sex with heavier-set forequarters, a dewlap and crescent shaped horns (Gardner et al., 2014). The cows are slighter, with a pelage that ranges in colour from light tan to dark brown, a dark brown-black ventral area, a dark brown-black spine, white buttocks, white stockings, a white muzzle, and sometimes develop a paler forehead (Gardner et al., 2014). Their horns are smaller in diameter and length and with a noticeable crescent shape (Gardner et al., 2014). Banteng calves are born pale brown and develop rapidly, with horn buds visible in the first and second months, and pelage darking with maturity over the course of 3–4 years. Banteng frequently suffer injury from thorny vegetation, from physical contact with each other, and from hunting activity such as snares (Gardner et al., 2021), and they manifest as permanent scars which can be used for individual recognition and to help estimate population density.

Bornean Bantengs are highly social animals and commonly form bachelor herds and mixed-sex herds (Journeaux et al., 2018). Individuals often separate from the herd and are solitary for a temporary period, regrouping at a later time and often in a favoured grazing or foraging location. The most common encounters with bantengs in Tabin Wildlife Reserve, Sipitang Forest Reserve and Sapulut Forest Reserve were solitary bulls, followed by mixed-sex herds in Malua and Kuamut Forest Reserves, and a combination of mixed-sex herds and solitary bulls in Maliau Basin Conservation Area Buffer Zones (Journeaux et al., 2018). In recent years, herds containing up to 23 individuals have been observed in Sabah, however these are temporary congregations and always occur within forest with an open canopy and an abundance of suitable forage.

Preliminary investigations of breeding in Bornean Bantengs suggest they do not appear to be constrained by (wet/dry) seasonality, with the frequency of births highest during the months of March and September (Journeaux et al., 2018). This may imply that environmental conditions do not constrain this energy-demanding biological process, although animals in poor body condition have been noted throughout the year at Tabin (J. Payne, pers. comm.), which is likely to inhibit reproduction. Visible signs of pregnancy are difficult to observe in banteng cows, as they have minimal show, unlike in domestic cattle. During the labour, preliminary observations indicate they give birth alone, presumably because the cow either seeks solitude away from the herd or they are unable to keep up. Within a few hours of birth, mother and calf are capable of travelling long distances to regroup with the herd (P. Gardner, pers. obs.).

Bantengs preferentially select and spend long periods of time foraging in open degraded areas in secondary forest in Sabah that have lower plant species richness (Gardner et al., 2019a), but less is known about their foraging behaviours within primary forest; as most of Sabah's forest have been logged previously. Logged forest is therefore very important for conservation of banteng (Prosser et al., 2016). Prosser et al. (2016) found bantengs had higher body conditions in forests that have been logged recently using Reduced Impact Logging techniques, and this may be due to the short-term benefits of increased understorey growth of pioneer plant species which are suitable forage for banteng.

Bantengs are a mixed feeder, grazing and browsing on a range of plant species, but this is thought to be site-specific; Olsen (2002) noted distinctions in vegetation composition at two bantengs foraging sites in Maliau and Tabin, with one dominated by a grass (*Paspalum conjugatum*) and herb (*Chromolaena odorata*, synonym *Eupatorium odoratum)*, while the other contain a great abundance of fern *(Diplazium esculentum)*. In a more recent survey (2011–2016*)* by Danau Girang Field Centre, bantengs were also found to regularly visit areas containing an abundance of the same fern species in West Tabin, and bite marks were commonly observed (P. Gardner, pers. obs.). Other plant species that are consumed by banteng in Sabah include (Asteraceae) *Mikania cordata* and *Chromolaena odorata*, (Cyperaceae) *Cyperus difformis*, *Fimbristylis littoralis* and *Scleria* sp., (Leguminaseae) *Desmodium triflorum*, (Poaceae) *Eleusine indica* and (Selaginellaceae) *Selaginella* sp. (Gardner et al., 2019a), wild fruit (Gardner et al., 2014), young (Poaceae) bamboo shoots as well as stripping bark from a tree (species unknown) in dense forest in Tabin Wildlife Reserve (P. Gardner, pers. obs.).

An important dietary component is sodium which has limited availability in tropical forests; bantengs may well be deficient in sodium (Journeaux et al., 2018) and they may actively seek a source of sodium or increase visits to mineral sources (Phillips, n.d.). They are common users for natural mineral licks in Deramakot Forest Reserve (Matsubayashi et al., 2007a) and other reserves across Sabah. Bantengs are also drawn to artificial mineral blocks and loose salt deployed by Sabah Forestry Department officers in Malua Forest Reserve. This was further corroborated by a study by Phillips (n.d.) in 2015–2016 which documented geophagy at loose salt deposits and mineral blocks deployed in four forests across Sabah; Segaliud-Lokan, Deramakot, Paitan and Sugut Forest Reserves.

Ranging Behaviour

The cryptic nature of bantengs in the tropical rainforest means it is difficult to study their ranging behaviour, so there are no accurate estimates of their daily travel distances and home range size (Gardner et al., 2014). Based on camera-trap surveys, recaptures of recognisable individuals revealed that bantengs travelled at least 10 km and 23 km in Malua Forest Reserve and Tabin Wildlife Reserve, respectively, over a one-year period (Gardner et al., 2014). It is highly probably that bantengs can and do travel more than 1.5 km on daily basis in seasonal freshwater swamp and lowland dipterocarp forest (Gardner, 2015). Large contiguous forest with little obstruction is important for banteng movement and formation of larger herds; banteng herds have been observed travelling between Malua Forest Reserve and Kuamut Forest Reserve (Journeaux et al., 2018). Seasonal changes may also influence banteng movement. Bantengs were recorded as less active during wet season, particularly following flooding of seasonal swamp and lowland riparian forests, and as a result of fluctuations in food supply, leading to migration to higher grounds, especially in Tabin Wildlife Reserve (Gardner et al., 2018).

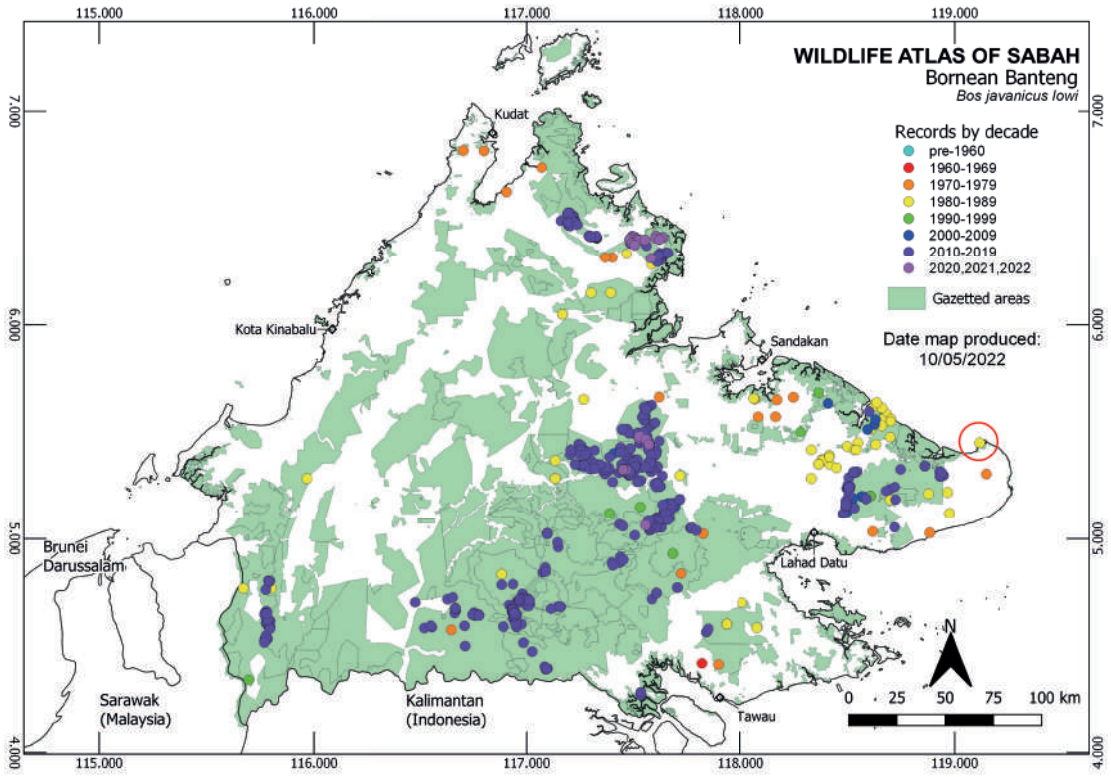


Figure 2. Records of Bornean Banteng dating from pre-1960 to 2022

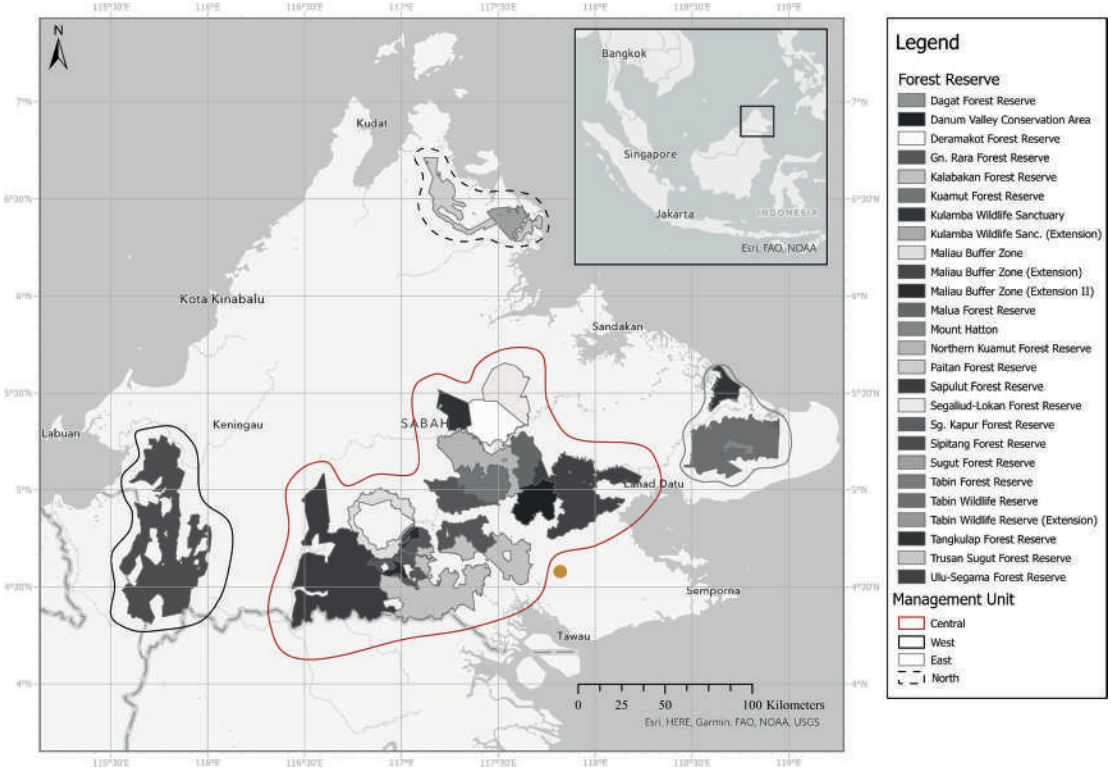


Figure 3. Shows four management units of bantengs: a) Sipitang, b) Paitan-Sugut; c) Tabin-Kulamba; d) Central Forest, with potentially a fifth management unit in the Tawau Hills forests (brown dot)

Distribution in Sabah

Based on surveys in 2011–2016, the distribution of banteng in Borneo covers Sabah (Malaysia) and Kalimantan (Indonesia), but remains unconfirmed in Sarawak (Malaysia) or Brunei (Gardner et al., n.d.). In Sabah, camera-trap surveys, sign surveys and direct sightings from the last decade confirmed the persistence of banteng in forest areas (Gardner et al., n.d.; Lim et al., 2021). Most of the forest areas are highly fragmented (Gaveau et al., 2014; 2016). The Sabah meta-population is largely confined to the central and eastern forests (Gardner et al., n.d.). The central forest is the remaining largest contiguous forest in Sabah and consists of various forest reserves with different management practices, and contains the largest banteng sub-population in the state (e.g. Deramakot Forest Reserve, Malua Forest Reserve and Maliau Basin Conservation Area Buffer Zone) (Gardner et al., n.d.; Lim et al., 2021). The other fragmented sub-populations include southern (e.g. Kalabakan Forest Reserve and Sapulut Forest Reserve) and south-western areas (e.g. Sipitang Forest Reserve). The north-eastern (e.g. Paitan Forest Reserve and Sugut Forest Reserve) and eastern areas (e.g. Tabin Wildlife Reserve and Kulamba Wildlife Reserve) contain the far-isolated sub-populations. Compared with the first state-wide survey, the current banteng distribution has been significantly reduced due to habitat loss and poaching in the last 40 years, resulting in localised exterminations (Davies & Payne, 1982; Gardner et al., n.d., 2014). One instance is the extirpation of a banteng sub-population in the Dent Peninsular due to habitat loss and hunting (Gardner et al., 2014; Figure 2).

Forest Connectivity

Habitat fragmentation leads to the isolation of banteng sub-populations and restricts movement and dispersal in Borneo. In Sabah, almost all banteng sub-populations have been found confined within fragmented protected and production forest reserves, primarily due to forest conversion to monoculture plantations and construction of linear infrastructures (Gardner et al., n.d.). The central forests of Sabah are important for forest connectivity and a large core area allows individuals to avoid hunters and seek refuge, and facilitates movement and dispersal (Journeaux et al., 2018).

Bantengs in Sabah can be geographically divided into four management units (Figure 3) — the north-eastern, eastern, central, and south-western Sabah, with the north-eastern, eastern and south-western management units under greater pressure of extirpation if habitat reduction, poaching and risk of hybridization escalate (Lim et al., 2021). These pressures also apply to the very small population in Tawau Hills or Ulu Kalumpang area (WWF unpub. survey report, 2019).

The banteng is listed as an ‘Endangered’ species on the IUCN Red List of Threatened Species; the Bornean Banteng subspecies has the smallest population size with an estimated population of 300 to 550 individuals in 1982 (Davies & Payne, 1982), and subsequent estimates of less than 300 by Boonratana (1997) have been updated with information from surveys over the 2011–2016 period (Gardner et al., 2019b) which underpin conservation plans. The shy and endangered Bornean Banteng has a declining trend, but qualifying this requires sufficient detections to estimate robust population parameters, which are currently unavailable. Using intensive camera trapping and individual identification from ambiguous natural marks by two observers, we estimated the baseline population density of Bornean Bantengs in Malua and Tabin forests in Sabah (Malaysian Borneo, which show a state-wide population estimate of over 326, with a number of small banteng populations not surveyed, such as Kulamba and Ulu Kalumpang/Tawau Hills (Table 1). The largest populations are in Segaliud-Lokan/Deramakot/Tangkulap and Tabin.

Table 1. Banteng populations in Sabah

Banteng sub-population	Forest Area	Est. population (2011–2016)
Sipitang	Sipitang	33
Paitan-Sugut	Trusan Sugut / Sugut	17
	Paitan	18
Tabin-Kulamba	Tabin	52
	Kulamba	present
Central Forests	Segaliud-Lokan	46
	Tangkulap	17
	Deramakot	22
	Ulu Segama / Danum	present
	Malua	36
	Kuamut	30
	Imbak Canyon	present
	Maliau Basin	31
	Sapulut	16
Others	Kalabakan	present
	Ulu Kalumpang FR	present

Most conspicuous population changes over this time period have been localised extinctions of bantengs, including Bonggaya, Lower Kinabatangan, and the south-eastern region of the Dent Peninsula (SWD, 2019a; Figure 4); however more observations of bantengs were obtained from the south of Sabah (Maliau, Sipitang, Sapulut) in areas that probably had populations at that time but would have been difficult to access during the time of the first survey by Davies and Payne (1982).

Conservation

In Sabah, Bornean Banteng decline is directly attributed to hunting (Gardner et al. 2021) and indirect snaring, habitat loss (including pastures) and fragmentation leading to a reduction of gene flow, road development (Pan Borneo Highway) and hybridization with domestic cattle. It is therefore critical for the State Government and NGOs to adopt conservation strategies to address these threats and implement them vigorously, as described in the Bornean Banteng Action Plan for Sabah (SWD, 2019a).

1. Increase enforcement on the ground by supporting and strengthening Sabah Forestry Department's enforcement team 'PROTECT' and Sabah Wildlife Department's recently established 'Intelligence Unit'. Patrolling should be implemented in the range of the species, within the Central Forest, the Tabin and Kulamba, the Paitan and Sugut and the Sipitang ranges.
2. To address habitat loss and fragmentation, any area with presence of banteng needs to be

managed sustainably by developing and maintaining pastures and salt licks within and near the home ranges of existing herds. Landscape connectivity should be maintained within each of the six sub-populations, and corridors should be established (when possible) between those management units (Lim et al., 2021).

3. Road development, and especially the planned Pan Borneo Highway, will further fragment the populations of banteng. It is therefore necessary to design and establish animal crossings, such as tunnels or bridges, and engage with the Sabah Department of Public Works during the design and alignment of the Pan Borneo Highway, especially during the development of the Kalabakan section that would further fragment the banteng habitat between Sapulut Forest Reserve and Maliau Basin Conservation Area.
4. To prevent hybridization with livestock and evaluate the risk of infectious disease and harmful pathogen transmission, it is recommended to carry out a risk assessment of the presence of domestic cattle and potential hybrids within and around protected areas, such as Kalabakan Forest Reserve, and Tabin and Kulamba Wildlife Reserves.

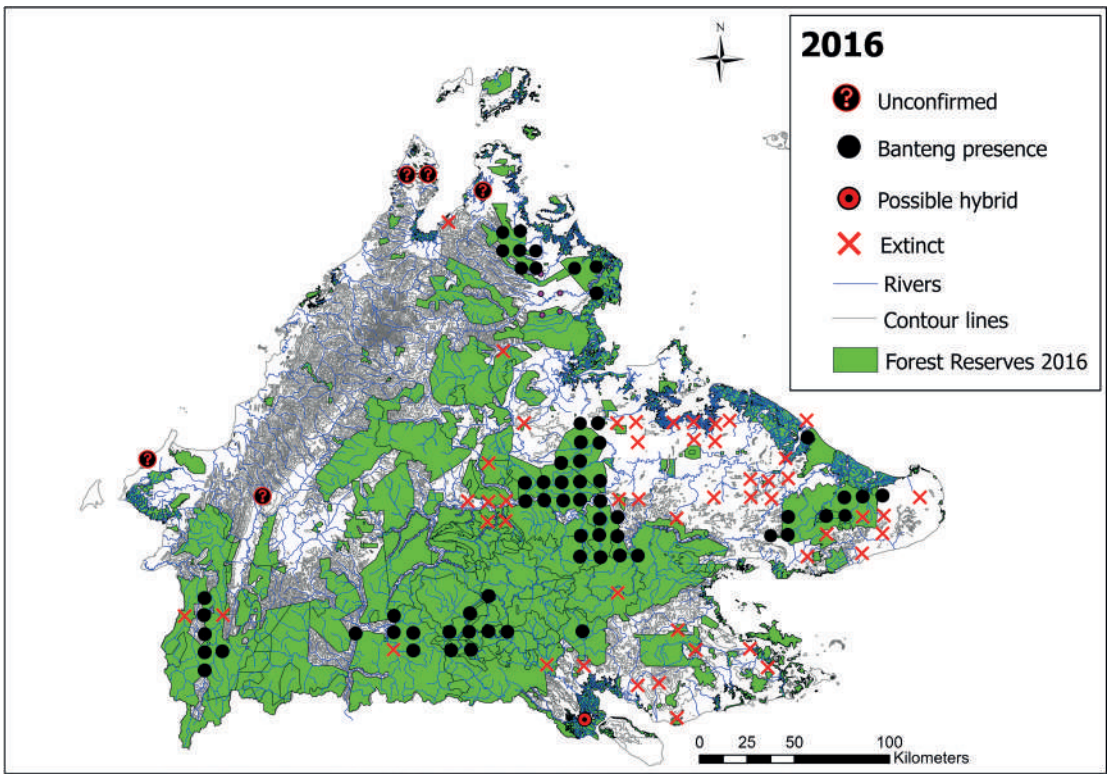


Figure 4. Shows widespread contraction of the banteng species range since 1980, mostly as a result of habitat loss to agricultural/oil palm plantation development (from SWD, 2019c)



Figure 5. Evidence of hunted and snared banteng © Danau Girang Field Centre and © Olsen (2002, far right).

Captive breeding of bantengs in Sabah

Abdul Hamid Ahmad, John Payne and Zainal Zahari Zainuddin

Hunting is a serious threat to Sabah's banteng and the Bornean Banteng Species Action Plan for Sabah contains an action to "set up a captive breeding programme in Sabah". Captive management and reproduction of bovids is well known. By securing a few Bornean Bantengs from several wild herds, it will be possible to build a genetically-diverse managed population, and boost the number of annual births beyond that seen in wild herds. Captive breeding prevented the extinction of the European bison, *Bison bonasus*, from a starting point of 19 individuals in zoos in 1927 which were managed to result in over 7,000 now, most living wild. The kouprey, *Bos sauveli*, could have been saved from extinction if captive breeding had been pursued in the 1950s, when there were an estimated 800 individuals, and when an initial attempt was abandoned.

Expertise for safe capture and captive management of banteng already exists in Sabah. The precise model and lessons learned will come from captive breeding of seladang, *Bos gaurus hubbacki*, in Pahang, Peninsular Malaysia. The most important lesson was that capture myopathy often kills live-captured seladang except those under a few weeks old at time of capture. This is an unavoidable syndrome whereby some wild mammal species, when under stress, quickly build up lactic acid in the blood which affects heart function, resulting in death from heart failure. Other lessons include the fact that space and resources for large, herding animals in any one facility become limiting, that at any one time about half of managed captive individuals are too old to breed or sub-fertile, and that in the absence of management, inbreeding depression becomes evident (Rosli et al., 2016). In addition to avoiding risk of mortality, two significant advantages of acquisition of calves are that good nutrition can be assured to adulthood, and the resulting adults will be tractable for close management. Captive facilities could be established in reserves and on corporate-owned land, and management could be out-sourced.

Acknowledgements

PCG, HYL, BG would like to thank the following funders, organisations and counterparts: Houston Zoo, Yayasan Sime Darby, Malaysian Palm Oil Council, Woodland Park Zoo, Cardiff University, Sabah Forestry Department, Sabah Wildlife Department, Sabah Forest Industries, Prof. Michael Bruford and the numerous rangers, officers and concession holders that welcomed us and facilitated banteng surveys conducted across the state of Sabah. Peer review was provided by John Payne, mapping from Adi Shabrani and editorial input from Glyn Davies.

Data Sources

Individuals / organizations (Number of records): Brodie, Jeddidah (18); Gardner, Penny (1702); Haysom, Jessica (60); Hearn, Andrew (103); Guharajan, Roshan (74); Lim Wing Shen (4); Muhammad Edri Nurdin (1); WWF-Malaysia (589). *Publications (Number of records*): Bernard et al., 2014 (1); Boonratana, 1997 (4); Boonratana & Sharma, 1993 (2); Chung et al., 2019 (4); Davies & Payne, 1982 (24); Dawson, 1992 (6); Gardner et al., 2017 (1); Harrison, 1998 (1); Ishige et al., 2017 (1); Journeaux et al., 2018 (4); Kee et al., 2018 (1); Lim et al., 2019 (11); Lim S. P., 1993 (1); Regip, 2003 (1); Samejima & Ong, 2012 (10); Samejima et al., 2012 (1); SFD, 2016 (3); SFD, 2017 (4); SFD, 2018 (2); Shukor et al., 2011 (1); Sollmann et al., 2017 (3); Wilting & Mohamed, 2010 (3); WWF-Malaysia, 1985 (10).



Sambar Deer in Deramakot Forest Reserve © WWF-Malaysia

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Sambar Deer (*Rusa unicolor*)

Jedediah F. Brodie and Roshan Guharajan

Introduction

The Sambar Deer (*Rusa unicolor*) is the largest member of the Cervidae (deer family) in Sabah. Globally, its range stretches from South Asia (Bangladesh, Bhutan, India, Nepal, Sri Lanka) and southern China throughout mainland Southeast Asia (Cambodia, Lao PDR, Myanmar, Peninsular Malaysia, Thailand, Vietnam) to insular East (Hainan Islands and Taiwan) and Southeast Asia (Brunei Darussalam, East Malaysia, Indonesian Borneo, and Sumatra). The IUCN elevated the species from 'Least Concern' to 'Vulnerable' in 2008 due to a >50% decline in abundance within three generations (Leslie, 2011); the population continues to show a decreasing trend (Timmins et al., 2015c). Other names for the species include *sambur* in India and *rusa*, *payau*, and *tambang* in Malaysia.

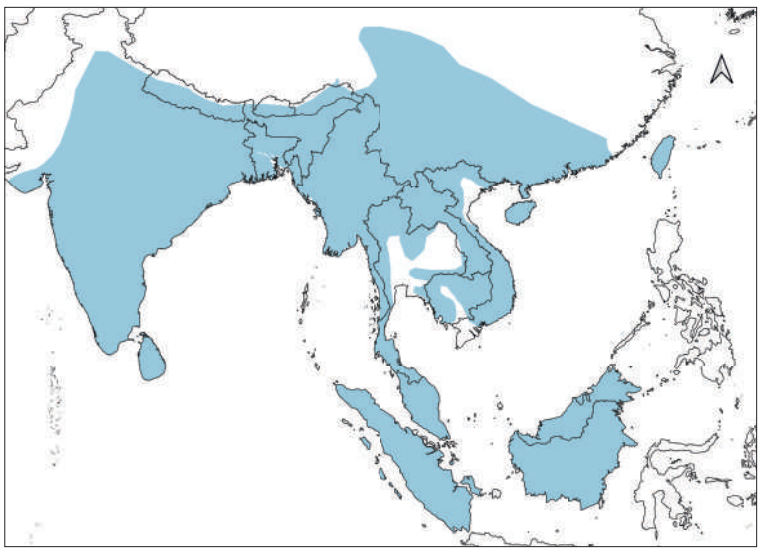


Figure 1. Global range for Sambar Deer (IUCN, 2015a)

Taxonomy

Originally placed in the large and geographically widespread genus *Cervus*, Sambar were later classified into a smaller, tropical genus *Rusa*. However, recent genetic analysis suggests that *Rusa* is not monophyletic, either being paraphyletic with *Cervus* (Zurano et al., 2019) or embedded within a paraphyletic *Cervus* (Pitra et al., 2004). If the latter turns out to be supported, *Rusa* will likely be reconsidered as a sub-genus of *Cervus*, and the Sambar once again classified as *C. unicolor*. Until that time, however, we follow the IUCN taxonomy of considering the Sambar to be in the full genus *Rusa*. The species is considered to have seven subspecies, with the one found in Sabah (and

throughout Borneo) being *R. unicolor* ssp. *brookei* (Leslie, 2011).

Sambar stand 102–160 cm at the shoulder with 162–246 cm head and body length (Nowak & Paradiso, 1991). Those in Borneo are smaller and have smaller antlers than populations on the mainland, particularly those in India (Leslie, 2011). The colouration is fairly uniform brown (hence the specific epithet) and slightly lighter in juveniles and females than in adult males. As in nearly all cervids, only the males have antlers. These are shed seasonally in northern parts of the species' range, but antler phenology is not known in less seasonal climes such as Sabah. Sambar antlers are unique among cervids in having three tines with the brow tine being relatively long and branching at an acute angle from the main beam (Leslie, 2011). Another interesting feature is a 'sore spot', which is prominent during breeding, from which a milky secretion is rubbed on trees (Phillipps & Phillipps, 2018; Figure 2a).



Figure 2. a) Female, showing the 'sore spot' on the neck that is unique to Sambar Deer and exudes a milky hormone that is rubbed on tree trunks, and fawn © WWF-Malaysia; b) A male Sambar in the Hose Mountains, Sarawak © J. Brodie

Natural History

There are no detailed studies in Sabah, so information from elsewhere in Asia is summarised here. Sambar are quite generalist in their habitat selection, living in forest, savanna, open grasslands, shrublands, and wetlands (including peat) (Schaller, 1967; Timmins et al., 2015c). Their populations are usually higher in moist than in dry forests (Karanth & Sunquist, 1992). At least in some areas they prefer hilly terrain (Johnsingh et al., 2004). In Sabah, Sambar occur from sea level up to 3,000 m elevation on Mt. Kinabalu (Payne et al., 1985).

Diet breadth in Sambar is very broad (Timmins et al., 2015c), and they are more generalized in this respect than other sympatric cervids (Schaller, 1967). They have been recorded feeding on ~180 plant species in India (Johnsingh & Sankar, 1991), including both grasses ('grazing') and woody vegetation ('browsing') (Ngampongsai, 1987; Sankar, 1994; Semiadil et al., 1995). As such, Sambar may be seen in open grasslands, such as those along riverbanks, more often than species such as muntjac (*Muntiacus* spp.) and chevrotains (*Tragulus* spp.). They can also consume substantial amounts of fallen fruit (Brodie et al., 2009b).

Male Sambar in some areas can move up to ~20 km per day during the rut (Timmins et al., 2015c), but otherwise little is known about their daily movement patterns or home range size. Sambar are

thought to be mostly non-social (Karanth & Sunquist, 1992; Schaller, 1967) though large numbers may aggregate in rich feeding areas or around water (Timmins et al., 2015c). Most records from a camera trapping survey in Maliau Basin Conservation Area, Sabah, were of single individuals (i.e. the mean ±SE group size was 1.12 ±0.02) (Brodie et al., 2015a). Sex ratios in many populations are strongly biased towards females (Timmins et al., 2015c).

Daily activity of Sambar seems to be non-specific to a particular time (cathemeral; O'Brien et al., 2003; van Schaik & Griffiths, 1996), though there are noticeable activity peaks during dusk and dawn (crepuscular; Schaller, 1967) and at night (nocturnal; Kawanishi & Sunquist, 2004).



Figure 3. Camera-trap images of Sambar male without antlers in Deramakot FR © WWF-Malaysia; b) Female with fawn browsing in Ulu Kalumpang FR © WWF-Malaysia

Distribution in Sabah

Most of the information on Sambar in Sabah comes from camera-trap surveys or presence-absence records, such as track and sign surveys (Davies & Payne, 1982). The species is regularly detected on cameras (Brodie et al., 2015b), and such surveys provide valuable insight into the distribution and habitat preferences of the species across the State. Though likely widely distributed in forested areas of Sabah, confirmed Sambar records are mostly from the central and eastern portions of the State (Figure 4) very likely because most robust surveys have been done in these areas. With future surveys in western and particularly south-western Sabah, more information on Sambar distribution will be available. Similarly, Sambar population densities have not been thoroughly examined anywhere in Borneo.

Threats

Impacts of Logging

As habitat generalists, Sambar are very tolerant of selective logging (Timmins et al., 2015c) and indeed may be more abundant in logged than in unlogged forests (Davies et al., 2001; Heydon, 1994), at least as long as hunting is controlled. In Sabah and Sarawak, Sambar appear to strongly prefer logged forest (Brodie et al., 2015a; 2015c). This is likely because logging, by opening the forest canopy, enhances growth of understory vegetation (particularly grasses) favoured by Sambar as forage. However, other evidence suggests that Sambar may only prefer logged forests where the

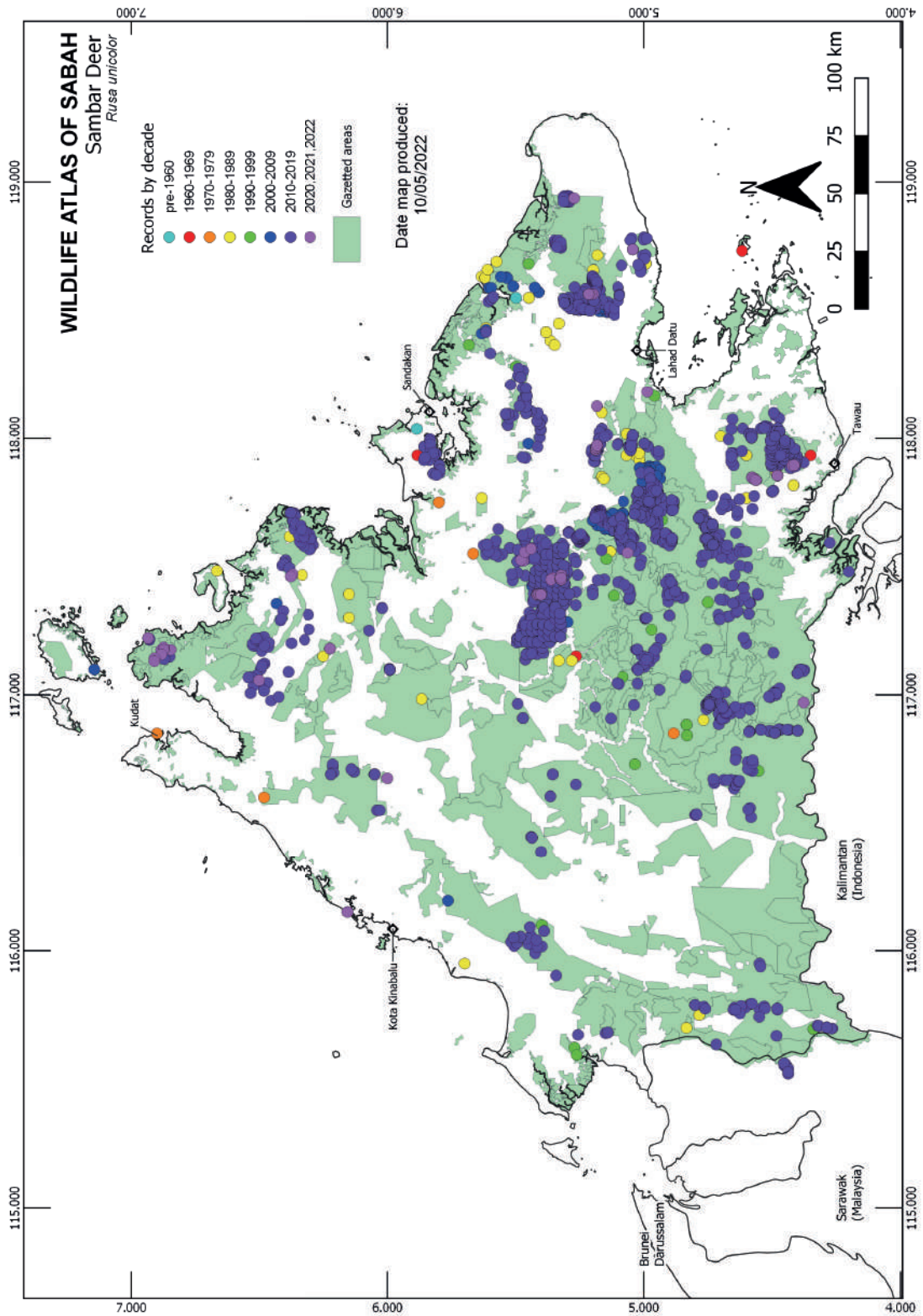


Figure 4. Records of Sambar Deer

logging occurred long enough ago that some aspects of the forest structure have recovered. In a large-scale analysis of logging and hunting across Sabah and Sarawak, Sambar appeared to avoid recently-logged forests, but were the species with the highest preference (out of 30 taxa) for forests that had been logged ≥10 years previously (Brodie et al., 2015b).

Impacts of Agriculture and Infrastructure

Though Sambar are resilient to selective logging, they are not tolerant of forest conversion to agriculture, including most monoculture tree plantations. A camera-trapping study in oil palm estates near Danum Valley did not detect Sambar in plantations (Yue et al., 2015). They have been detected (albeit sparsely) in the *Acacia* plantations in Pitas, in areas close to natural forest (Ng & Ratnayeke, unpub. data). Sambar do occur in some coconut and *Acacia* plantations outside of Sabah; this may reflect an ability of the species to survive in landscapes that that have been highly converted but that retain some natural vegetation cover (Timmins et al., 2015c). Sambar are considered destructive in recently established tree plantations, as they feed on native tree saplings (A. Hastie, Sabah Forestry Department, pers. comm.)

Impacts of Hunting

Hunting is the dominant driver of Sambar decline across their range (Timmins et al., 2015c). Sambar are sought after for meat everywhere they occur; in many areas their meat is sometimes valued more highly than that of other ungulates (Timmins et al., 2015c), though may not always be as preferred as that of wild pigs (*Sus* spp.). Hunting is used for local consumption nearly everywhere, but because of their high market value, much of the meat is also sold in markets and even traded internationally (Duckworth et al., 1999; Kumara & Singh, 2004). Due to the commercialization of Sambar meat, the demand for it is effectively unlimited (Timmins et al., 2015c). Sambar antlers are used in traditional medicine in some areas and associated higher hunting pressure on males could explain the female-biased sex ratios of many populations (Timmins et al., 2015c). Antlers are often displayed as hunting trophies throughout Sambar range (Timmins et al., 2015c), though it is not known whether acquiring such trophies is actually an impetus for hunting. Finally, recreational and social values are important drivers of Sambar hunting in areas such as the Paitan Forest Reserve, Sabah (Wong et al., 2012).

It is important to note that the impacts of logging and hunting, though treated separately here, are inextricably linked for many animals. Logging and hunting are both widespread activities, and an increase in one activity tends to exacerbate the impacts of the other. For example, logged forests increase the accessibility of formerly remote areas to hunting (Brodie et al., 2012), while professional hunting is enhanced in logging concessions to provide food to the workers in the logging camps (Bennett & Dabahan, 1995; Bennett & Gumal, 2001). Indeed, the most prominent impact of logging on many ungulates in Borneo may be the associated hunting, often to the point of species extirpation (Bennett & Gumal, 2001).

In Malaysian Borneo, Sambar were a particularly important meat source for workers in logging camps in the 1990s and their meat was sold in restaurants across Sarawak (Bennett & Gumal, 2001). Caldecott (1988) reported that, in the mid-1980s, 1,500 Sambar carcasses per year were sold in markets along the Rajang River alone.

Throughout their range, Sambar are hunted with guns, dogs, and snares (Jathanna et al., 2003; Kumara & Singh, 2004) usually year-round (Wong et al., 2012). In parts of Borneo, blowpipes

remain common hunting implements as well, and capture of young animals can even be attempted with machetes (Brodie, pers. obs.). Snaring remains common in many areas, but firearms are likely the most common method of harvesting Sambar (Bennett, 2000; Timmins et al., 2015c). In parts of Sabah and elsewhere, Sambar are hunted by driving on roads at night, using spotlights to locate animals and guns to kill them. In the Paitan Forest Reserve, Sabah, Sambar are mostly hunted with dogs and then speared (Wong et al., 2012). Finally, Sambar are also frequent visitors to salt licks (Matsubayashi et al., 2007a; Matsuda et al., 2015b), exposing them to sit-and-wait hunters there.

Hunting is responsible for the declines in and extirpation of numerous Sambar populations (Steinmetz et al., 2008), as well as the decreasing trend of the species overall (Timmins et al., 2015c). In the early 1990s, Sambar made up 35% of all wild meat killed in Sabah but a much smaller proportion in Sarawak, likely because the species had already been greatly reduced in abundance there (Bennett, 2000). Variation in Sambar sign across sites in Malaysian Borneo at this time was explained by hunting pressure more than by habitat characteristics (Bennett, 2000). The population declines have only continued — from 2008 to 2014, Sambar sign detections were reduced by ~40% across a broad swath of Sarawak. In the few areas where they are not heavily hunted, such as Imbak Canyon Conservation Area in Sabah, Sambar may be among the most commonly-detected large animals (Bernard et al., 2013). Though selective logging may increase habitat quality for Sambar in some areas, the effect of this on Sambar populations overall is far outweighed by the associated increases in hunting (Bennett & Gumal, 2001; Timmins et al., 2015c).

Impacts of Climate Change

Sambar in the lowlands of Sabah could potentially be affected by near-term temperature rises. Many lowland mammals in Malaysian Borneo appear minimally affected by recent temperature fluctuations (Brodie et al., 2017), though temperatures are now rising beyond historical ranges. If Sambar are susceptible to rising temperatures, there is a reasonable amount of higher-elevation forested areas to move into, as long as suitable corridors are maintained to allow these elevational range shifts (Williams et al., 2020b). Given the species' broad diet breadth, they may be quite capable of transitioning to the new food sources at higher elevations. Indeed, Sambar in Taiwan occur across a wide elevational range feeding on the plants that happen to be available in each elevational zone (Timmins et al., 2015c).

Conservation

For now, hunting and forest conversion are clearly the dominant threats to Sambar in Sabah and elsewhere in their range. Given that crop monocultures and urban areas are not viable habitats for Sambar, the expansion of these areas will also negatively impact the species.

There may be little additional forest clearance for oil palm expansion in Sabah because the state is striving towards jurisdictional certification from the Roundtable on Sustainable Palm Oil, which would prohibit forest clearance for plantation development. Increasing size of urban areas and other settlements is a concern, however, as the human population of Sabah increases. The expansion of the road network, for example with the Pan-Borneo Highway and its feeder roads, will certainly fragment and affect Sambar habitat and increase the exposure of some populations to elevated hunting. Populations in fragmented landscapes where targeted hunting for Sambar occurs, such as the Lower Kinabatangan Wildlife Sanctuary, are under much more pressure in terms of long-term

viability. In contrast, populations in central Sabah, where forest cover is much more contiguous, are likely to have far better prospects.

Malaysia's commitment to the Convention on Biological Diversity (1992) and the tri-national Heart of Borneo Conservation Initiative, along with the state of Sabah's intention to protect 30% of its land as Totally Protected Area, mean that a higher proportion of forest cover could be retained in Sabah than in many other parts of Southeast Asia. Moreover, with the explicit focus on habitat connectivity embodied in all of these agreements, the forest cover that is retained should hopefully be relatively well-connected. For example, in a state-contracted effort to prioritize new areas for elevated conservation status to achieve the 30% protection goal, a focus was made on securing areas that enhanced connectivity between existing protected areas and that linked lowland and highland areas to facilitate climate-induced species range shifts (Williams et al., 2020b). Without robust estimates of Sambar population density in different forest types, and lacking information on their dispersal behaviour and meta-population structure, it remains impossible to precisely assess how changes in forest cover and conservation status across Sabah will affect the long-term viability of Sambar in the state. Nevertheless, given their generalist habitat requirements and tolerance of habitat disturbances such as selective logging, Sambar are likely to be at minimal risk of near-term extinction in the state as long as hunting is controlled.

Acknowledgements

Permissions for the various research projects in Sabah reported upon here were granted by the Sabah Biodiversity Centre and, in the case of earlier studies, the Economic Planning Unit of Malaysia. Most studies also depended on support from agencies such as the Sabah Forestry Department, Yayasan Sabah, the Sabah Wildlife Department, and/or Sabah Parks as well as local communities. Most of the projects reported on herein are also indebted to numerous field technicians, guides, and collaborators in the forests and communities where they worked; in particular we thank P. Salutan, O. Helmy, G. Reynolds, H. Bernard, L. Ambu, Teoh S. W., A. Granados, and P. Williams.

Data Source

Individuals / organizations (Number of records): Brodie, Jedediah (634); Dee Arnielia Gundeh (2); Freddie Jude Juliani (1); Gardner, Penny (476); Guharajan, Roshan (738); Haysom, Jessica (2628); Hearn, Andrew (2215); Lim Wing Shen (4); Muhammad Edri Nurdin (1); 1StopBorneo Wildlife (1); Forest Solution Malaysia (39); Sabah Forestry Department (7); Sabah Museum (1); WWF-Malaysia (1781). *Open source database (Number of records):* eMammal (88). *Publications (Number of records):* Abdullah et al., 1995 (16); Bernard et al., 1997 (1); Bernard et al., 2013 (5); Bernard et al., 2014 (2); Bernard et al., 2019 (1); Bili, 2014 (8); Boonratana, 1997 (10); Boonratana & Sharma, 1993 (2); Bornion Timber, 2021 (5); Chung et al., 2019 (11); Davies & Tan, 2019 (3); Davis, 1962 (2); Dawson, 1992 (6); Deere et al., 2017 (41); Granados, 2016 (1); Granados et al., 2016 (1); Harrison, 1998 (1); Hawkins et al., 2019 (1); Heydon, 1994 (1); Ishige et al., 2017 (4); Kee et al., 2018 (1); Kehoe, 2011 (4); Ketol et al., 2009 (1); KOPEL, 2016 (2); KOPEL, 2019 (1); Lim, 1996 (2); Lim S. P., 1993 (2); Matsubayashi et al., 2007 (1); Matsuda et al., 2014 (1); Mingueza, 2018 (2); Murphy, 2007 (1); Nakabayashi et al., 2014 (2); Onoguchi & Matsubayashi, 2008 (2); Payne et al., 1989 (1); Prudente et al., 2009 (1); Rahman & Abdullah, 2002 (1); Rajaratnam, 1995 (1); Regip, 2003 (1); Ross et al., 2013 (6); Samejima & Ong, 2012 (28); Samejima et al., 2012 (1); SFD, 2016 (11); SFD, 2017 (24); SFD, 2018 (5); SFD, 2019 (5); Shukor et al., 2011 (2); Sollmann et al., 2017 (3); Tuen et al., 2002 (1); Webb, 2016 (3); Wilting & Mohamed, 2010 (5); Wong, 2011 (6); Wong et al., 2012 (1); WWF-Malaysia, 1985 (4).



Red Muntjac at Ulu Kalumpang Forest Reserve © WWF-Malaysia

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Bornean Yellow Muntjac (*Muntiacus atherodes*) and Red Muntjac (*Muntiacus muntjak*)

Quentin Phillipps and Glyn Davies

Introduction

Both species of muntjac in Sabah are medium-sized deer that walk with a distinctive gait, "head carried low, the back slightly arched and the hindquarters high, lifting the feet high off the ground at every step" (Payne et al., 1985). Both species give a characteristic loud call, which sounds like a dog's bark and is surprisingly loud for their size, and for this reason, another common name for the species is Barking Deer. Throughout Sabah they are known by their Malay name, *kijang*.

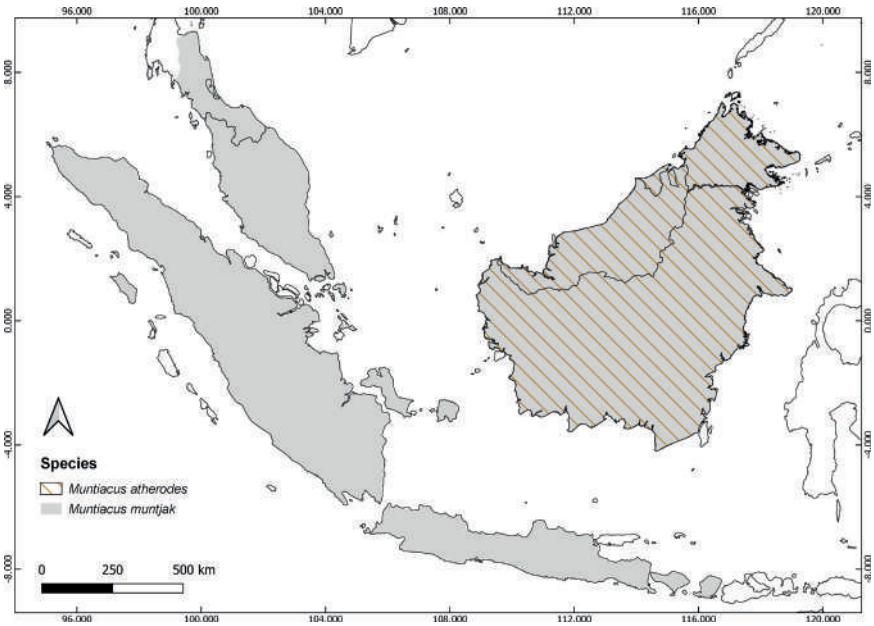


Figure 1. Bornean Yellow Muntjac and Red Muntjac species ranges in SE Asia (IUCN, 2008b; 2016)

There are 12 muntjac species worldwide with a distribution from India east to Taiwan and south to the Lesser Sunda islands of Indonesia. Borneo hosts 2 species of muntjac (Mattioli, 2011): the southern Red Muntjac, *Muntiacus muntjak*, subspecies *muntjac* Zimmerman (1780), with a native distribution from the Malay Peninsula to Sumatra, Java and Borneo and the Lesser Sundas, and the Bornean Yellow Muntjac, *Muntiacus atherodes,* which is a Borneo endemic (Figure 1). Recent genetic analyses (Zhang et al., 2021) show the Bornean Yellow Muntjac separated from the Red Muntjac long ago, indicating that it is an ancient and phylogenetically primitive and distinct endemic species of Borneo.

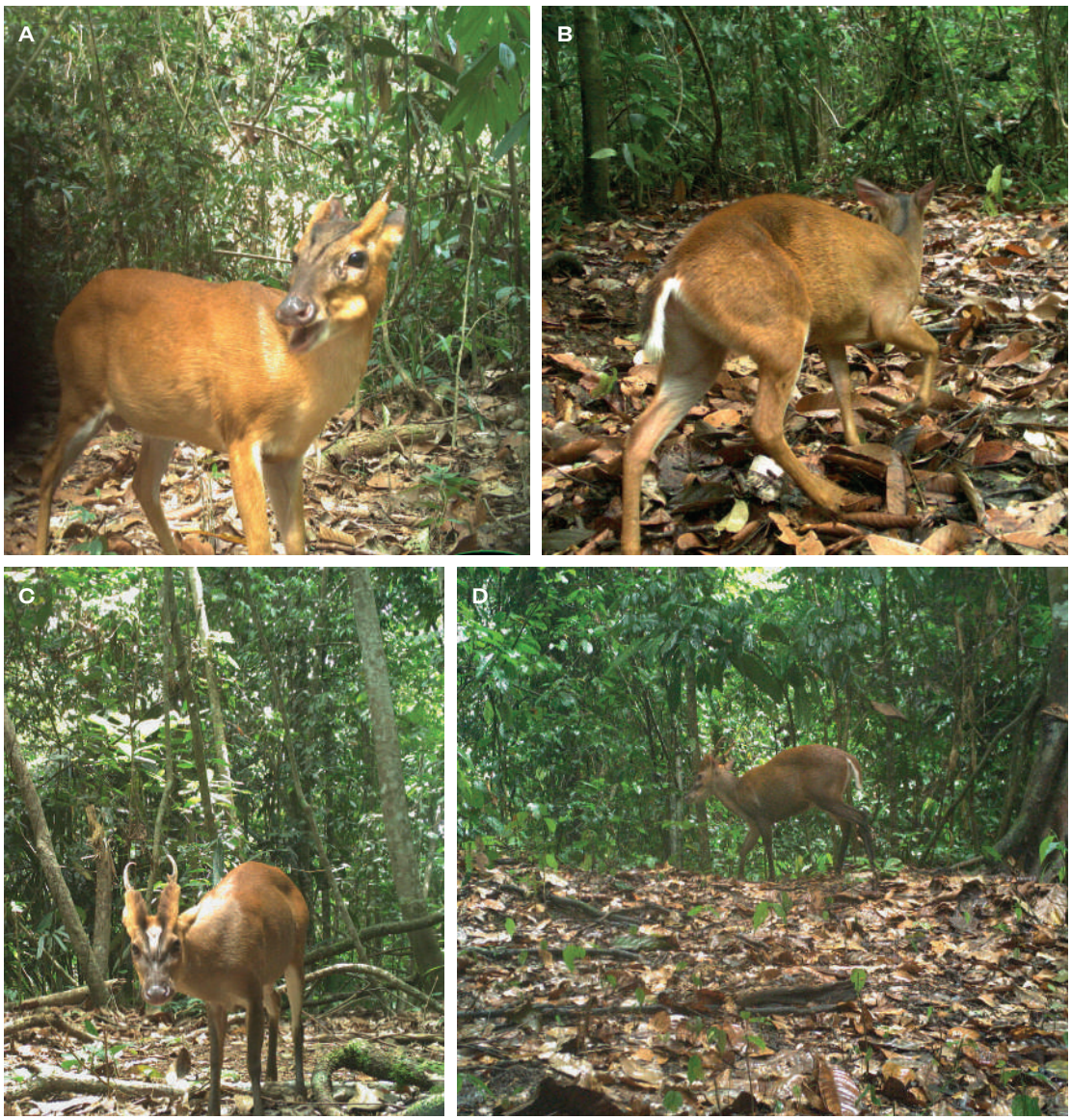


Figure 2. Shows the key identification characters for muntjac species (https://borneomammals.online/?s=muntjac), which are commonly confused. a) Bornean Yellow Muntjac male and b) Bornean Yellow Muntjac female (rear); c) and d) Red Muntjac males; all photos © WWF-Malaysia

The separation of the two into separate species was published in 1982 (Groves & Grubb, 1982), which means that any reports attributed to Red Muntjac in Sabah before that time may in fact be referring to Bornean Yellow Muntjac, and so early records have not been analysed here because of this confusion.

Males have antlers; a small, simple, single branch in the Bornean Yellow Muntjac and a larger, two-branched antler in the Red Muntjac. Both species' males have sharp long canine teeth, sometimes referred to as tusks, in the upper jaw used for fighting rival males, and these teeth are 'loose' and can be heard rattling at close range (Payne et al., 1985).

Early records from Sabah's unlogged lowland forests (Davis, 1962) showed Bornean Yellow Muntjac to be living in pairs (on 3 occasions) or singly (1 occasion). In a recent camera-trap study (Wearn et al., unpub. data), over one third of Bornean Yellow Muntjac records (n=449) were of male-female pairs, compared to less than 10% of Red Muntjac records (n=2,614), indicating a closer male-female pair bond in the former. Both muntjac species in Sabah have juvenile animals in all months of the year, with a peak in March and June for Bornean Yellow Muntjac, and seemingly with fewer juveniles for both species between August–December (Assou, 2017).



Figure 3. a) Bornean Yellow Muntjac fawn and doe © WWF-Malaysia; and b) Red Muntjac fawn with dotted marking along the back © WWF-Malaysia

Davis (1962) noted that the "barking" call of the Bornean Yellow Muntjac was heard in daylight hours in both old logged and unlogged forest, and Heydon (1994) confirmed that both males and females bark, mostly during daylight hours, but with occasional "barks" between 18.00–23.00 hours. Red Muntjac in Sabah also call throughout the day, and at night. Moreover, on Trus Madi in June 2018, calls and replies were made on consecutive mornings between individuals at the same three locations, separated by 300–500 m (WWF-Malaysia Trus Madi survey report).

In addition to the barking calls, muntjac have prominent scent glands between their eyes, and below their eyes, and also between the hooves on their back feet which are all important in communication. The facial glands are rubbed on vegetation and leaf litter, and it is likely that muntjac can also detect the recent passage of other muntjac on trails through the forest undergrowth from the scent deposited by the glands on their feet (Cooke, 2019).

Natural History

Little is known about the ecology of muntjac in Sabah. They differ in body size: Red Muntjac (20–28 kg) and Bornean Yellow Muntjac (14–18 kg). Although both are locally common forest dwellers, the Bornean Yellow Muntjac populations are predominant in lowland forest, especially in closed canopy areas, and Red Muntjac dominant in hill and montane forest, with more open canopies. Both muntjac species are active during the day with a peak at dawn and a lesser peak at dusk, with Red Muntjac having an additional minor peak around midnight (Assou, 2017; Figure 4).

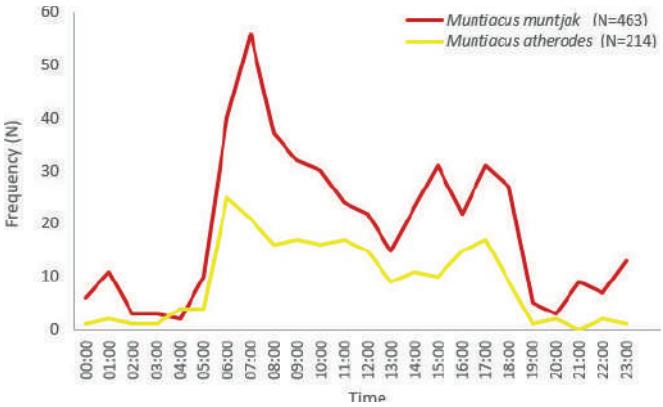


Figure 4. Time of day when camera trap images were taken (Source: WWF field records)

Diet

The muntjac have a ruminant digestive system, and because of their relatively small body size, need higher quality foods than large-bodied sambar and banteng. They therefore browse on nutritious young leaves and feed on fruits. As Heydon (1994) showed in his detailed study in Ulu Segama, the two species differ with the smaller Bornean Yellow Muntjac incorporating more fruits in their diets, and the Red Muntjac more browse. This distinction, which matches the difference in their body weights, is a big factor in explaining their ecological separation.

Fruit eating by muntjac can include quite a range of species. Brodie et al. (2009a) describe the dispersal of a plum-like fruit with a hard stone, *Choerospondias axillaris,* by Red Muntjac in Thailand. A very similar size fruit with a hard stone, *Irvingia malayana,* is dispersed by muntjac in Borneo, whereby the large fruit is swallowed and the stone is later regurgitated. The local name for *I. malayana* is *Pau Kijang* or muntjac mango.

Muntjac also feed on fallen fruits, with fallen fig fruits commonly sought out. Fallen fruit are not regularly available across all parts of the forest, due to seasonal fruiting patterns for many trees and shrubs, leading to periods with few fruits. And there are also large variations in fruit production between years. In Ulu Segama, the relatively large home range (69 ha) of both male and female Bornean Yellow Muntjac may be an adaptation to increase the 'fruit catchment area', with a consequence that their home ranges tend to be larger than other muntjac species, and male home ranges can only overlap one, similar-sized female home range, unlike other muntjac where the male territory can overlap several females' (Heydon, 1994).

Muntjac will also need to fall back on eating herbs and browse when fruits are in low supply, and the extent of this browsing, especially for Red Muntjac, is likely to have an impact on the young leaves of seedlings and saplings low on the forest floor.

Distribution and Abundance in Sabah

Camera-trap images from Sabah show that Red and Bornean Yellow Muntjac populations are partially allopatric, whereby some localities contain only one species, or if two species occur, then one predominates (Figure 5). The clearest distinction relates to elevational variation. The Bornean Yellow Muntjac was the only species found in camera-trapping studies in the lowlands forests of Deramakot Forest Reserve (FR), Sepilok, Kinabatangan Wildlife Sanctuary, Sugut and Trusan Sugut FRs, with a single Red Muntjac record from Sugut FR. Red Muntjac dominate in the western highlands and Lingkabau FR (Assou, 2017; Samejima & Ong, 2021; WWF survey reports).

In the locations where the two species are found together there is an elevational gradient from lowlands upwards, with forests changing in vegetation type. In Tawau Hills Park (THP), at low elevations in the Merotai section and around THP HQ, only Bornean Yellow Muntjac were recorded. Ascending Mt. Lucia in that area, both species are recorded along the same transects, with pictures of both species feeding together under the same fruiting fig tree at 900 m (1StopBorneo camera-trap images). Similarly, in a study at Gunung Palung NP in SW Kalimantan with continuous forest cover between sea level and 1,100 m, Selwyn (2020) found that Bornean Yellow Muntjac were most common lower down, whilst the Red Muntjac population increased with elevation. This corresponds with similar reports from Brunei (J. Charles, pers. comm.).

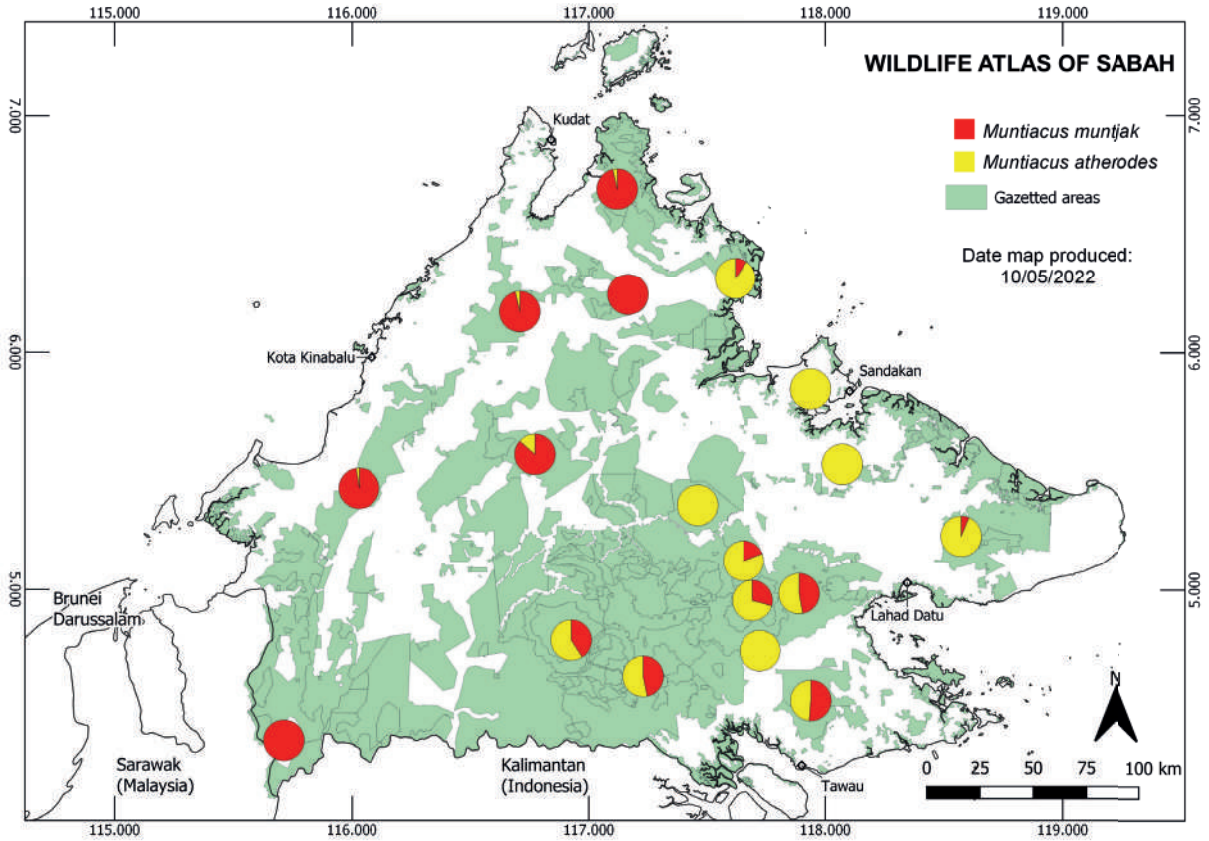


Figure 5. Map showing relative proportion of camera-trap images of Red (*M. muntjak*) and Bornean Yellow (*M. atherodes*) muntjac, at sites with at least 500 camera-trap records (after Assou, 2017; Samejima & Ong, 2012)

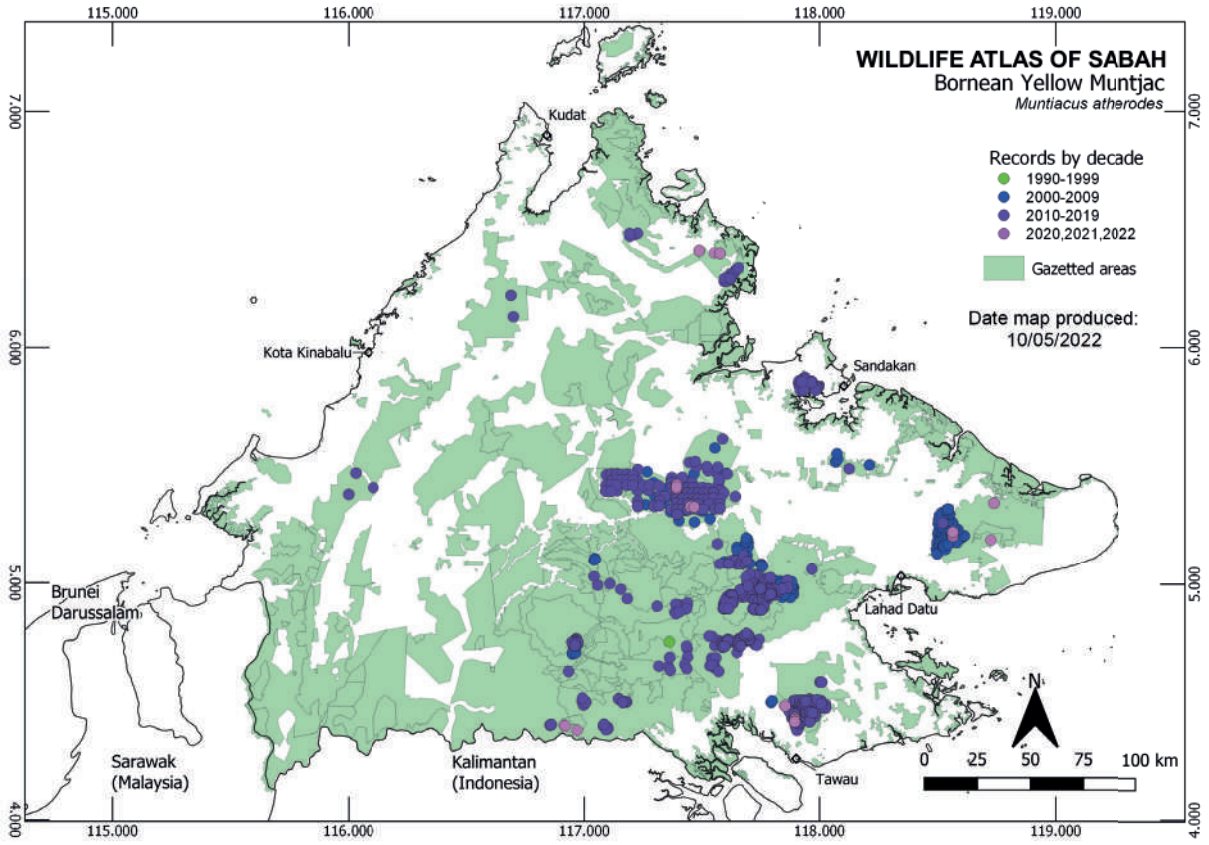


Figure 6. Bornean Yellow Muntjac distribution records (only after 1990)

Table 1. Bornean Yellow Muntjac relative population estimates in different habitats (after Assou, 2017)

Bornean Yellow Muntjac	Elevation (m asl)	Unlogged	Logged	Palm Oil	Source
Kinabatangan (logged >20 yrs before)	5–135		0.16 **per**		Assou, 2017
Sepilok / Minat Teguh	1–134	6.04 **per**		4 **per**	Assou, 2017
Deramakot (RIL ca. 3–15 years before)	20–300		5–10 **per**		Samejima & Ong, 2012
Tabin (logged 20–30 years ago)	10–430		19.86 **per**		Assou, 2017
Malua (logged 1 year ago)	70–290		3.72 **per**		Assou, 2017
Ulu Segama (logged 16 years ago)	150–410		5.30 **per**		Assou, 2017
Danum Valley Conservation Area	150–800	15.12 **per**		1.08 **per**	Assou, 2017
Tawau Hills Park	200–1,200	21.70 **per**			Assou, 2017
Crocker Range	383–1,452	0.12 **per**			Assou, 2017

Notes: **per** = independent pictures / 100 camera trap days**;** RIL = Reduced Impact Logging

Looking at just the Bornean Yellow Muntjac, it is distributed all over Sabah, with an abundance

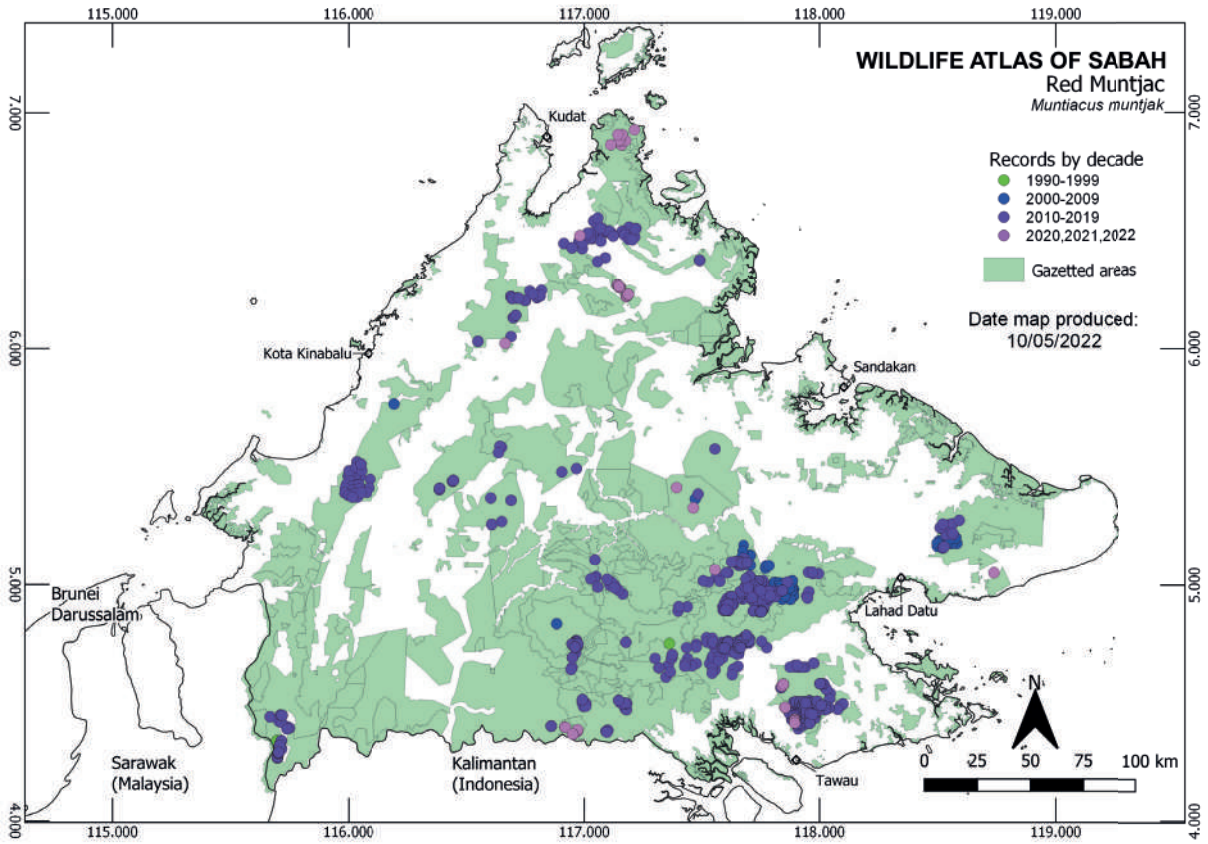


Figure 7. Red Muntjac distribution records (only after 1990)

Table 2. Red Muntjac relative population estimates in different habitats (after Assou, 2017)

	Elevation (m asl)	Unlogged	Logged	Palm Oil	Source
Kinabatangan (logged >20 yrs before)	5–135		0		Assou, 2017
Sepilok / Minat Teguh	1–134	0		0	Assou, 2017
Deramakot (RIL ca. 3–15 years ago)	20–300		0		Samejima & Ong, 2012
Tabin (logged 20–30 years ago)	10–430		1.11 **per**		Assou, 2017
Malua (logged 1 year ago)	70–290		0.65 **per**		Assou, 2017
Ulu Segama (logged 16 years ago)	150–410		4.95 **per**		Assou, 2017
Danum Valley	150–800	7.36 **per**		0.14 **per**	Assou, 2017
Tawau Hills Park	200–1,200	18.59 **per**			Assou, 2017
Crocker Range	383–1,452	2.96 **per**			Assou, 2017

Notes: **per** = independent pictures / 100 camera-trap days**;** RIL = Reduced Impact Logging

of records from the eastern lowlands and Deramakot region, and few records from the central and western highlands (Figure 6). Considering population abundance in different parts of Sabah, Bornean Yellow Muntjac are impacted by elevation, logging and hunting (Brodie et al., 2015b), but there are no recent detailed hunting studies in Sabah, so comparisons are limited to unlogged and logged forest and oil palm plantations. This has been possible using the large dataset provided by Andrew Hearn and colleagues at WildCru, Oxford University, UK (Assou, 2017), and looking at the number of times each species was photographed in every 100 nights of camera-trap survey which gives relative abundance estimates (Table 1).

Bornean Yellow Muntjac relative abundance is highest in unlogged lowland forests, but with low encounter rates in Sepilok, perhaps because it is a moderately small patch of forest surrounded on three sides by farmlands and has experienced pressures of hunting and domestic dog intrusions. Similarly it is low in the Kinabatangan because of the fragmented and degraded nature of the forests there. All the logged forest sites show low encounter rates except two sites: Tabin, logged 20–30 years ago and left to regenerate, and some parts of Deramakot where Reduced Impact Logging has been carefully practiced since 1997. Hunting is also low to moderate at both these sites.

The Red Muntjac is found throughout Sabah, and is most abundant in the western highlands and mountain ranges, and is present in the forest surrounding Kinabalu Park HQ and probably up to the tree line at 3,300 m, although rarely seen (Figure 7). They are noticeably scarce in the eastern lowlands, as noted for Sepilok, Kinabatangan WS, Deramakot, and Tabin (Table 2). A comparison of 16 sites in Sabah (1) and Sarawak (15) indicated Red Muntjac were at relatively low population densities below 500 m, rising to a maximum around 1,250 m elevation before the population declined at higher elevations, and they showed a preference for more “rugged terrain” (Brodie et al., 2017). Analysis of camera-trap records from Sabah also showed a strong increase in predicted presence of Red Muntjac with decreasing tree cover — they prefer more open areas (Assou, 2017).

It is not possible to determine whether Red Muntjac camera-trap encounters are low in Tabin, Malua and Ulu Segama logged forest because of logging or elevational effects — probably the latter (Table 2). Only at higher elevations, where Red Muntjac are more numerous, is there evidence that they increase in density following logging, and so the relatively low numbers in the Crocker Range are likely a consequence of long-term and high hunting, rather than a reflection of the quality of vegetation.

In terms of predation, only three wild animals in Borneo are big enough to kill adult muntjac: reticulated pythons, crocodiles and clouded leopards. Only a very large python could swallow a whole muntjac and so such events are rare. Male clouded leopards weigh on average 24 kg so would have no difficulty in killing a large muntjac, and their activity peak just before dawn coincides with the activity peaks of both muntjac species (Assou, 2017). In addition, family groups of Yellow-throated Marten are known to predate muntjac (Phillipps & Phillipps, 2016). Most muntjac deaths, however, are probably of fawns and youngsters during the first two months from predation by locally common carnivores including: Malay Civet, Banded Civet, Bay Cat, Marbled Cat and Leopard Cat, as well as two species of python and one species of monitor lizard.

Threats

Impacts of Logging

There are clear indications that logging in lowland Sabah has a strongly negative effect on Bornean Yellow Muntjac populations (Figure 8), although recovery of populations 20–30 years after logging in western Tabin does offer hope for recovery of populations elsewhere. The moderate encounter rates in Deramakot, where there is little hunting pressure and Reduced Impact Logging, show that the negative impacts of logging can be moderated, but not removed entirely (Samejima & Ong, 2012). By contrast for Red Muntjac, the studies in Ulu Segama (Davies et al., 2001), in Kalabakan/ Maliau Basin (Wearn et al., 2017; 2022), and in the highlands of Sarawak (Brodie et al., 2015b) all show that logging has a positive effect on Red Muntjac populations — they increase.

Heydon (1994) provided the likely explanation for these different responses to logging (Davies et al., 2001; Heydon & Bulloh, 1997). Monitoring the changes to the forest 12 years after logging showed a larger area of grass/herbs (3% of the area) compared with unlogged forest (0.5%), and a great reduction in fruit availability. Although the numbers of trees were similar (466/ha versus 448/ ha in unlogged forest), the logged area was dominated by pioneer trees species which tend to have dry and very small fruits not suitable for muntjac, and there was a one third reduction in strangling figs. Combined this gave an estimated 53% reduction in 'muntjac fruit' availability (Davies et al., 2001), which had a marked negative effect on the commoner Bornean Yellow Muntjac.

Impacts of Agriculture

Clearance of forest for monoculture oil palm plantations, as noted above, has a devastating effect on muntjac populations. Where the plantations abut forest land, some muntjac are recorded in the plantation area, but these are one tenth or less the numbers found in unlogged forest (Yue et al., 2015). Based on camera-trap data from three sites in Sabah (Kalabakan, Maliau and Brantian Tatulit VJR), Bornean Yellow Muntjac have a 75% likelihood of population decline when primary forest is logged, and a further 95% chance of decline when logged forests are converted to oil palm plantations. Similar impact applies to the more adaptable Red Muntjac: 50% chance of decline from unlogged to logged forests, and 80% chance of decline when converting logged forest to oil palm plantations (Wearn et al., 2017). Preliminary surveys from industrial tree plantations in Pitas indicate that Red Muntjac can adapt to this habitat, even in lowland areas once Bornean Yellow Muntjac have become scarce.

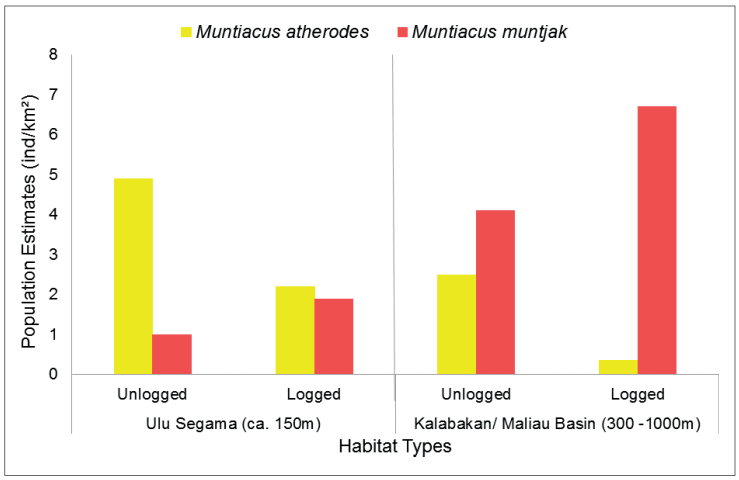


Figure 8. Impacts of logging on muntjac populations. Ulu Segama 12-year logged forest (Heydon & Bulloh, 1997; Davies et al., 2001) and Kalabakan/ Maliau Basin 3- to 6-year old logged forests (Wearn et al., 2022)

Impacts of Hunting

Muntjac have long been a target of human hunting, whether with guns, spears and nets, or snare traps. Early reports from Sabah describe hunters luring muntjac towards them to get a close shot by making a 'call' when blowing through folded leaves held between finger and thumb (Keith, 1939; Phillipps & Phillipps, 2016). The extent of hunting of muntjac across Sabah in the mid-1990s indicated that they contributed a modest 6.5% of the total hunting bag, compared to much higher number of kills of Bearded Pigs and Sambar (Bennett et al., 2000).

Looking at the results presented here, muntjac appear resilient to hunting and trapping at moderate levels in logged and unlogged forests, with evidence of probable declines in Sepilok, as well as the Crocker Range and south-west Sabah where long-standing hunting pressure and reduced wildlife populations have been noted for many years (Bennett et al., 2000; Brodie et al., 2015b; Davies & Payne, 1982). With the recent catastrophic declines in Bearded Pig numbers following the African Swine Fever epidemic, however, additional hunting pressure is likely to be switched to deer species and this may reduce muntjac populations further.

Impacts of Climate Change

Another critical uncertainty is the impact of climate change. It is likely that temperatures will increase, and suitable habitats may become limited to higher and cooler areas. This will pose a challenge for the Bornean Yellow Muntjac, which prefers lower elevations and forest connectivity will be essential if populations are to be able to migrate from lower to higher areas. Furthermore, fruit abundance and patterns of production are also likely to be affected.

Conservation

The IUCN threat category for the Bornean Yellow Muntjac is 'Near Threatened', with populations greatly reduced by destructive logging, and further losses when logged forests are cleared for oil palm plantations. Many populations have already been lost, but remaining strongholds include Deramakot FR, the Danum Valley Conservation Area, the lower slopes of Tawau Hills Park, Maliau Basin and Tabin Wildlife Reserve. These sites need careful management to allow natural regeneration of forest habitat following logging, with special attention to maintaining/encouraging preferred fruit producing trees, such as figs (*Ficus*) species, and those from Annonaceae, Ebenaceae and Meliaceae (Heydon, 1994).

The more widespread Red Muntjac is categorised as of 'Least Concern' being found through the central and western forests, with strongholds at higher elevations in Kinabalu Park, Crocker and Trus Madi ranges, Lingkabau FR and the higher levels of Maliau Basin, Tawau Hills Park and adjacent Ulu Kalumpang FR. The large central forests area is an important supplement and connecting region, for both muntjac species, between their respective strongholds.

Finally, continued vigilance is needed to minimise negative impacts of unsustainable hunting and trapping, especially for urban markets with their large demand for forest meat. The Sabah Wildlife Conservation Enactment (1997) categorises both muntjac species as Schedule 3, meaning they can be hunted with a licence, but this should not encourage hunting in protected areas which needs to have more reliable monitoring to inform law enforcement actions.

There are many interesting research questions which need to be answered, the most important of which relate to thorough studies of the diets of both muntjac species, and more details of Red

Muntjac ecology in Sabah highlands and mountain ranges. The extent to which Reds inhibit tree regeneration by browsing on saplings, and Yellows can adapt to less frugivorous diets are important extensions of such ecological studies. Finally, for both muntjac, what is the impact of hunting and trapping now, and looking ahead?

Acknowledgements

With many thanks to Andy Hearn and colleagues at WildCru for use of data from a major study involving 10,064 independent detections of muntjac from camera traps placed by Hearn and Ross for their clouded leopard studies between May 2007–December 2013, at 10 different sites in Sabah. These were collated and analysed by D. Assou. Field records were provided by many others listed below, and Jedediah Brodie shared additional field data from Sapulut, analysed by Adi Shabrani.

Many thanks also to Oliver Wearn and Jessica Haysom for sharing unpublished field records and population estimates, and to Jedediah Brodie, John Payne and Oliver Wearn for constructive peer-review comments.

Data Sources

Red Muntjac

Individuals / organizations (Number of records): Brodie, Jedediah (492); Gardner, Penny (24); Guharajan, Roshan (1); Haysom, Jessica (7533); Hearn, Andrew (3769); Muhammad Edri Nurdin (1); Forest Solution Malaysia (68); Sabah Forestry Department (24); WWF-Malaysia (1072). *Open source database (Number of records):* eMammal, 2021 (105). *Publications (Number of records):* Abdullah et al., 1995 (21); Bernard et al., 1997 (1); Bornion Timber, 2021 (7); Bunya et al., 2010 (1); Deere et al., 2017 (56); Heydon, 1994 (1); Lim, 1993 (2); Matsubayashi et al., 2011 (2); Murphy, 2007 (1); Onoguchi & Matsubayashi, 2008 (1); Ross et al., 2013 (4); SFD, 2016 (8); SFD, 2017 (2); Shukor et al., 2011 (1); Wilting & Mohamed, 2010 (1); York et al., 2013 (2).

Bornean Yellow Muntjac

Individuals / organizations (Number of records): Brodie, Jedediah (477); Gardner, Penny (28); Guharajan, Roshan (598); Haysom, Jessica (12470); Hearn, Andrew (5063); Sabah Forestry Department (3); WWF-Malaysia (1365). *Open source database (Number of records):* eMammal, 2021 (86). *Publications (Number of records):* Bernard et al., 1997 (1); Chung et al., 2019 (1); Dawson, 1992 (4); Deere et al., 2017 (30); Granados, 2016 (2); Heydon, 1994 (1); Matsubayashi et al., 2011 (1); Onoguchi & Matsubayashi, 2008 (1); Ross et al., 2013 (6); Samejima & Ong, 2012 (28); Samejima et al., 2012 (1); SFD, 2016 (4); SFD, 2017 (8); SFD, 2018 (1); Webb, 2016 (3); Wilting & Mohamed, 2010 (1); York et al., 2013 (1).



Greater Mousedeer © Oliver Wearn

16

Lesser Mousedeer (*Tragulus kanchil*) and Greater Mousedeer (*Tragulus napu*)

Hisashi Matsubayashi

Introduction

Both Lesser Mousedeer, *Tragulus kanchil* (Raffles, 1821), and Greater Mousedeer, *Tragulus napu* (Cuvier, 1822), are widely distributed from continental Southeast Asia to the Malay Peninsula, Sumatra and Borneo (Timmins & Duckworth, 2015a; 2015b). Formerly *T. kanchil* was considered part of species *T. javanicus*, which is now considered to be endemic to Java. Therefore, there are three mousedeer species groups: the *T. javanicus*, the *T. napu*, and *T. versicolor*. Within the *T. javanicus* group three species are recognized: *T. javanicus* (from Java), *T. williamsoni* (from northern Thailand and possibly southern China), and *T. kanchil* (from the rest of the range), and 16 subspecies are recognized in *T. kanchil* (Groves & Grubb, 2011; Meijaard & Groves, 2004).

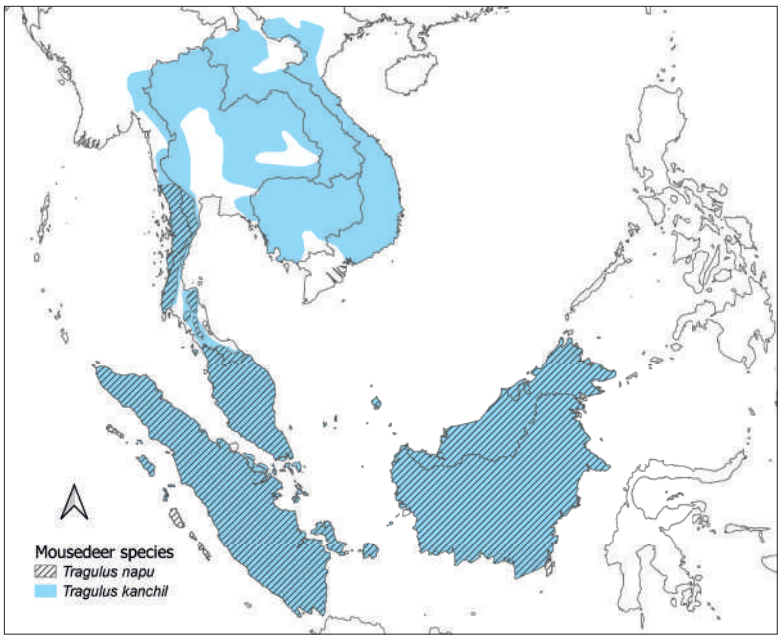


Figure 1. Species distribution of both mousedeer species in SE Asia (IUCN, 2015b; 2015c)

Taxonomy

The pelage of the dorsal surface of the Lesser Mousedeer is relatively uniformly coloured, reddish-brown mixed with fine black; the crown of the head and nape are dark black, which helps to distinguish it from the Greater Mousedeer. That of ventral surface is whitish. Brown and white marking on throat appear as one white line in profile (Figure 2). Head and body length 425–485 mm, shoulder height 250–300 mm, weight 2.0–2.5 kg (Francis, 2008; Payne et al., 1985; Yasuma & Andau, 2000). In Sepilok, the mean body mass of captured adult males was 1.9±0.2 kg (n=8) and that of adult females 2.1±0.3 kg (n=5), corresponding with the figures of 2–2.5 kg for adults collected at other sites (Davis, 1962). Adult males have enlarged canines on the upper jaw, and bulging intermandibular glands showing below the jaws (Figure 2a), but there is no significant difference in the adult body mass between the sexes.

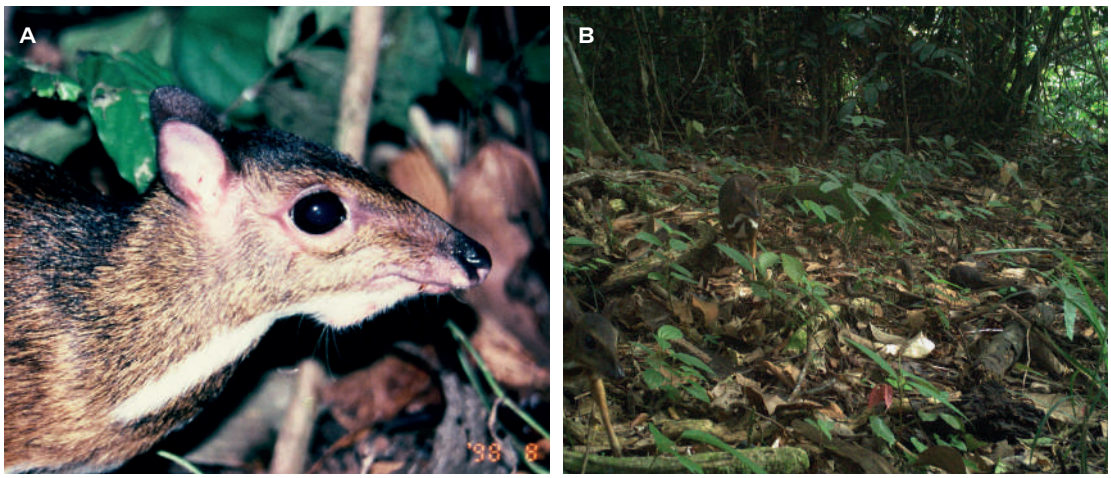
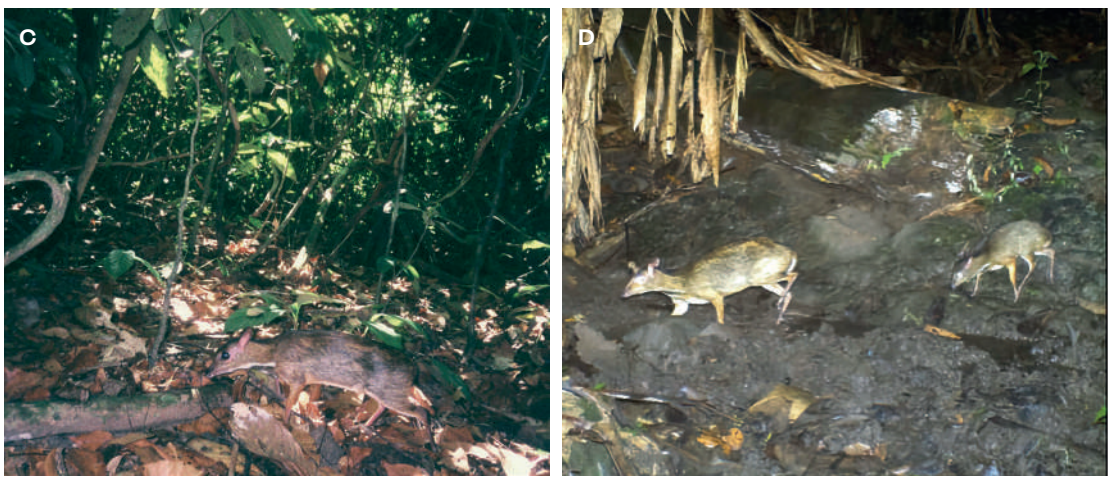


Figure 2. a) Lesser Mousedeer adult male at Sepilok © Hisashi Matsubayashi; b) Pair caught on camera trap at Ulu Kalumpang Forest Reserve © WWF-Malaysia;



c) Adult female active in the daytime at Tabin © Hisashi Matsubayashi; d) Adult female and juvenile at a salt lick in Deramakot © Hisashi Matsubayashi;



e) Footprint at Sg. Mantri © WWF-Malaysia; and f) Footprint and faeces at Sepilok © Hisashi Matsubayashi

The Greater Mousedeer is relatively uniformly coloured, grey-buff and blackish-brown, while the ventral surface is whitish. The pelage on the flanks can appear 'grizzled' with black hair, sometimes in diffuse stripes, which helps to distinguish it from the relatively more uniform pelage of the Lesser Mousedeer. Brown and white markings on throat appear in profile as two white lines, one originating in front of chin, and one in the middle of throat — appearing as a broken white line beneath the chin and throat (compared with the Lesser Mousedeer's unbroken white line; Figure 3). Head and body length is 500–600 mm, shoulder height 300–350 mm, and they weigh nearly twice as much as the Lesser Mousedeer at 3.5–4.5 kg (Davis, 1962; Francis, 2008; Payne et al., 1985; Yasuma & Andau, 2000). Like the Lesser Mousedeer, only adult males have enlarged canines from the upper jaw and bulging intermandibular glands (Figure 3a).

For both Lesser and Greater Mousedeer, they are sometimes referred to as Lesser or Greater Oriental Chevrotain, and are referred to as *pelanduk* throughout Sabah. The Malay word *kancil* tends to be used in Peninsular Malaysia.

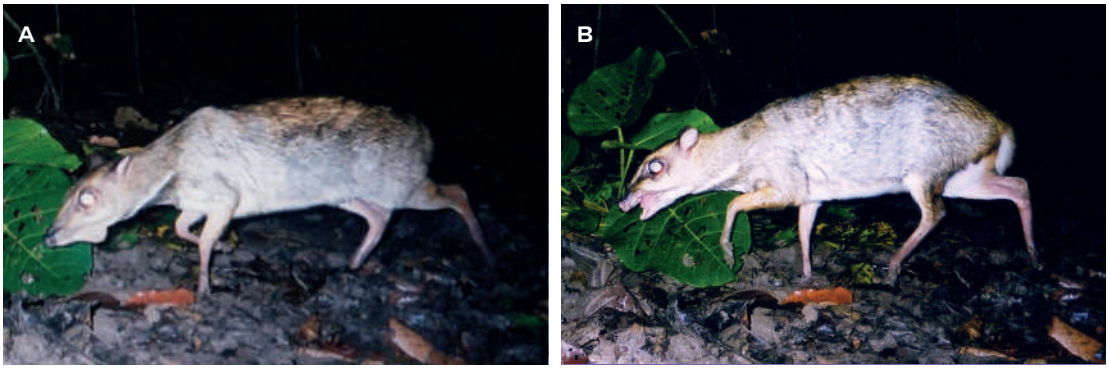


Figure 3. Greater Mousedeer a) Adult male © Hisashi Matsubayashi; b) Adult female in Tabin © Hisashi Matsubayashi

Natural History

The Lesser Mousedeer is highly solitary. In Sepilok, based on direct sightings over a 2-year study period (1998–2000; N=66), 94% were solitary individuals and 6% were in pairs. No larger groups were recorded. The social system seems to be largely monogamous, although males can sometimes be polygamous (Matsubayashi et al., 2006). Much less is known about the Greater Mousedeer, but it is likely to show similar social behaviour. In captivity, Ralls et al. (1975) reported that a "squeaking" vocalization by male Greater Mousedeer was associated with the approaching and scent marking of the female's back. They also observed that the mousedeer produced a noise like a drumbeat, which could be heard throughout the enclosure, by stamping on the floor with one hind hoof, or with both hind hooves simultaneously.

Lesser Mousedeer are mainly active during the day, and use forest canopy gap areas in the unlogged forest in Sepilok, where light penetrates to encourage plant growth in the forest understory, and the dense undergrowth of creeping bamboo are favoured foraging sites (Figure 2c). Rest areas tend to be open, drier ridges at night (Matsubayashi et al., 2003). The diet includes fallen fruits, fallen green and/or dead leaves, especially of pioneer tree species, leaf shoots, and fungi (Matsubayashi et al., 2003). The fruits and soft leaves of pioneer plants are probably favoured because they are likely to have lower concentrations of secondary metabolites that may be toxic or inhibit digestion (Matsubayashi et al., 2003). They also visit salt licks regularly (Matsubayashi et al., 2007a; Figure 2d).

Fewer details are known about the Greater Mousedeer, but detailed camera trapping, captures, and direct observations in Tabin (2002–2003) showed that in this old logged forest, Greater Mousedeer were active both during the day and the night, while Lesser Mouse deer were mainly active in the daytime (Matsubayashi & Sukor, 2005).

Furthermore, based on camera-trap survey results from Sepilok, Greater Mousedeer were never recorded in forest canopy gap areas, compared with 16 records of Lesser Mousedeer in these habitat

Table 1. Home range and population estimates for mousedeer in Sabah

	Sepilok	**Danum**	**Danum**
	UNLOGGED		**LOGGED** (after 2–12 yrs)
Lesser Mousedeer			
Home range (ha)	Male: 5.9±0.4 ha, Female: 4.3±0.7 ha		
Population (indiv/km^2)	*ca.* 40 indiv/km^2	30 indiv/km^2 (range *ca.* 20–40)	Range: 10–15 indiv/km^2
Greater Mousedeer			
Home range (ha)		[1]*ca*. 7.5 ha	
Population (indiv/km^2)		54 indiv/km^2 (range *ca.* 35–65)	Range: 8–20 indiv/km^2
Sources	Matsubayashi et al., 2003	[1]Ahmad, 1994; Heydon & Bulloh, 1997	Heydon & Bulloh, 1997

patches (Matsubayashi et al., 2003). Thus, the two mousedeer species appear to be ecologically separated, at least to some extent, by both differing activity patterns and habitat preferences.

Considering home range sizes as an indicator of population density, both species appear to occupy consistently small home ranges with little overlap between home ranges of the same sex, male home ranges overlap female (Ahmad, 1994; Matsubayashi et al., 2003). However, estimates for both species can show substantial variation (Table 1), which probably correlates with the species' habitat preferences.

Heydon and Bulloh (1997) reported that in two primary forest sites in Danum, Greater Mousedeer were much more abundant than Lesser Mousedeer. For the first 12 years after logging, however, both species' populations dropped markedly, by as much as one tenth of population estimates in the unlogged forest sites. Indeed, both species had similarly low population densities in 2-, 5- and 12-year old logged areas. Camera trap surveys in Sabah indicated that the Greater Mousedeer was more sensitive to logging than the Lesser Mousedeer. Wearn et al. (2017) estimated that the local abundance of Lesser Mousedeer in ~5–15 year old logged forest was actually 29% higher than in old-growth forest. Meanwhile, the abundance of the Greater Mousedeer was 31% lower in logged forest compared to old-growth forest.

Furthermore, Lesser Mousedeer numbers were correlated with the abundance of small fruits, which is consistent with diet records, whilst Greater Mousedeer densities, and overall mousedeer

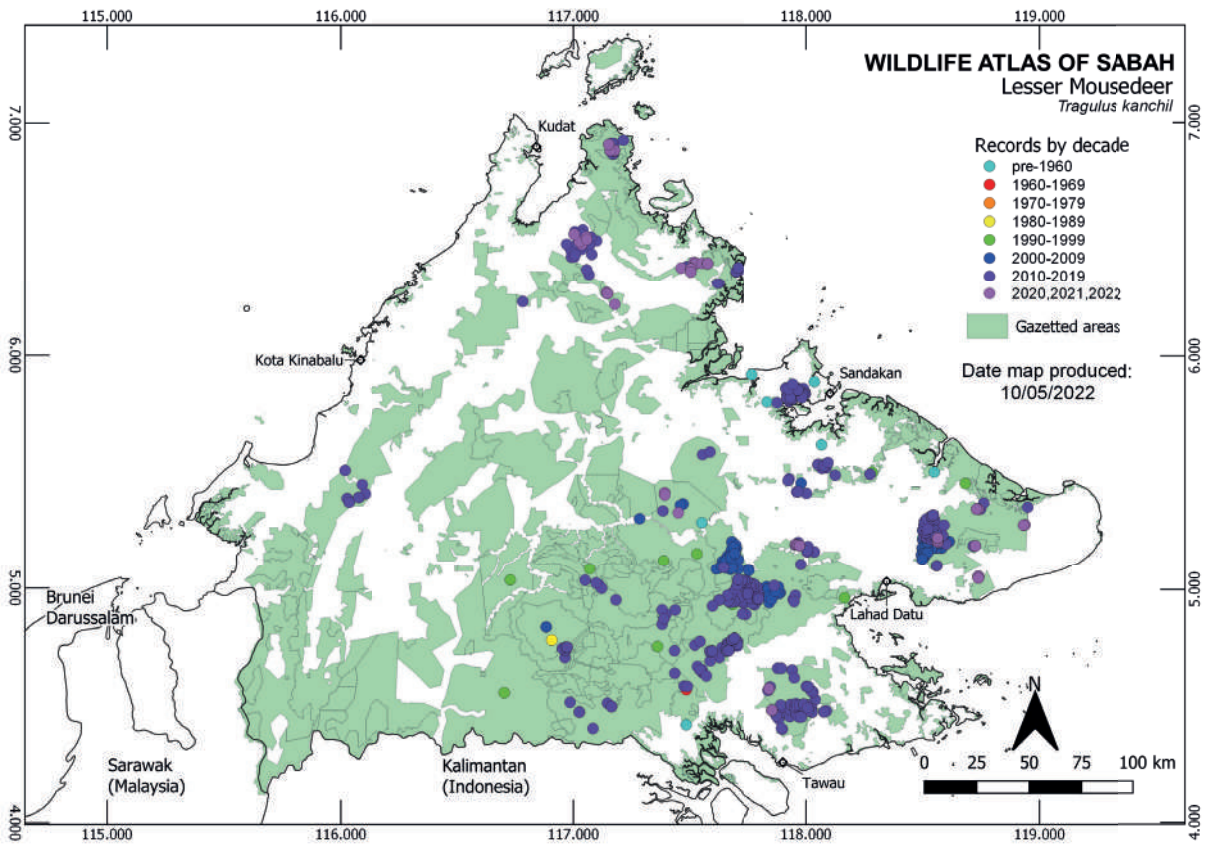


Figure 4. Records of Lesser Mousedeer

biomass, were correlated with the density of large strangling *Ficus* trees (Heydon & Bulloh, 1997). It is important to recall, however, that Lesser Mousedeer include more than small fruits in their diets, and also consumed leaf litter and/or mushrooms as food resources (Matsubayashi et al., 2003), the abundance of which are also likely to be important in influencing population densities. Indeed the combined abundance of both species in the degraded forests of Tangkulap/Deramakot FRs (Samejima & Ong, 2012) probably reflects this point.

Distribution in Sabah

The results of the state-wide faunal surveys in the early 1980s, which concentrated on unlogged forests at that time, indicated that unlogged forests appeared to have the highest abundance for both mousedeer species, especially below 500 m altitude (Davies & Payne, 1982). Comparing the two species distribution maps today (Figures 4 & 5), there are fewer recent records of the Greater Mousedeer, probably reflecting the widespread logging throughout Sabah since the early 1970s. Also, there are remarkably few records of either species outside of forest estates, indicating neither species seems to fare well in oil palm landscapes where there are few small fruits, the leaf litter layer is removed or modified, and there is an abundance of dogs and hunters or snares. Intensive camera-trapping surveys never recorded mousedeer inside oil palm plantations (Wearn et al., 2017).

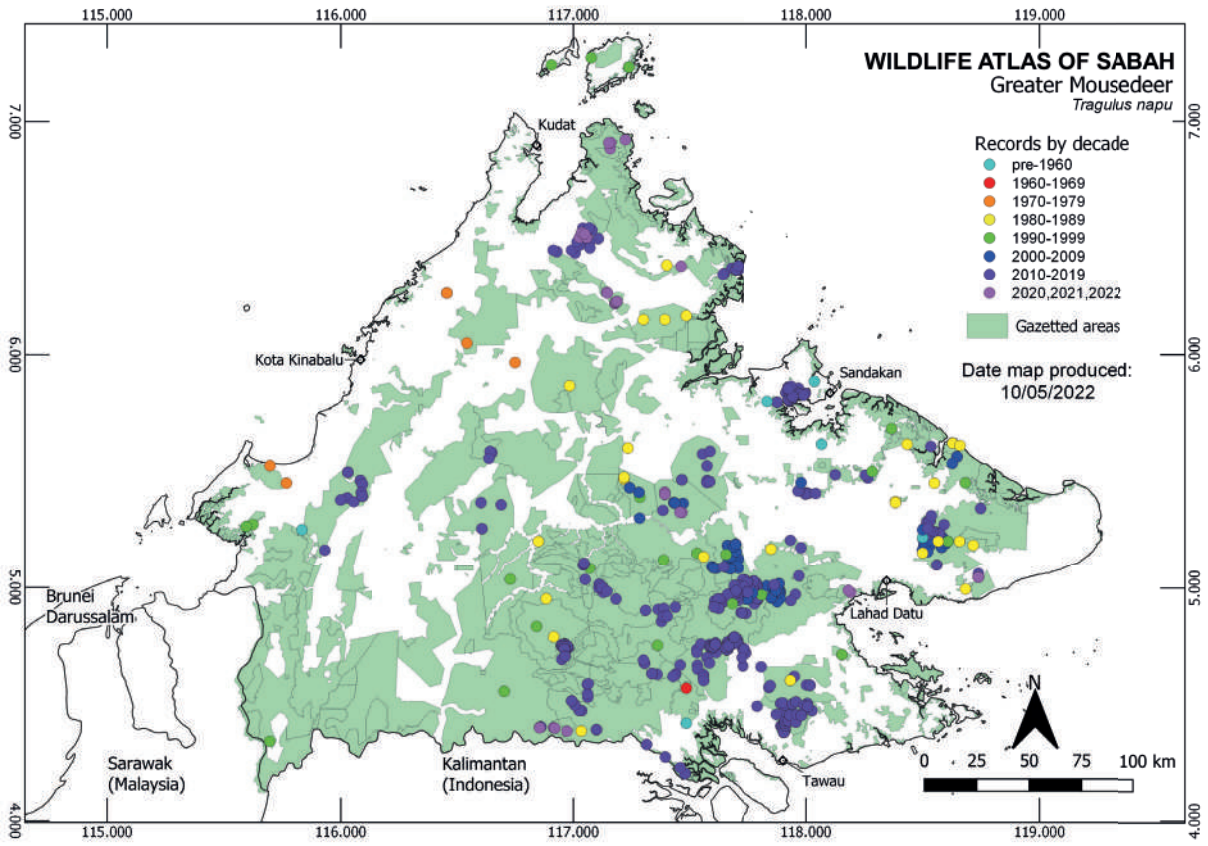


Figure 5. Records of Greater Mousedeer

Conservation

Both Lesser and Greater Mousedeer are categorized as species of 'Least Concern' in the IUCN Red List, which notes also that "unsustainable hunting and logging will cause local extinction of this species". From a Sabah perspective, both species are widespread in lowland and upland forests, and both probably show population declines above 500 m asl.

Brodie et al. (2015b) reported that hunting was a more serious long-term threat than logging for 91% of primate and ungulate species. Both species are vulnerable to being trapped in snares set for any game animal, and are shot at night when hunters pick up the eye-shine of resting animals with torches (Phillipps & Phillipps, 2018). Indeed in Tabin there is ample evidence of hunters using nets and dogs to catch small and medium sized ungulates (Hearn et al., 2017). This hunting pressure exists, despite their small size delivering relatively little meat for the hunting effort, and Davis (1962) observed, "despite their small size and delicate appearance the flesh of these animals is coarse, far inferior to that of the muntjac or sambar deer". The impact of hunting, which cannot be easily separated from vegetation changes because logging opens up the forest to hunters, has not been studied, nor the impact of other predators, and some reports that mousedeer hide underwater to avoid predation (Phillipps & Phillipps, 2018).

Both Lesser and Greater Mousedeer's long-term survival depends on maintaining blocks of both unlogged and well-regenerated logged forests in lowland and upland areas, where there is minimal hunting and trapping. The longer term impacts of climate change have yet to be understood, although it is likely that upland forests may become more important for the species' survival (Brodie, 2016).

Acknowledgements

I would like to thank Dr. Glyn Davies for editorial assistance, Mr. Adi Shabrani for species distribution maps and comments from reviewers: Dr. Jedediah Brodie and Dr. Ollie Wearn. Mousedeer study in Tabin was supported by a Grant-in-Aid for Scientific Research (No.1357027) from the Ministry of Education, Culture, Sports, Science and Technology, Japanese Government.

Data sources

Lesser Mousedeer

Individuals / organizations (Number of records): Haysom, Jessica (2483); Hearn, Andrew (2320); Forest Solution Malaysia (64); Sabah Forestry Department (4); WWF-Malaysia (902). *Open source database (Number of records):* eMammal, 2021 (109). *Publications (Number of records):* Abdullah et al., 1995 (3); Bernard et al., 1997 (1); Boonratana & Sharma, 1993 (1); Boonratana, 1997 (6); Bunya et al., 2010 (1); Chasen & Kloss, 1931 (2); Davies & Tan, 2019 (4); Davies & Payne, 1982 (1); Davis, 1962 (6); Deere et al., 2017 (22); Heydon, 1994 (1); Kee et al., 2018 (1); Kehoe, 2011 (2); Ketol et al., 2009 (1); KOPEL, 2016 (3); KOPEL, 2019 (1); Matsubayashi et al., 2005 (1); Onoguchi & Matsubayashi, 2008 (2); Payne et al., 1989 (1); Prudente et al., 2009 (1); Rajaratnam, 1995 (1); Ross et al., 2013 (6); Samejima et al., 2012 (1); SFD, 2016 (5); SFD, 2017 (4); Shukor et al., 2011 (2); VertNet, 2010 (1); Webb, 2016 (1); Wilting & Mohamed, 2010 (2).

Greater Mousedeer

Individuals / organizations (Number of records): Haysom, Jessica (6830); Hearn, Andrew (1621); Forest Solution Malaysia (31); Sabah Forestry Department (27); Sabah Museum (8); WWF-Malaysia (327). *Open source database*

(Number of records): eMammal, 2021 (16); VertNet, 2010 (1). *Publications (Number of records):* Abdullah et al., 1995 (1); Bernard et al., 1997 (1); Boonratana & Sharma, 1993 (2); Boonratana, 1997 (9); Bornion Timber, 2021 (4); Bunya et al., 2010 (1); Chasen & Kloss, 1931 (2); Davies & Tan, 2019 (3); Davies & Payne, 1982 (25); Davis, 1962 (5); Dawson, 1992 (4); Deere et al., 2017 (19); Heydon, 1994 (1); Kee et al., 2018 (1); Kehoe, 2011 (1); KOPEL Bhd, 2019 (1); Lim, 1993 (1); Lim, 1996 (2); Matsubayashi et al., 2005 (1); Mullin & Colley, 1972 (1); Onoguchi & Matsubayashi, 2008 (2); Payne et al., 1989 (1); Prudente et al., 2009 (1); Rajaratnam, 1995 (1); Ross et al., 2013 (6); Samejima et al., 2012 (1); SFD, 2016 (5); SFD, 2017 (11); SFD, 2018 (2); Shukor, 1996 (3); Webb, 2016 (2); Wilting & Mohamed, 2010 (3).

Carnivores and Pangolin

Melynda Cheok and Adi Shabrani

Borneo, the third largest island in the world, is home to 26 extant species of the Carnivora order, all of which are found in Sabah. With the exception of domestic cats and dogs, all carnivores in Borneo are native to the island. Borneo supports three endemic carnivore species, the enigmatic Borneo Bay Cat (*Catopuma badia*), Hose's Civet (*Diplogale hosei*) and Bornean Ferret-badger (*Melogale everetti*), and two unique Bornean subspecies of Sun Bear (*Helarctos malayanus euryspilus*) and Sunda Clouded Leopard (*Neofelis diardi borneensis*). In prehistoric times, tigers (*Panthera tigris*) were believed to inhabit Borneo based on three osteological specimens in Madai caves (Sabah) and Niah caves (Sarawak), which dated about 14,000 years ago (Cranbrook, 2016). The order Carnivora is derived from the Latin words meaning "to consume flesh", but the name can be misleading as not all of the members of the order are obligate meat eaters. The carnivores have many variations in skull shape and dentition, allowing a varied diet — such as sun bears and Binturongs feeding extensively on fruits (Nakabayashi & Ahmad, 2018).

The Sunda Pangolin (*Manis javanica*) belongs to the order Pholidota and is the only extant member of the order in Borneo. There used to be a second species, the Giant Pangolin (*Manis paleojavanica*) which is believed to have gone extinct around the same time as the tiger's extinction on the island. Their unique features include a fully scaled skin, and they also have no teeth and so feed exclusively on ants and termites.

Both carnivores and pangolins are typically very timid and habitually avoid contact with humans. Pangolins, although seeming capable of hurting humans with their big claws, generally take a defensive stance by curling up when threatened. Furthermore, the carnivores in Sabah are generally small bodied, compared with tigers and leopards in Peninsular Malaysia. Conflict with humans only really arises when sun bears accidentally encounter humans while foraging, or when civets and mongooses raid chicken pens.

Sadly, as noted in the following chapters, a number of carnivores and the pangolin are subjected to poaching by humans. In contrast to other wildlife hunted in Sabah, which is mainly for food, sun bear and pangolin body parts are traded as ornaments, hunting trophies or traditional medicine. The high demand for pangolin scales in traditional medicine has pushed the species to the brink of extinction, and the eight species of pangolins were declared to be the most trafficked species in a global black market, valued at billions of US dollars (Hughes, 2021). While pangolins tend to be collected by targeted hunting, the wide range of carnivore species are often killed as 'bycatch' because they are non-target species captured during food hunting expeditions (Mohd-Azlan et al., 2017). In addition to the focused hunting and trapping, habitat loss and degradation is another fundamental threat to many carnivores.

Around 40% of the carnivore species in Sabah are listed as either 'Vulnerable' or 'Endangered', while pangolins are listed as 'Critically Endangered' in the IUCN Red List. At the local level, Sabah Wildlife Conservation Enactment 1997 provides legal protection to all carnivore species and the pangolin. Under Part I Schedule 1 of the State law, keeping, collecting, killing and selling of wildlife is a crime punishable by fine and/or jail. However, several carnivores (including some IUCN

'Endangered' species) are listed under Part I Schedule 2, which allows for hunting with a license. In spite of that, the demand for carnivore and pangolin body parts within the state seems to be rampant. Sabah has prosecuted 23 cases related to pangolins since 2002 (Miwil, 2019), with the biggest arrest of a smuggling syndicate recording 30 tonnes of pangolins/parts (Pantel & Anak, 2010). In another case, a man was sentenced to jail and fined for the possession of sun bear parts in Kota Kinabalu (Geraldine, 2018). Illegal pet keeping occurs in Sabah as well, with a recent offence in Kota Belud, where the offender was fined RM15,000, in default of four months' jail for illegally keeping a sun bear since 2015 (Anjumin, 2021).

In recent years, conservation of small carnivores in Borneo has been brought into focus through the Bornean Carnivores Symposium (Wilting et al., 2016), where one of the frequently raised issues was the limited data available on Bornean carnivores. The symposium has established the Bornean Carnivore Database to gather data from various resources (some of which are used to produce carnivore maps in this atlas), as well as highlight key areas for conservation in Borneo. Meanwhile, for the pangolin there is an effort from various stakeholders, including the Sabah state government, to establish a pangolin conservation centre to promote conservation and serve as a rescue centre — although the COVID-19 pandemic has delayed the start of this project.

For the purpose of this Wildlife Atlas of Sabah, the editors selected a small range of carnivore species to highlight the rarest species and show the range of ecological niches — from forests to oil palms to rivers, and elaborate on the conservation issues. The selection was constrained by the shortage of detailed field studies in Sabah, but there is enough information to inform general conservation management needs, and it is hoped that later editions of the atlas will include more carnivore species.

Table 1. Wild species of Carnivora and pangolin species in Sabah

Species	IUCN status	SWCE	Diet preferences	Habitat preferences (plantations includes fruit orchards etc.)
Bears (Ursidae)				
Bornean Sun Bear, *Helarctos malayanus**	**VU**	**I**	**Omnivorous[1]**	**Unlogged & logged forest, plantations[1,5]**
Cats (Felidae)				
Borneo Bay Cat, *Catopuma badia*	EN	II	Carnivorous^	Unlogged & old logged forest[6]
Sunda Clouded Leopard, *Neofelis diardi**	**VU**	**I**	**Carnivorous[2]**	**Unlogged & logged forest[7]**
Marbled Cat, *Pardofelis marmorata*	NT	II	Carnivorous[2]	Unlogged & old logged forest[8]
Flat-headed Cat, *Prionailurus planiceps*	EN	II	Fish and aquatic preys[2]	Lowland forested rivers[9]
Sunda Leopard Cat, *Prionailurus javanensis*	LC	II	Carnivorous[2]	Unlogged & logged forest, plantations[10]
Civets (Viveridae)				
Malay Civet, *Viverra tangalunga**	**LC**	**II**	**Omnivorous[2]**	**Unlogged & logged forest, plantations[11]**
Banded Linsang, *Prionodon linsang*	LC	II	Carnivorous[2]	Unlogged & logged forest[12]
Common Palm Civet, *Paradoxurus philippinensis*	LC	II	Omnivorous[2]	Unlogged & logged forest, plantations[12]
Masked Palm Civet, *Paguma larvata*	LC	II	Omnivorous[2]	Unlogged highland forest[13]
Binturong, *Arctictis binturong**	**VU**	**II**	**Largely frugivorous[3]**	**Unlogged and logged forest[14]**
Small-toothed Palm Civet, *Arctogalidia stigmatica*	LC	II	Omnivorous[2]	Unlogged & old logged forest[15]
Banded Palm Civet, *Hemigalus derbyanus*	NT	II	Carnivorous[2]	Unlogged forest & old logged forest[12]
Hose's Civet, *Diplogale hosei*	VU	II	Carnivorous^	Unlogged highland forest[16]
Otter Civet, *Cynogale bennettii*	EN	II	Fish and aquatic prey[2]	Forested lowland rivers and swamp[17]
Mongooses (Herpestiidae)				
Short-tailed Mongoose, *Herpestes brachyurus*	NT	II	Carnivorous^	Unlogged & logged forest[2]
Collared Mongoose, *Herpestes semitorquatus*	NT	II	Carnivorous^	Unlogged & logged forest[18]
Badger (Mephitidae)				
Malay Badger, *Mydaus javanensis*	LC	II	Omnivorous[2]	Unlogged & logged forest[18]

Species	IUCN status	SWCE	Diet preferences	Habitat preferences (plantations includes fruit orchards etc.)
Weasels and Otters (Mustelidae)				
Yellow-throated Marten, *Martes flavigula*	LC	II	Omnivorous[2]	Unlogged & logged forest, plantation edge[12]
Malay Weasel, *Mustela nudipes*	LC	II	Omnivorous[2]	Unlogged & logged forest, plantation edge[12]
Bornean ferret-badger, *Melogale everetti*	EN	II	Not enough known	Unlogged and logged highland forest[19]
Hairy-nosed Otter, *Lutra sumatrana**	**EN**	**II**	**Fish & aquatic prey[2]**	**Forested rivers and swamps[20]**
Smooth-coated Otter, *Lutrogale perspicillata**	**VU**	**II**	**Fish & aquatic prey**	**Forested rivers and swamps[20]**
Asian Small-clawed Otter, *Aonyx cinereus**	**VU**	**II**	**Crustacean & aquatic prey**	**Forested rivers and swamps[20]**
Pholidota				
Pangolin				
Sunda Pangolin, *Manis javanica**	**CR**	**I**	**Specialized ant / termite eater[4]**	**Unlogged & logged forest, plantations[21]**

SWCE status: Totally protected (Schedule 1), Protected — Limited hunting and collection under licence (Schedule 2) and Protected — Hunting licence is required (Schedule 3)

*** Species chapters in this section**

^ Not enough information to confirm its true dietary behaviour.

[1] Wong et al. (2002), [2] Phillipps & Phillipps (2018), [3]Nakabayashi & Ahmad (2018), [4] Zhang et al. (2021), [5]Wong & Guharajan (see Bornean Sun Bear chapter), [6]Mohd-Azlan and Sanderson (2007), [7]Hearn et al. (2018), [8]Hearn et al. (2016), [9]Wilting et al. (2010), [10]Mohamed et al. (2013) , [11]Evans & Goossens (see Malay Civet chapter), [12]Nakabayashi et al. (2021), [13]Semiadi et al. (2016), [14]Nakabayashi et al. (see Binturong chapter),[15]Duckworth et al. (2016), [16]Mathai et al. (2019), [17]Veron et al. (2006), [18]Wong et al. (2018), [19] Wilting et al. (2016), [20]Wai & Goossens (see Otters chapter), [21]Panjang & Goossens (see Pangolin chapter)

17

Bornean Sun Bear (*Helarctos malayanus euryspilus*)

Roshan Guharajan and Wong Siew Te

Introduction

The Bornean Sun Bear in Borneo is the smallest bear in the world, and yet they have a fierce reputation for being dangerous to humans if alarmed (Phillipps & Phillipps, 2018). They are widespread in the State, where they are generally known by the Malay name, *beruang madu*.

Taxonomy

Bornean Sun Bears are considered to be a single species *Helarctos malayanus*, with Borneo populations considered a distinct subspecies (*H. m. euryspilus*) based on differences in skull and dental morphology (Meijaard, 2004). Recent mitochondrial DNA evidence indicates an ancient split between Bornean Sun Bears in the entire Sundaic region (Borneo, Sumatra and Peninsular Malaysia) and mainland bears (Kunde et al., 2017; Lai et al., 2021). Moreover, Lai et al. (2021) report a more recent split between East and West Malaysian bears indicating historical barriers to gene flow within Sundaland. Phylogenetic patterns in this study suggest that Bornean Sun Bears migrated southwards from Indochina during the mid-Pleistocene, when the Sunda shelf was a contiguous landmass. Populations then differentiated in Peninsular Malaysia and Malaysian Borneo during interglacial periods when sea levels rose.

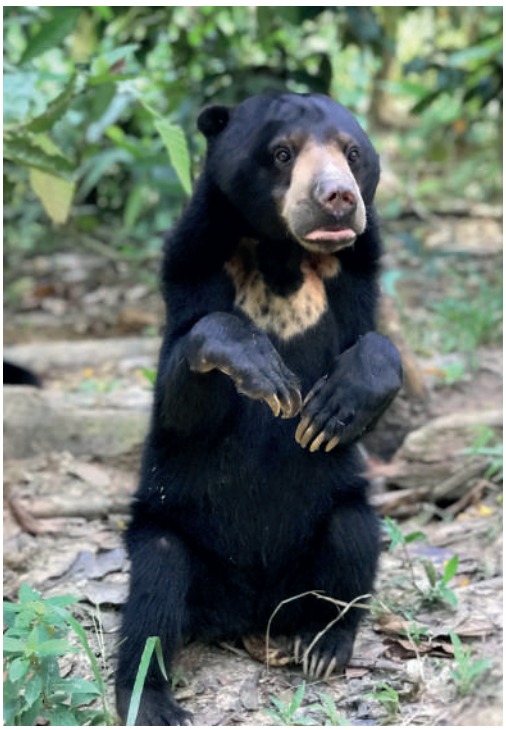


Figure 1. Each Bornean Sun Bear has a distinct and unique chest patch that can be used for individual identification © Wong Siew Te

Natural History

In Sabah, Bornean Sun Bears are opportunistic feeders and dietary generalists that feed on a wide variety of vegetative and animal matter in the forest. Bornean Sun Bears have been recorded consuming more than one hundred species of wild fruits and a variety of invertebrates and their larvae (e.g. ants, termites, earthworms, beetles, millipedes), including bee honey and bee larvae (Figure 2). Small vertebrates such as tortoises and bird eggs are also consumed (Wong et al., 2002) and Bornean Sun Bears have been recorded preying on nesting hornbills (Kunde & Goossens, 2021). Typically, fruit production in the lowland dipterocarp forests of Borneo is sparse, with synchronized mass flowering and fruiting events occurring at irregular intervals of 2 to 11 years (Appanah, 1985) — referred to as mast-fruiting years.



Figure 2. a) 7-month old Bornean Sun Bear foraging on decayed wood for termites and other invertebrates; b) A juvenile showing good climbing skills foraging on a bee hive. Both photos © Wong Siew Te

Populations of Bornean Sun Bear and other mammals experience extended periods of food scarcity during inter-mast intervals (Janzen, 1974; Wong et al., 2005). During mass fruiting events, Bornean Sun Bears incorporate a large variety of fruits in their diet and serve as important seed dispersers. Figs (*Ficus* spp.) are not seasonal masting species, producing fruits year-round and are therefore a very important food source during inter-mast intervals (Wong et al., 2002). Bornean Sun Bears are great climbers and spend a considerable amount of time high up in trees, resting and harvesting fruit and stingless bee hives high on trees. In areas where oil palm fruit is available, Bornean Sun Bears will supplement their diet with this crop (Guharajan et al., 2018). There have been a few cases where Bornean Sun Bears have developed a taste for human foods, such as cooking oil and rice (Wong S.T., pers. obs.), bringing them into conflict situations with people.

The ecological roles of Bornean Sun Bears in the forest ecosystem are closely related to their feeding habits. Seeds of a wide variety of wild fruits they consume are swallowed whole, passed through their digestive tract, and are excreted in the faeces far away from the mother tree. Thus, Bornean Sun Bears play an important role as seed dispersers. When feeding on *Microcerotermes* spp. — a termite species that attacks live trees in the forest — Bornean Sun Bears play a role as "forest doctors" by controlling populations of these termite colonies and protecting many trees

from being attacked by the termites. Bornean Sun Bears also serve as "forest engineers" when they excavate stingless bee hives to feed on their honey and larvae, and create large cavities in trees for cavity nesters like hornbills. They serve as "forest farmers" when they dig forest soils to look for earthworms, enhancing soil aeration and nutrient cycles and promoting seed germination. In short, a Bornean Sun Bear is intricately woven into the complex forest web of life.

Population estimates for Bornean Sun Bears are currently unavailable in Sabah. In a Thai national park, Bornean Sun Bear density was estimated to be approximately 5.9 bear/100 km (Ngoprasert & Gale, 2012). It is possible that Bornean Sun Bear density may be higher in Sabah, where competition for food and space with the larger Asiatic Black Bear does not occur. Home range sizes of Bornean Sun Bears in Sabah have been estimated to be as large as 15 km^2 on average. These were estimated using VHF radio-collars placed on wild animals (Wong et al., 2004). In the state of Pahang, however, wild Bornean Sun Bears fitted with GPS-collars were recorded with much larger home ranges (up to 30 km^2; Cheah, 2013). This discrepancy may be due to GPS-collars generally being able to collect more locations than radio-collars, resulting in larger home ranges, or it could reflect true home range size differences.

Bornean Sun Bear movement patterns seem to be most strongly influenced by the availability of food (Wong et al., 2004). Activity patterns vary greatly and seem to depend on the level of human disturbance. For example, in areas with high levels of human disturbance or at the edge of protected areas, Bornean Sun Bears are mostly nocturnal-crepuscular (Guharajan et al., 2018; Tee et al., 2021), whereas in areas with little human disturbance bears are mostly diurnal (Wong et al., 2004). Information on Bornean Sun Bears breeding in the wild is scarce. There is no defined breeding season (Frederick et al., 2010) and females usually give birth to one cub every few years (Scotson et al., 2017). Female Bornean Sun Bears use natural cavities in the forest, such as fallen hollowed tree trunks and cavities in large standing trees, as dens to give birth and nurse their young (Wong et al., 2004).



Figure 3. A Bornean Sun Bear mother and cub captured on camera trap in Deramakot Forest Reserve © WWF-Malaysia

Table 1. Estimated home range sizes of Bornean Sun Bears from studies in Malaysia

Home range size	Collar type	Method	Location	Reference
14.8 km² (male average)	VHF radio	95% kernel density estimate	Danum Valley FR; Ulu Segama FR	Wong et al., 2004
5.1 km² (male maximum)	VHF radio	Minimum convex polygon	Tabin WR and oil palm plantation	Normua et al., 2004
1.3 km² (female maximum)	VHF radio	Minimum convex polygon	Tabin WR and oil palm plantation	Normua et al., 2004
27.5 km² (male average)	GPS	95% kernel density estimate	Krau WR and oil palm plantation (Pahang)	Cheah, 2013
5.3 (female average)	VHF radio	95% kernel density estimate	Sungai Wain Protection Forest (Indonesia)	Fredriksson, 2012

Distribution in Sabah

Most records are from eastern Sabah where the majority of wildlife surveys were conducted. A recent study (Ng et al., 2021) detected bears in the Bengkoka Peninsula (see orange star; Figure 4) in the north of Sabah, and an ongoing Sabah-wide analysis indicates that large areas of western Sabah are suitable habitat for the species (Guharajan et al., in prep.)

Bornean Sun Bears have been recorded across a wide range of forest types, from primary forests (i.e. Danum Valley, Imbak Canyon, Maliau Basin Conservation Areas, etc.), logged forests (i.e. Ulu Segama Forest Reserve, Tabin Wildlife Reserve, Deramakot Forest Reserve, etc.) to very degraded forests such as the Kinabatangan Wildlife Sanctuary (Guharajan et al., in prep.). They also occur in *Acacia* tree plantations containing small patches of secondary forest (i.e. Bengkoka Forest Reserve and surrounding areas; Ng et al., 2021). Bornean Sun Bear survival in smaller, isolated forest fragments, such as small forest reserves or state land forests (i.e. Kabili-Sepilok Forest Reserve), over the long term is unlikely. There is current evidence that Bornean Sun Bears can use *nipah* and mangrove forests, but a more scientifically rigorous assessment is needed to ascertain the importance of these habitats for their survival.

Threats

Impacts of Selective Logging

Bornean Sun Bears can survive in both currently and previously logged forests (Brodie et al., 2015b; Hwang et al., 2021; Sollmann et al., 2017). However, it seems that forests with higher above-ground carbon density (an indication of more intact forests) are better Bornean Sun Bear habitat (Guharajan et al., in prep.). In logged forests, Bornean Sun Bears have been recorded using hollow logs as bedding sites (Wong et al., 2004).

Impacts of Commodity Plantations and Forest Fragmentation

Bornean Sun Bears can survive in forest fragments surrounded by oil palm (Deere et al., 2018; Guharajan et al., 2018) such as the Kinabatangan Wildlife Sanctuary and Kalabakan Forest Reserve. Their survival in these areas may be due in part to supplementing their natural diet with oil palm fruits (Guharajan et al., 2017), though conflicts with growers seem to be rare so far. Bornean Sun

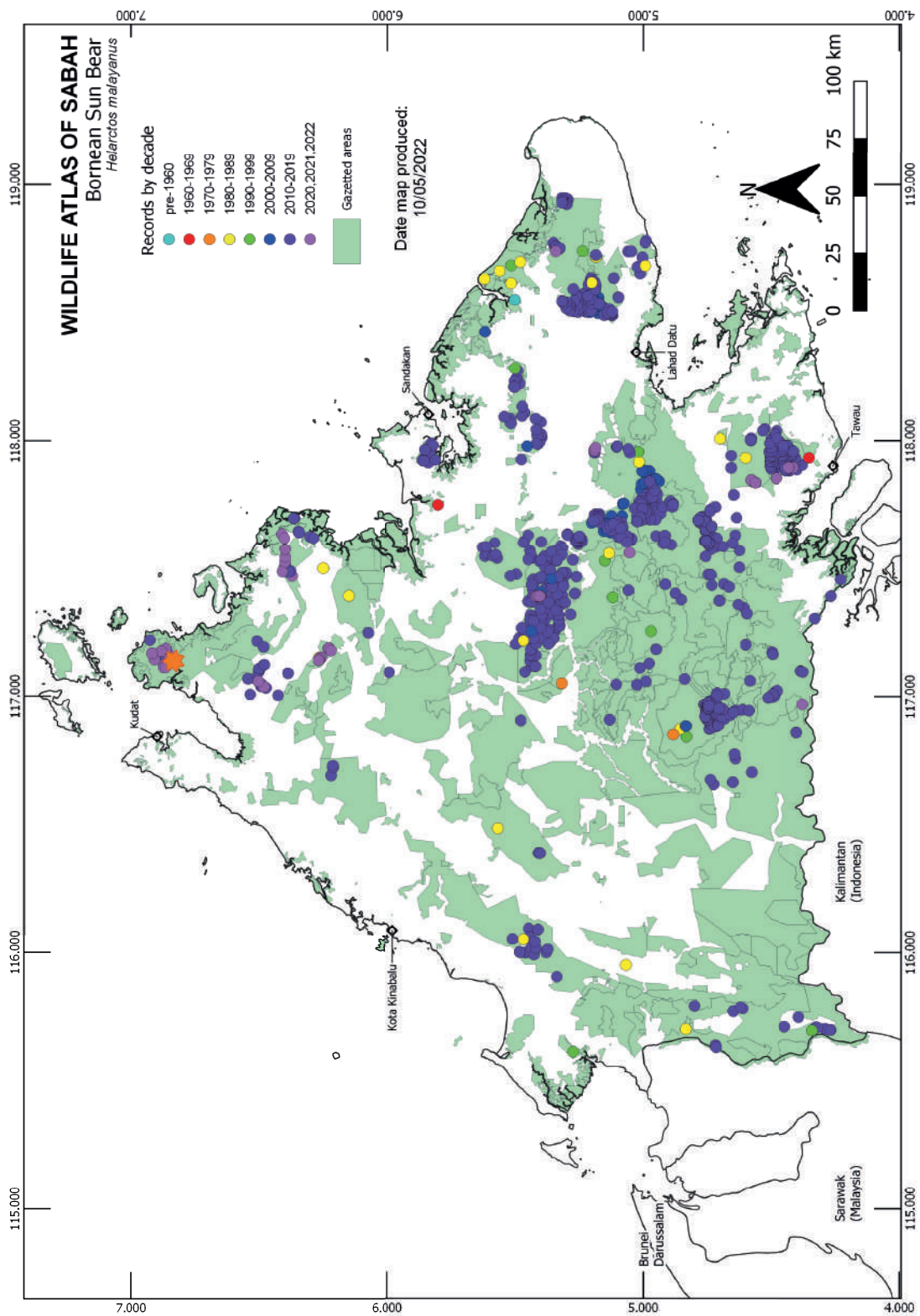


Figure 4. Records of Bornean Sun Bear

Bears have also been detected in *Acacia* plantations containing fragments of natural forest (Ng et al., 2021).

Impacts of Hunting

Precise information on how hunting impacts Bornean Sun Bears is difficult to obtain. However, we may realistically assume that data on Bornean Sun Bear products from Traditional Chinese Medicine shops (Gomez et al., 2020) and bear parts from seizures (Or et al., 2017) represent only a small number of the total bears killed (Crudge et al., 2019). Hunters know the value of bears and bear parts; therefore, bears may be targeted or killed as bycatch. Bornean Sun Bears living near oil palm plantations are especially vulnerable to hunting when they move into planted areas from the forest. Although snaring is used by hunters in Sabah, there is no indication yet of the widespread snaring using steel cables occurring as it does in parts of Peninsular Malaysia. Such levels of snaring would have much greater impacts on Bornean Sun Bears if used in Sabah. Proactive measures to deter such commercial hunting must continue in Sabah to prevent this.

Illegal Wildlife Trade

Bornean Sun Bear bile is illegally used in Traditional Chinese Medicine (TCM). In 2012, a survey of TCM shop owners in Sabah showed that most reported bear bile was sourced locally (i.e. from poached Bornean Sun Bears; Lee et al., 2015). Bornean Sun Bears, especially cubs, are also victims of the pet trade.

Conservation

The continued survival of Bornean Sun Bears in Sabah will depend on continued good practices in sustainable forest management and anti-poaching efforts. The goal to keep at least 30% of Sabah's forests within Totally Protected Areas will certainly be beneficial to Bornean Sun Bears. Even so, there is still a large area (likely 40%) of Bornean Sun Bear range that will remain mostly in Class II Forest Reserves (Commercial Forests). A unified landscape level approach, like the Critical Conservation Landscapes (CCL) being developed by the Forest Research Centre, has the potential to allow for more holistic management and monitoring of Bornean Sun Bear habitat across different forest classes. It is hoped that the CCL programme will obtain the necessary support to ensure its success.

Founded in 2008, Bornean Sun Bear Conservation Centre (BSBCC) aims to conserve Bornean Sun Bears through holistic approaches that incorporate improved animal welfare, education, research, rehabilitation and ecotourism. BSBCC is based at Sepilok, in partnership with Sabah Wildlife Department (SWD), Sabah Forestry Department, and Land Empowerment and People (LEAP). The centre has helped SWD to take care of 66 rescued Bornean Sun Bears as of 2022, and ten of these rescued Bornean Sun Bears have been successfully rehabilitated and released into the wild.

Acknowledgements

WST would like to thank Sabah Wildlife Department, Sabah Forestry Department and LEAP for the partnership to establish BSBCC; Sabah State Government, Malaysia Ministry of Tourism and Culture, Sime Darby Foundation, Hasanah Foundation and many other funding agencies for financial support. We thank Shyamala Ratnayeke for peer review feedback, and Glyn Davies for editorial assistance.

Data sources

Individuals / organizations (Number of records): Brodie, Jedediah (151); Gardner, Penny (185); Haysom, Jessica (739); Hearn, Andrew (827); Guharajan, Roshan (133); Muhammad Edri Nurdin (1); 1StopBorneo Wildlife (4); Forest Solution Malaysia (47); Sabah Forestry Department (4); WWF-Malaysia (228). *Open source database (Number of records):* eMammal, 2021 (6). *Publications (Number of records):* Abdullah et al., 1995 (5); Bernard et al., 2013 (2); Bernard et al., 2014 (2); Bili, 2014 (2); Boonratana, 1997 (7); Boonratana & Sharma, 1993 (1); Chung et al., 2019 (3); Davies & Tan, 2019 (4); Davies & Payne, 1982 (17); Davis, 1962 (1); Dawson, 1992 (2); Deere et al., 2017 (23); Harrison, 1998 (1); KOPEL, 2016 (2); Lim, 1996 (1); Lim, 1993 (2); Mahyudin et al., 2010 (1); Mingueza, 2018 (1); Nakashima et al., 2008 (1); Onoguchi & Matsubayashi, 2008 (1); Payne et al., 1989 (1); Prudente et al., 2009 (1); Samejima & Ong, 2012 (25); Samejima et al., 2012 (1); SFD, 2016 (2); SFD, 2017 (3); SFD, 2018 (1); SFD, 2019 (1); Sheldon & Francis, 1985 (1); Shukor et al., 2011 (2); Sollmann et al., 2017 (3); Tee et al., 2020 (9); Wilting & Mohamed, 2010 (1); York et al., 2013 (1).



Smooth-coated Otters at Kg. Mengkabong © Sarah Lim

18

Smooth-coated (*Lutrogale perspicillata*), Asian Small-clawed (*Aonyx cinereus*) and Hairy-nosed (*Lutra sumatrana*) Otters

Leona Wai and Benoit Goossens

Taxonomy

Otters belong to the subfamily: Lutrinae and are grouped together with martens, weasels and badgers, under the order: Carnivora and family: Mustelidae (Payne & Francis, 2007; Phillipps & Phillipps, 2016). There are 13 otter species distributed around the world and only four can be found in Sabah: Smooth-coated Otter (*Lutrogale perspicillata*), Asian Small-clawed Otter (*Aonyx cinereus*), Hairy-nosed Otter (*Lutra sumatrana*) and Eurasian Otter (*Lutra lutra*). In Sabah, Smooth-coated and Asian Small-clawed otters are commonly seen, meanwhile the Hairy-nosed Otter is rare and there have been only a few sightings. The Eurasian Otter was claimed to be extinct in Borneo during the Borneo Carnivore Symposium in 2011, but in 2015 there was a single photograph of Eurasian Otter taken from Danum Valley Conservation Area. No other recent records have been found, and so it will not be described in this chapter.

The Smooth-coated and Asian Small-clawed otters are widely distributed across Asia, with confirmed presence in Nepal, India, Bangladesh, Bhutan, Southwest China, Myanmar, Thailand, Vietnam, Philippines, Indonesia, Singapore and Malaysia (Hussain et al., 2011; Payne & Francis, 2007; Phillipps & Phillipps, 2016; Sivasothi & Nor, 1994). Both species are well-adapted to many aquatic habitat types, which include montane, peat swamp and mangrove forests, coastal areas, paddy fields and even in oil palm plantations (Khan et al., 2010; Sivasothi & Nor, 1994).

The rare Hairy-nosed Otter is known to occur in Malaysia, Brunei, Indonesia, Thailand, Cambodia and Vietnam (Kruuk, 2006; Sasaki et al., 2009; Wright et al., 2008), where it is believed to occur in swamps, mangroves and lowland flooded forests, mountain streams and occasionally, oil palm plantation streams (Kruuk, 2006; Latifiana & Pickles, 2013; Payne & Francis, 2007; Phillipps & Phillipps, 2016; Sivasothi & Nor, 1994; Wai et al., 2021, Wright et al., 2008). In the past, direct sightings of Hairy-nosed Otter were very rare and its occurrence was only determined by specimen/

skin records (Sasaki et al., 2009). Recently, the species has been rediscovered via direct sightings, photographic evidence and roadkill carcasses in many regions, such as Cambodia (Long, 2000), Indonesia, including Sumatra (Latifiana & Pickles, 2013; Lubis, 2005), Vietnam (Dang et al., 2001) and Malaysia (Tan, 2015). Hairy-nosed Otter was not seen in Borneo for almost 100 years until it was rediscovered in Deramakot Forest Reserve via a camera-trap image (Wilting et al., 2010). Since then, there have been a few more sightings of Hairy-nosed Otter in Sabah: Tabin Wildlife Reserve (Ishigami et al., 2017), Deramakot Forest Reserve (Guharajan, pers. comm., 2018; Gordon, pers. comm., 2019; Wai et al., 2021) and Danum Valley Conservation Area (Pain, 2020).

Natural History

The largest among the three otter species, the Smooth-coated Otter's body length ranges from 1–1.2 m and weight ranges from 8–11 kg (Hussain, 2013; Payne & Francis, 2017; Phillipps & Phillipps, 2016). The fur appears to be velvety; the upperpart fur is brown and creamy underneath the neck towards the stomach area (Figure 2). Smooth-coated Otters are piscivorous mammals; their diet is dominated by fish, although they occasionally eat frogs, small monitor lizards, smaller mammals, insects and snakes (Foster-Turley, 1992; Kruuk, 2006). Their droppings, called spraints, are usually in a large pile with strong fishy smell and consist mainly of fish scales and bones (Kruuk, 2006). They are mostly active during the day (diurnal) but may also be seen travelling at night. They are very social mammals, with family group size ranging from 2–20 individuals. Smooth-coated Otters have been observed demonstrating cooperative hunting behaviours, which makes it easier for them to catch prey (Khan et al., 2010).

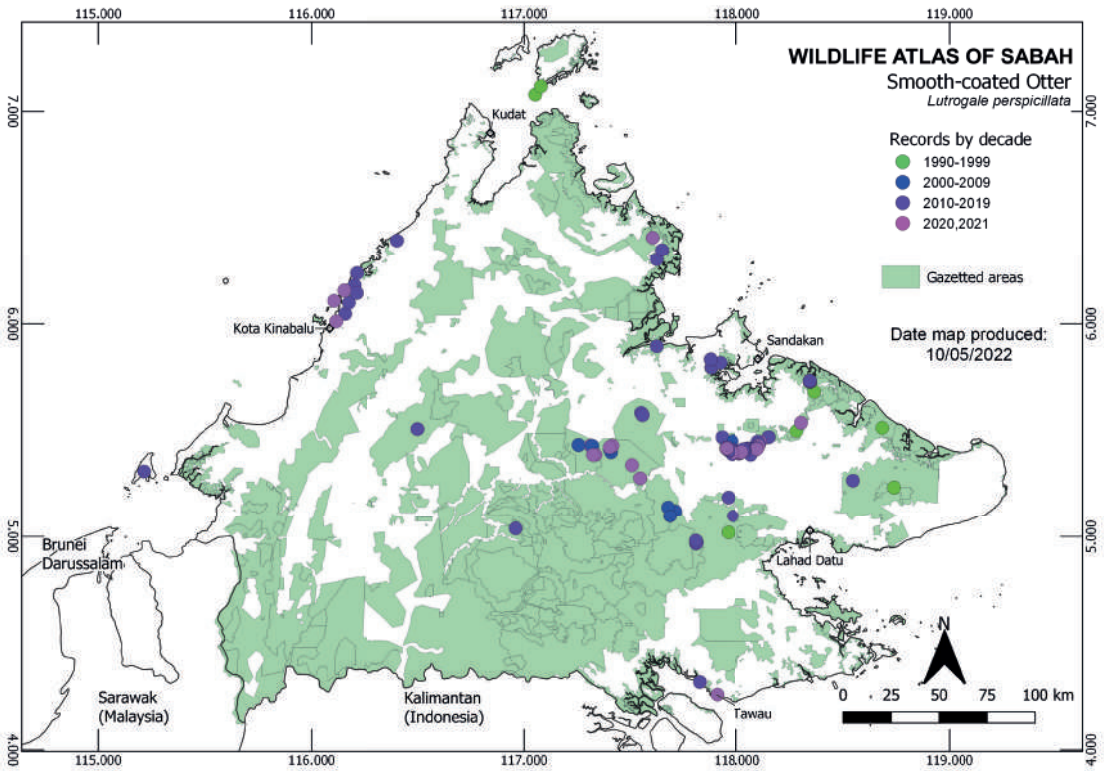


Figure 1. Distribution of Smooth-coated Otter — recorded along the large rivers in Eastern Sabah, the west coast, and even up on Trus Madi (1,200 m)



Figure 2. Smooth-coated Otter resting on a river bank in Lower Kinabatangan Wildlife Sanctuary © Rudi Delvaux

Being the smallest of the three species, the Asian Small-clawed Otter's body length ranges from 0.4–0.7 m and their weight ranges from 2–5 kg (Hussain et al., 2011; Payne & Francis, 2007; Phillipps & Phillipps, 2016;). The fur is brown and slightly pale on the underparts (Figure 4). The Asian Small-clawed Otter has a rounder head and narrow web between toes. It has small claws that are not visible on its footprint tracks. This species is mostly active during the night (nocturnal) but may be seen in the daytime too. Asian Small-clawed Otters' main diet is crabs, shrimps, other crustaceans and molluscs, occasionally smaller fish and insects (Foster-Turley, 1992; Hussain et al., 2011). They are very social animals, with family group size ranging from 2–12 individuals (Hussain et al., 2011).

Both species are highly adaptable to disturbed environments. They can survive in human dominated landscapes such as urban areas, man-made fish ponds, paddy fields and oil palm plantations. In Singapore, Smooth-coated Otters have been documented using completely bare and vertical cement pipes for their dens, or in otter terms, holt (Theng & Sivasothi, 2016). Although they can survive in a heavily disturbed environment, this type of habitat is not natural nor optimal



Figure 3. A group of Smooth-coated Otters roaming freely in a park in Singapore © Bernard Sean



Figure 4. Asian Small-clawed Otter foraging for food at Tawau Hills Park © Shavez Cheema

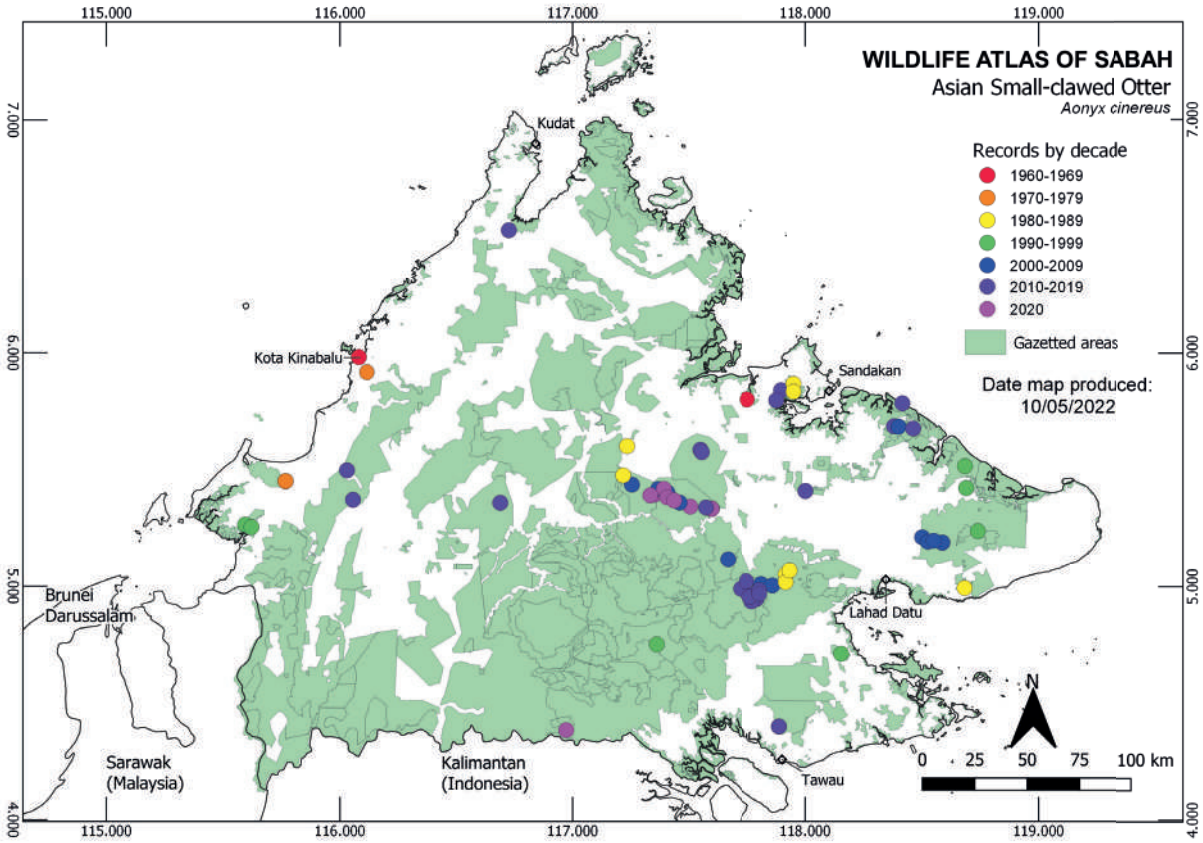


Figure 5. Distribution of Asian Small-clawed Otter

for them and may affect their natural behaviour and physiology. In their natural habitat, both of these species prefer habitats with dense vegetation with many natural trees on the river bank for building their holts, as well as habitat with good water quality and with high abundance of prey (Anoop & Hussain, 2004; Shenoy et al., 2006). Although these two species can occur in the same habitat, their habitat selection is mostly influenced by their prey preferences. Smooth-coated Otters often prefer big rivers with high abundance of large-sized fish, while Asian Small-clawed Otters will choose smaller streams with high abundance of crustaceans and molluscs.

One of the most distinctive features of Hairy-nosed Otters compared to other Bornean otter species is that they have dark fur and white fur on the lips, chin and upper throat (Figure 6). They also have thick whiskers which make their nose appear to be hairy (Kruuk, 2006; Wright et al., 2008). Their body length ranges from 0.5–1 m and their weight ranges from 3–8 kg (Payne & Francis, 2007; Wai et al., 2021; Wright et al., 2008). This species is seen to be active throughout the day and usually solitary, but can also be found in groups of up to six individuals. Its diet consists mainly of fish, and sometimes snakes, frogs, crustaceans, insects and small mammals (Kanchanasaka, 2001; Kruuk, 2006). Its spraint is usually in a cylindrical shape that does not emit a detectably strong fishy smell, and usually found at the base of a large tree or log (Kanchanasaka, 2001).

Hairy-nosed Otters are a very elusive species and very sensitive to human disturbance, therefore it is difficult to see and study them in the wild (Kruuk, 2006; Wright et al., 2008). Little is known



Figure 6. Hairy-nosed Otter walking on the side of the road at Danum Valley Conservation Area © Deborah Pain

about their habitat preferences but they are believed to prefer well-vegetated habitats with sufficient food sources and less human disturbance. They are known to occur in swampy areas and small streams. In Sumatra, the Hairy-nosed Otter was seen in mangrove swamp forests (Latifiana & Pickles, 2013) and in Thailand, it was seen in higher altitude rocky streams (Sivasothi & Nor, 1994). In Sabah, the sightings of Hairy-nosed Otter occur in lakes, main roads and oil palm plantations, although all these areas are adjacent to swamp areas (Wai et al., 2021).

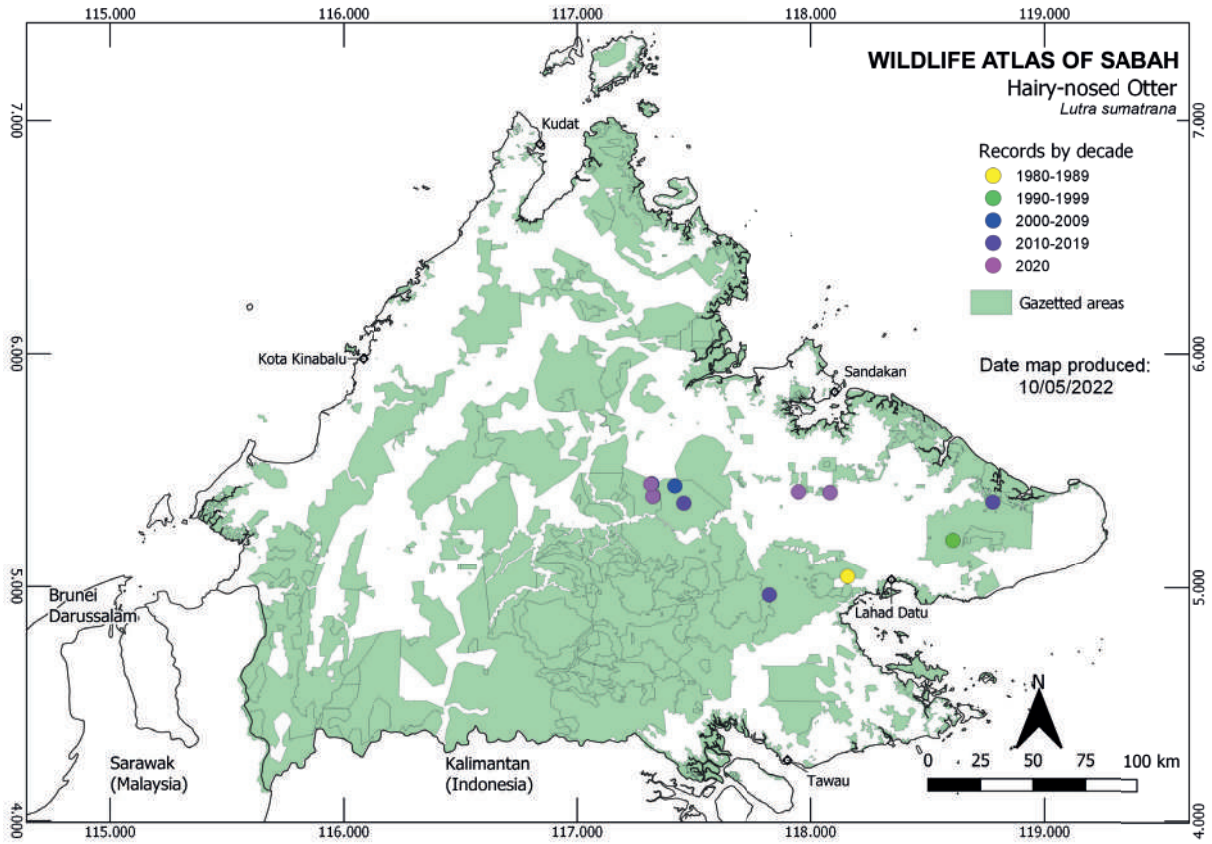


Figure 7. Records of Hairy-nosed Otter

Threats and Pressures

Otters are facing many threats that could lead to their population declines, which include loss of riparian forest/wetland habitats, water pollution (with agricultural chemicals), illegal hunting as well as human-otter conflict (Anoop & Hussian, 2004; Bedford, 2009; Duplaix & Savage; 2018; Gomez & Bouhuys, 2018; Khan et al., 2010; Kruuk, 2006; Peterson & Schulte, 2006; Prakash et al., 2014). Human activities in riparian forests decrease habitat quality, thus causing otter populations to decline (Anoop & Hussain, 2004; Bedford, 2009; Peterson & Schulte, 2006). Since otters use both aquatic and terrestrial environments, they are vulnerable to habitat changes in both ecosystems. Furthermore, an increase in road construction can increase otters' vulnerability. For example, in the Kinabatangan District alone in 2020, three different species of otters were killed on roads.



Figure 8. Roadkill of the rare Hairy-nosed Otter in Lower Kinabatangan Wildlife Sanctuary © Norsalleh Taing



Figure 9. Asian Small-clawed Otter on public display © Aaron Gekoski/World Animal Protection

Another dangerous threat to otters is illegal hunting for fur and pet trade across different species in Asia (Duplaix & Savage, 2018; Gomez & Bouhuys, 2018; Kruuk, 2006; Khan et al., 2010; Prakash et al., 2014; Rao et al., 2010). The scale of illegal otter trade in Sabah is still unknown due to lack of records, but hunters will target otter cubs by killing the parents, and keep the cubs in cages. In Indonesia, wild otters are captured, bred and sold as pets (Gomez & Bouhuys, 2018; World Animal Protection, 2019). The demand for pet otters is further boosted by social media, where cute otter videos are constantly displayed. Although there have been reports of otters being kept as pets in Sabah, it is not a major threat at the present time.

Human-otter conflict continues to rise in an alarming rate as humans encroach into otters' habitats. The conversion of natural freshwater into commercial fish farms is forcing otters to forage food in human-modified landscape (Khan et al., 2010; Poledníková et al., 2013). Otters are often considered as pests by fishermen and fish farmers because they steal their fish and damage their fishing equipment (Khan et al., 2010; Kruuk, 2006; Michalski et al., 2012; Poledníková et al., 2013; Prakash et al., 2014), causing them to have a negative perception towards otters. There are also reports of otters causing secondary damage; fish dying from stress due to otter predation (Adamek et al., 2003; Poledníková et al., 2013). In Malaysia, otters have been reported to steal fish and shrimp from aquaculture projects (Foster-Turley, 1990). There have been a few reports where otters were poisoned and killed cruelly by fish farmers in Peninsular Malaysia.

Table 1. Protection status of the otter species in Sabah

Otter species	Current Population Trend	Sabah Wildlife Conservation Enactment (1997)	IUCN Red List	CITES
Asian Small-clawed Otter	Declining	Schedule II	Vulnerable	Appendix I
Smooth-coated Otter	Declining	Schedule II	Vulnerable	Appendix I
Hairy-nosed Otter	Declining	Schedule II	Endangered	Appendix II
Eurasian Otter	Declining	Not listed	Near Threatened	Appendix I

Conservation

Otters will continue to decline in Sabah because of the threats they are facing, and proper conservation action needs to be implemented to ensure they do not go extinct. Otters are often neglected in terms of conservation due to lack of information, and a thorough survey should be conducted promptly across the whole state. The information obtained can help us to better understand their population trends, distribution, habitat preferences, as well as identify and understand the local threats in detail to inform conservation planning and policy-making processes.

Besides research, strict regulation and law enforcement is also important for otter conservation. The species is currently listed in Schedule 2 under the Sabah Wildlife Conservation Enactment 1997, where otters can still be hunted with limited licence. In order to control the illegal trade of otters, we need to strengthen their protection status by upgrading otters to Schedule 1, where hunting is prohibited and there is a higher penalty for offenders. However, regulations and laws are not enough, they should be enforced strictly by the enforcement agencies. Enforcement agencies should have a good relationship and communication with one another to ensure offenders will be caught and prosecuted effectively. Moreover, monitoring of online (social media, websites) and offline (market) trade should be done regularly.

Wetland or riparian forests should be protected areas, and protection for otters' critical habitats should be strengthened, such as Lower Kinabatangan and Segama Wetlands (78,803 ha) which is an international Ramsar site including the Lower Kinabatangan Wildlife Sanctuary, Deramakot Forest Reserve, Danum Valley and Imbak Canyon Conservation Areas, Tabin Wildlife Reserve, and a number of west coast rivers and estuaries, such as the Tuaran River stretch. Thorough Environmental Impact Assessment (EIA) should be done before starting any development project that will involve wetland habitat to assess the impact of the project towards otters and other wildlife.

Besides engaging and educating, we need to invest extra effort to reduce human-otter conflict amongst people whose livelihoods depend heavily on fish products. Local fishermen and fish farmers need to be involved in discussions and planning on the best methods to reduce human-otter conflict in their areas. Budget and other resources should be allocated to implement mitigation actions, and offer compensation on damages caused by otters. Creating alternative livelihoods for people who are affected by otters is also one of the ways to reduce human-otter conflict. Continuous effort and long-term planning are key to change people's behaviour and mindset towards otters.

Finally, the public, including local and international tourists, plays a huge role in ensuring successful otter conservation. We need to engage and educate the public about the importance of

otters to the environment and promote living in harmony with otters, especially in conflict areas. The public should be encouraged to participate in otter conservation efforts, which can be as simple as maintaining the cleanliness of rivers by not throwing rubbish.

Acknowledgements

Deepest thanks to our sponsors, Sime Darby Foundation, Houston Zoo, Cardiff University and Full Circle Foundation, for supporting our otter research project. Sincere thanks to Danau Girang Field Centre, Universiti Malaysia Sabah, Institute for Tropical Biology and Conservation, KOPEL, IUCN Otter Specialist Group, Sabah Forestry Department and Sabah Wildlife Department for the collaboration and support for this project. Thanks to Glyn Davies for editorial input and everyone who has contributed to the otter species records in Sabah.

Data Sources

Smooth-coated Otter

Individuals / organizations (Number of records): Gardner, Penny (1); Hearn, Andrew (16); Lee, Clement (3); Li, Frank (1); Lim, Sarah (7); Quentin, Phillipps (1); Porter, Lindsay (34); Wai, Leona (30); 1StopBorneo Wildlife (1); DGFC (5); HUTAN KOCP (1); WWF-Malaysia (7). *Publications (Number of records):* Bernard et al., 2013 (1); Boonratana & Sharma, 1993 (2); Boonratana, 1997 (3); KOPEL, 2016 (1); Prudente et al., 2009 (1); Shukor, 1996 (2); Sollmann et al., 2017 (3); Wai, 2019 (34); Wilting & Mohamed, 2010 (1); Wilting et al., 2010 (1).

Asian Small-clawed Otter

Individuals / organizations (Number of records): Brodie, Jedediah (2); Guharajan, Roshan (1); Hearn, Andrew (19); Wai, Leona (21); 1StopBorneo Wildlife (2); SFD-FRC (1); Sabah Museum (7); WWF-Malaysia (1). *Publications (Number of records):* Abdullah et al., 1995 (2); Bernard et al., 1997 (1); Boonratana, 1997 (2); Bornion Timber, 2021 (1); Davies & Payne, 1982 (9); Kehoe, 2011 (1); Lim, 1996 (2); Rajaratnam, 1995 (1); Regip, 2003 (1); Samejima et al., 2012 (1); Sollmann et al., 2017 (3); Wilting & Mohamed, 2010 (1); Wilting et al., 2010 (1).

Hairy-nosed Otter

Individuals / organizations (Number of records): Burger, Richard (1); Gordon, Mike (1); Pain, Deborah (1); Wai, Leona (5); WWF-Malaysia (1). *Publications (Number of records):* Davies & Payne, 1982 (1); Dawson, 1992 (1); Ishigami et al., 2016 (1); Rudi et al., 2016 (1); Wilting et al., 2010 (1).

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Malay Civet (*Viverra tangalunga*)

Meaghan N. Evans and Benoit Goossens

Introduction

The Malay Civet, (*Viverra tangalunga*; Gray, 1832) also known as the Malayan Civet, Oriental Civet or Tangalung, is one of the 34 currently recognised extant species of the Viverridae family, which broadly includes civets, genets, and oyans (Jennings & Veron, 2009). Although this diverse family has undergone revisions following systematic molecular evaluations (e.g. Nyakatura & Bininda-Emonds, 2012; Patou et al., 2008; Veron et al., 2015), the taxonomy of Malay Civets has largely remained consistent (Veron et al., 2014). The species is classified as a member of the Viverrinae subfamily with five additional species of both Asian and African Civets (Jennings & Veron, 2009), and diverged from its sister species approximately 4.6 million years ago (Gaubert & Cordeiro-Estrela, 2006).



Figure 1. Malay Civet (*Viverra tangalunga*) © Rudi Delvaux

Currently, Malay Civets are found throughout the Sundaic and Wallacea regions of Southeast Asia, including Borneo, Peninsular Malaysia, several islands of Indonesia and the Philippines, and Singapore (Duckworth et al., 2016; Jennings & Veron, 2011; Lim & Ou Yang, 2012). Genetic analyses conducted by Veron et al. (2014) concluded Borneo was likely the ancestral origin of the species, and natural dispersal to other regions occurred during the Pleistocene. However, their results also concluded populations located east of Wallace's Line (e.g. Sulawesi, the Moluccas) and some islands in the Philippines were likely introduced by humans, although the explicit reason for such transportation remains unknown.

Natural History

Malay Civets are the second largest viverrid in Borneo after the Binturong (*Arctictis binturong*), with most adults weighing approximately 3–7 kg (Evans, 2019). Capture-based studies have reported some geographic variance in civet body weight; animals in Peninsular Malaysia (Jennings et al., 2010) were significantly heavier than those sampled in Sabah (Colón, 2002; Evans, 2019) and Sulawesi (Jennings et al., 2006), although differing sample sizes and field methodologies may confound the full extent of this pattern. Furthermore, there is evidence El Niño-Southern Oscillation (ENSO) climatic events influence the body weight of Malay Civets (Evans, 2019; Seymour et al., 2017), likely due to the associated altered patterns of plant part production within tropical landscapes (e.g. Harrison, 2001).



Figure 2. Malay Civet, showing the unique markings © Rudi Delvaux

Each animal bears a black and white pelage patterned with a striking combination of spots and stripes (Figure 2); individual civets can be identified by these unique markings. The species displays male-dominated sexual dimorphism for several different body measurements across its range (Colón, 2002; Evans, 2019; Jennings et al., 2006; Jennings et al., 2010; Sum, 2011). As with all Viverridae species, both male and female Malay Civets have a pronounced perineal scent gland that produces a pungent secretion. Also called 'civet oil', these secretions contain civetone, an aromatic macrocyclic compound (Sack, 1915). Although the role of these glands has not explicitly been assessed in wild Malay Civets, other species use them to mark territory boundaries (Randall, 1979) or display reproductive readiness (AZA, 2010).



Figure 3. Camera-trap photograph of an adult female Malay Civet with a kit in the Lower Kinabatangan Wildlife Sanctuary © M. Evans

Malay Civets are behaviourally solitary except for breeding females accompanied by kits (Figure 3); camera traps in Sabah photographed adult females with one or two kits (Evans, unpub. data). Previous observations suggested civets may have reproductive cycles coinciding with either dry (Davis, 1962; Wade, 1958) or wet seasons (Colón, 1999). However, within six years of sampling, Evans (2019) did not document any temporal predictability of breeding in the Kinabatangan Floodplain. In captivity, females gave birth to between 1–3 kits with no observable predictability (Razak Jaffar, pers. comm.). Gestation duration is unknown, but is likely similar to those of other civet species (e.g. approx. 65–80 days in captive African Civets *Civettictis civetta*; Ewer & Wemmer, 1974; 67 days in captive Small Indian Civets *Viverricula indica*; Balakrishnan & Sreedevi, 2007). The age of dispersal and sexual maturation are similarly unknown.

Despite being a member of the order Carnivora, Malay Civets are broad dietary generalists, eating fruit, insects, amphibians, reptiles, and small mammals including bats (Colón & Sugau, 2012; Guharajan et al., 2017; Joscelyne, 2014; Macdonald & Wise, 1979). The species has been observed scavenging (Lim et al., 2020; Twining et al., 2017), although such opportunistic behaviours are

unlikely to form a central part of the diet. As active frugivores, Malay Civets have the potential to act as natural seed dispersers; indeed, Joscelyne (2014) recorded successful germination of assorted seeds extracted from civet faeces. Dietary intake may be influenced by landscape composition, as comparative serum biochemistry profiles suggest civets captured closer to oil palm (*Elaeis guineensis*) plantations may consume diets lower in protein than individuals sampled within more forested areas (Evans et al., 2020b).

Malay Civets are predominantly nocturnal, and crepuscular activity peaks have been recorded using both camera traps and telemetry (e.g. Azlan, 2005; Colón, 2002; Ross et al., 2017). In Sabah, GPS-collared male civets travelled between an average of 1–3.8 km per night, and the total length of an animal's nocturnal path was influenced by moon phase, rainfall, and accessed habitats (Evans, 2019). Specifically, males travelled the farthest on nights with low rainfall and during the third quarter moon. Nightly path lengths also reached a maximum when animals used both forests and oil palm plantations, and were shorter when individuals exclusively remained in either type of land cover (Evans, 2019). During daytime hours, civets created diurnal nesting sites, usually in protected features such as logs, dense undergrowth, or vine tangles that provide cover from predators, direct sun, and rain (Jennings et al., 2006; Jennings et al., 2010).

Deployments of remote tracking collars on Malay Civets have recorded a broad range of home range sizes: estimates vary from 27 ha in Kalimantan (Nozaki, 1994) up to 527 ha in the Kinabatangan Floodplain in Sabah (Evans, 2019). Intermediate home range sizes were recorded in Danum Valley (mean 110 ha, n=12) (Colón, 2002), Sulawesi (mean 71 ha, n=7) (Jennings et al., 2006), Peninsular Malaysia (mean 143 ha, n=5) (Jennings et al., 2010), and Sarawak (50 ha, n=1) (Macdonald & Wise, 1979). Using movement-based home range models, Evans et al. (2021) reported a mean total home range of 113 ha (n=19) for males collared within the Kinabatangan Floodplain. In programmes that collared both sexes, male and female ranges did not differ in size. Furthermore, although civets are not considered territorial, data from concurrent tracking indicated males were rarely located within 100 m of each other (Evans, unpub. data).

Distribution in Sabah

Malay Civets have been recorded within a variety of habitats, including montane forests, both primary and secondary lowlands, peat swamps, within agricultural (notably oil palm and *Acacia mangium*) plantations, active logging concessions, and human settlements (e.g. Bernard et al., 2014; Cheyne et al., 2010; Duckworth et al., 2016; Maiwald et al., 2021; Mathai et al., 2010; Mathai et al., 2017; Mohd-Azlan et al., 2020b; Payne et al., 1985; Razali et al., 2018; Yue et al., 2015). Despite individuals documented up to 2,100 m, Malay Civets are most commonly considered a lowland species (Duckworth et al., 2016; Ross et al., 2016), although this may be influenced by survey bias.

Within Sabah, Malay Civets have been recorded within nearly all areas surveyed (Figure 4), and models by Ross et al. (2016) indicated most of Borneo is considered suitable habitat. Although the species does display a degree of spatial tolerance to disturbed and urbanised landscapes, there is evidence of an upper threshold to this persistence (Jailan et al., 2018; Jennings et al., 2015; Twining et al., 2017). To date, there have been no comprehensive assessments quantifying Malay Civet densities nor total population sizes at the state-wide scale. Research by Colón (2002) in Sabah determined civet densities were lower in the logged versus unlogged forests of Danum Valley (0.93 and 2.17 indiv/km^2, respectively). Transect-based surveys by Heydon & Bulloh (1996)

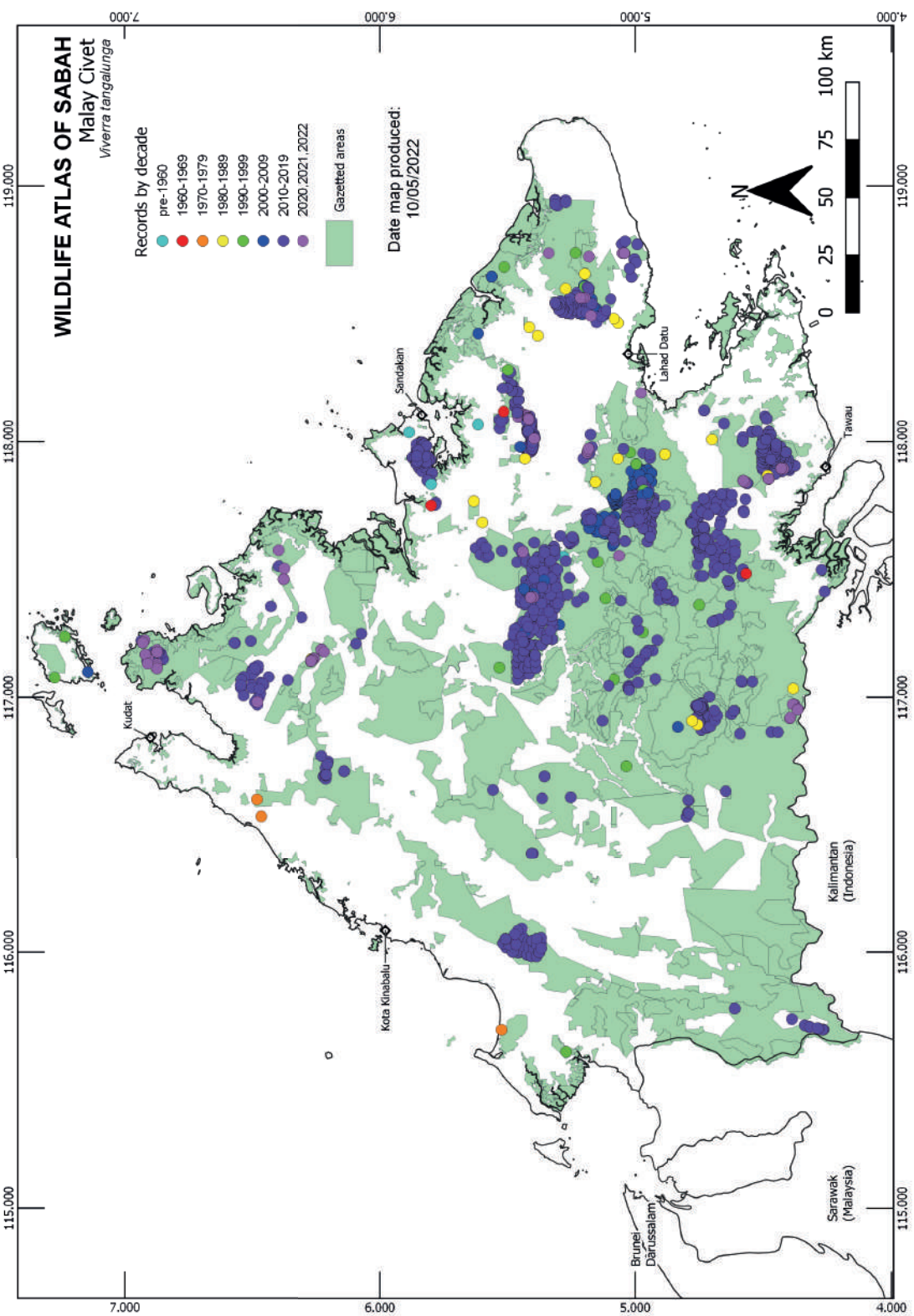


Figure 4. Malay Civet records

recorded similar results in Ulu Segama Forest Reserve. Following distance sampling protocols, localised Viverridae densities were derived from combining all observations of civet species, and and estimates for logged forests (6.4 indiv/km^2) were significantly lower than for primary forests (31.5 indiv/km^2). In Sulawesi, Malay Civet densities (1.36 indiv/km^2) were not significantly related to climatic events (Seymour et al., 2017).

To date, there have yet to be any reports of individuals surviving solely within agricultural or urbanised areas, which likely means Malay Civets require some degree of native vegetative cover (e.g. Evans et al., 2021; Jennings et al., 2010; Sudrajat & Putro, 2019). Indeed, in the heavily degraded Kinabatangan Floodplain, the size of Malay Civet home ranges scaled with the proportion of oil palm plantation contained within the range of a tracked individual (Evans et al., 2021a), indicating agricultural land is of lower suitability than even remnant and degraded forests for this generalist species. Collared Malay Civets most intensively used areas close to forest/oil palm plantation boundaries (Evans et al., 2021a). Surprisingly, nearly half of the males fitted with GPS-collars in the Kinabatangan Floodplain slept within the boundaries of oil palm estates (Evans, 2019; Evans et al., in prep.); further analysis of such adaptive behaviour is warranted.

Cultural Significance

Malay Civets are consumed as wild meat in Malaysian communities (Murphy, 2007; Shepherd & Shepherd, 2010; Yi & Mohd-Azlan, 2020); following a raid of an open-air market in Nabawan, Sabah, officials seized two carcasses of Malay Civets illegally sold for bush meat (Sabah Wildlife Department, pers. comm.). Although there are reports that civet oil is used in Asia for unspecified medicinal purposes (Jennings & Veron, 2009), we are not currently aware of any products derived from Malay Civets that hold medicinal or ornamental value within Sabahan culture. Due to the common perception of the species as a poultry- and crop-raiding pest, persecution of Malay Civets is, however, anecdotally commonplace.

Conservation

The Malay Civet is classified as 'Least Concern' by the IUCN with a stable population trend (Duckworth et al., 2016), and is not listed on CITES. Within Sabah, the species is a Schedule 2, Part 1 protected animal under the Wildlife Conservation Enactment (Sabah Wildlife Department, 1997), meaning it can be hunted with a governmentally issued licence. Outside of Sabah, legal status varies, with coverage broadly falling under general wildlife protection laws or ordinances; the species is not legally protected in Brunei or Indonesia (Azlan, 2003; Ross et al., 2016; Shepherd, 2008; Shepherd & Shepherd, 2010).

Despite their apparent persistence across a variety of habitats, land use changes and their associated anthropogenic stressors remain the main threats to Malay Civet populations. The development of roads negatively impacts localised civet populations, as the species is a commonly recorded fatality from vehicle collisions (Azhar et al., 2013; Healey et al., 2020). Linear infrastructure projects such as the Pan Borneo Highway will increase the rates of wildlife mortalities via direct collision, facilitated human access to once-remote forests, and further disruption to landscape-level population connectivity (Mohd-Azlan et al., 2020b; Sloan et al., 2019). Further, the loss and fragmentation of tropical forests is linked to increased hunting, poaching, and additional human

degradation of remnant habitat patches, such as illegal logging (e.g. Azhar et al., 2013; Deere et al., 2020; Gray et al., 2018). As most of the hunting in the tropics is reportedly opportunistic (Corlett, 2007), relatively abundant species such as Malay Civets are more likely to be encountered, and thus are commonly harvested in hunting surveys, regardless of permitting laws (e.g. Yi & Mohd-Azlan, 2018; Yi & Mohd-Azlan, 2020). Although international wildlife trade does not directly target Malay Civets to the same extent as species such as tigers or pangolins, it nonetheless poses indirect danger; the harvest of economically valuable species using non-selective and destructive traps, such as snares, within habitats used by civets will negatively impact local populations (Gray et al., 2018; Harrison et al., 2016).

Similarly, habitat loss and fragmentation carry epidemiological implications for both civet and, indeed, human populations. Given the increased accessibility of once-remote civet habitat paired with the species' ability to use altered landscapes, Malay Civets may be more readily exposed to diseases commonly found in domestic animals, such as canine distemper, feline, and/or canine parvovirus (e.g. Demeter et al., 2009; Piewbang et al., 2020; Xinyu et al., 2019). Conversely, civets are capable of transmitting zoonoses such as rabies (Susetya et al., 2008), coronaviruses (Bell et al., 2004), influenza (Roberton et al., 2006), *Toxoplasma gondii* (Tober et al., in prep.), and a suite of additional pathogens (Wicker et al., 2017) to humans. As seen in both the 2002 SARS-CoV and the ongoing SARS-CoV-2 pandemics, wildlife vectors can be directly threated with retaliatory actions (e.g. Neupane, 2020; Turcios-Casco & Gatti, 2020; Wang & Eaton, 2007).

In addition to diseases, Malay Civets are likely exposed to a variety of substances associated with humans such as pollutants. Ecotoxicological investigations by Evans et al. (2022) established preliminary evidence of both spatially-mediated and physiologically-impactful levels of heavy metals detected within Malay Civets alongside oil palm plantations. Concurrently, it is likely civets are at risk of poisonings from the use of anticoagulant rodenticides in agricultural and urban landscapes (Jennings, pers. comm.; Verwilghen, 2015).

Human-exploitation of Malay Civets may pose a future conservation concern for this species. Live civets have been observed for sale in wildlife markets across the region, although the explicit purpose of these sales is unknown (e.g. Nijman et al., 2014; Shepherd, 2008; Shepherd & Shepherd, 2010). Civets are increasingly in demand for both local and international pet trade; Roberts (2020) recorded nearly one million civet owners and enthusiasts across multiple social media platforms. Although the full extent of Malay Civet pet ownership is unknown, this easily-accessible and expanding online infrastructure supporting the captivity of small carnivores may springboard future human-wildlife conflicts.

Finally, expansion of the perfume or the *kopi luwak* (civet coffee) industries may distally threaten the species. Although civetone can be artificially synthesised (Choo et al., 1994), demand for animal-sourced products has led to the continued wild-capture and farming of civet species across several countries in Asia and Africa (Jennings & Veron, 2009), and growth of this market could impact Malay Civets. *Kopi luwak* is one of the most expensive beverages in the world, and is a delicacy made from coffee beans extracted from civet faeces (D'Cruze et al., 2014). Although production of *kopi luwak* is most frequently associated with palm civets (e.g. Carder et al., 2016; Shepherd, 2012), there are reports of Malay Civets within production establishments in Indonesia (Lewis-Whelan, unpub. data; Roberts, 2020); the true extent of the impact of this industry on the region's small carnivores is likely underestimated.

Acknowledgements

Field research was supported by Houston Zoo; the Sime Darby Foundation; Ocean Park Conservation Foundation Hong Kong; and Phoenix Zoo. We thank the Sabah Biodiversity Centre and the Sabah Wildlife Department for the approval and support of this research. We also appreciate peer-review feedback from Mohd-Azlan Jayasilan and editorial input from Glyn Davies.

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Individuals / organizations (Number of records): Brodie, Jedediah (271); Evans, Meaghan (107); Gardner, Penny (108); Guharajan, Roshan (813); Haysom, Jessica (1816); Hearn, Andrew (5611); Lim Wing Shen (1); Muhammad Edri Nurdin (1); 1StopBorneo Wildlife (2); DGFC (224); Forest Solution Malaysia (129); Sabah Forestry Department (20); Sabah Museum (3); WWF-Malaysia (324). *Open source database (Number of records):* eMammal (108); VertNet (2). *Publications (Number of records):* Abdullah et al., 1995 (4); Bernard et al., 1997 (1); Bernard et al., 2013 (3); Bernard et al., 2014 (3); Bili, 2014 (2); Boonratana, 1997 (9); Boonratana & Sharma, 1993 (1); Bornion Timber, 2021 (4); Chasen & Kloss, 1931 (1); Chung et al., 2019 (6); Colon & Sugau, 2012 (4); Davies & Payne, 1982 (21); Davies & Tan, 2019 (1); Davis, 1962 (3); Dawson, 1992 (1); Deere et al., 2017 (51); Evans et al., 2020 (49); Granados, 2016 (2); Harrison, 1998 (1); Hawkins et al., 2019 (1); Heydon, 1994 (1); Kee et al., 2018 (1); KOPEL, 2016 (1); KOPEL, 2019 (1); Lim, 1996 (1); Mahyudin et al., 2010 (1); Matsubayashi et al., 2011 (5); Nakabayashi et al., 2014 (2); Onoguchi & Matsubayashi, 2008 (2); Payne et al., 1989 (2); Prudente et al., 2009 (1); Rahman & Abdullah, 2002 (1); Samejima & Ong, 2012 (2); Samejima et al., 2012 (1); SFD, 2016 (7); SFD, 2017 (17); SFD, 2018 (2); SFD, 2019 (2); Shukor, 1996 (2); Sollmann et al., 2017 (3); Twining et al., 2015 (71); Webb, 2016 (4); Wells et al., 2005 (1); Wells et al., 2007 (1); Wilting & Mohamed, 2010 (3); Wilting et al., 2010 (1); York et al., 2013 (1).

20

Binturong (*Arctictis binturong*)

Miyabi Nakabayashi, Henry Bernard and Jedediah F. Brodie

Introduction

The Binturong is the largest member of the civet family (Viverridae), and the only Old-World Carnivora species with a prehensile tail. It has long fur, is relatively slow moving, and largely arboreal. The species is distributed from South Asia (Bangladesh, Bhutan, India, and Nepal) and southern China throughout mainland Southeast Asia (Cambodia, Lao PDR, Myanmar, Thailand, and Vietnam) to insular Southeast Asia (Indonesia, Malaysia, and Philippines). It is unconfirmed in Brunei Darussalam though likely to occur there. The species is classified as 'Vulnerable' by the IUCN Red List, with a decreasing population trend, but lacks a range-wide conservation action plan (Willcox et al., 2016).



Figure 1. a & b) Adult Binturong using prehensile tail to lower itself onto a branch in a tall tree crown in Maliau Basin Conservation Area © Jessica Haysom/DICE; c) Adult Binturong moving high in the canopy in Mt. Louisa Forest Reserve, showing distinctive white ear tips © Jessica Haysom/DICE

Taxonomy

The Binturong is the sole species in the genus *Arctictis*. A recent phylogeny based on sequencing the species' mitochondrial genome suggests that the Binturong is closely related to the palm civets, within the Paradoxurinae subfamily (Mitra et al., 2019). The sister genus to *Arctictis* may be *Paguma*

(the Masked Palm Civet), with which it is sympatric in Sabah and elsewhere (Mitra et al., 2019). The most recent common ancestor for the palm civets (including the Binturong), and the terrestrial civets (e.g. genus *Viverra*), lived about 23 million years ago. Nine subspecies of Binturongs are traditionally recognized based on pelage colour and body size variation, with the Sabah population belonging to the subspecies *A. binturong* ssp. *pageli* (Cosson et al., 2007). More recent genetic work, however, suggest that the species has two distinct groupings (one in Indochina and the other in the Sunda region), with the Borneo population potentially being a different subspecies (*A. binturong* ssp. *penicillatus*) (Veron et al., 2020).

Genetic differentiation between populations in Borneo and other regions is lower in Binturong than in other carnivores, such as Small-toothed Palm Civet (*Arctogalidia trivirgata*), suggesting that Binturong dispersal across the Sundaic region may have occurred more recently or else ongoing dispersal has resulted in higher gene flow among populations (Veron et al., 2020). The morphology of the Binturong is unique among civets, with the fur long, black and coarse, and a muscular, prehensile tail (Cosson et al., 2007). Body weight in adults can exceed 20 kg (Willcox et al., 2016).

Natural History

The species is largely arboreal, but appears to descend to the ground more frequently than had once been thought (Chutipong et al., 2014; Grassman et al., 2005b), and is regularly detected by ground-level camera-trap surveys (Willcox et al., 2016).

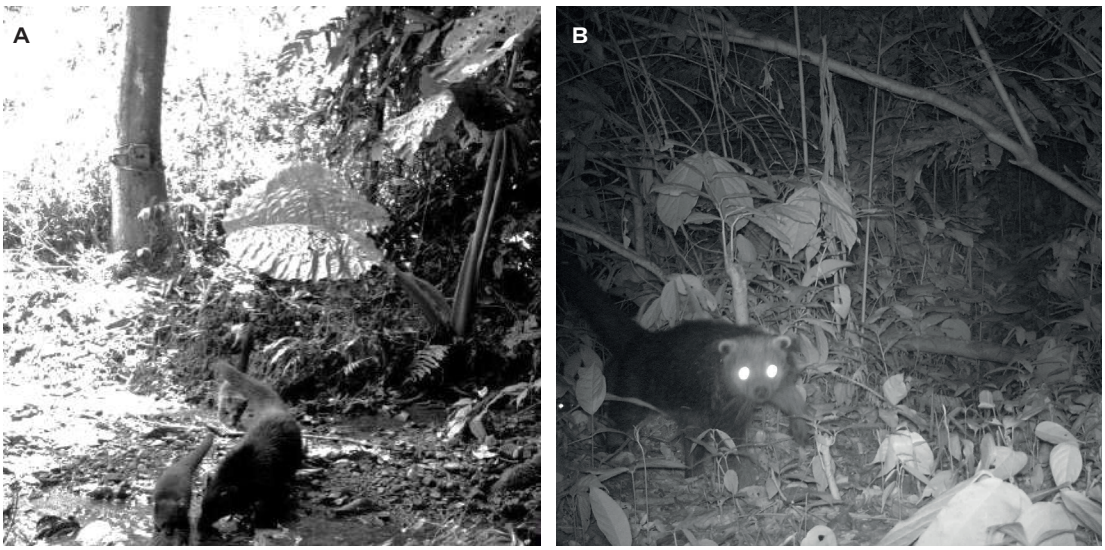


Figure 2. a) Camera-trap photograph of a Binturong mother and kits at 290 m elevation in Maliau Basin Conservation Area © J. Brodie and O. Helmy; b) Adult female Binturong captured on camera trap set along a trail in Danum Valley Conservation Area © Tomoko Kanamori

Binturongs are mostly frugivorous (Willcox et al., 2016), and may feed extensively on figs (*Ficus* spp.) (Murali et al., 2013). Indeed, a radio-collared female Binturong in Danum Valley was observed to feed only on seven species of *Ficus* over a 16-month period while apparently ignoring other fruiting taxa (Nakabayashi et al., 2017). Subsequent work with three radio-collared individuals in the same

study area found 13 *Ficus* and four non-*Ficus* food species, with fig trees accounting for ~88% of the feeding sites and largely driving the short-term movements of the collared animals (Nakabayashi & Ahmad, 2018). Binturongs are also thought to supplement their diet with small vertebrates, carrion, leaves, and may even occasionally catch fish by swimming and diving (Nowak & Paradiso, 1991).

The strong dependency on figs in their diet (70%) is largely provided by strangling figs (hemiepiphytic) species that typically have large canopies and fruit crops. When fruit from strangling figs and other foods were scarce or unavailable, Binturongs switched their diet to the world's largest-fruited fig species, *Ficus punctata*, as a fallback food (Nakabayashi & Ahmad, 2018). Binturongs tend to feed in the same fruiting trees, and have been recorded on one tree for up to 13 continuous days (Nakabayashi & Ahmad, 2018). They have unique defecation habits, depositing faeces on tree forks, branches, and epiphytic mats in the canopy that form suitable sites for strangling fig seed germination. Indeed Binturongs were estimated to be substantially more effective dispersers of fig seeds than other prominent fig consumers, such as gibbons and hornbills (Nakabayashi et al., 2019). Seed dispersal by Binturongs increases establishment success of strangling figs (Nakabayashi et al., 2019).

There are data on Binturongs from radio-collar studies in Danum Valley and Maliau Basin (Nakabayashi & Ahmad, 2018) that show estimated home range sizes of three females at each site, recorded over the course of 232 to 441 days, were 4.24 ± 0.79 [SD] km² (95% fixed kernel) and 1.54 ± 0.89 km² (95% Minimum Convex Polygon). In the drier forests of Thailand, a male Binturong in Phu Kieo Wildlife Sanctuary had an average home range size of 6.2 km² and an average home range overlap of 35% (Grassman et al., 2005b), and for a female in Thung Yai Naresuan Wildlife Sanctuary, it was 6.9 km² (Chutipong et al., 2014).

Daily activity patterns are highly variable and irregular (Zaw et al., 2008), with some studies reporting mostly nocturnal and crepuscular (at dawn and dusk) activity (Grassman et al., 2005b) and others reporting frequent diurnal (daytime) activity (Nettelbeck, 1997). Little is known about their social systems, although Binturongs give birth to litters of typically 1–3 kits (up to six in captivity) after gestation of ~92 days (Lekagul & McNeely, 1977). Adult size is reached in about one year and lifespan may be up to 18 years (Lekagul & McNeely, 1977). The generation time is considered to be ~6 years (Willcox et al., 2016).

Distribution in Sabah

Though likely widely distributed in forested areas of Sabah, confirmed Binturong records are sporadic and mostly from the central and eastern portions of the state (Figure 3), a pattern strongly influenced by the location of areas where studies have been focused (i.e. Binturongs can be reliably detected only where thorough surveys occur). Binturong abundance or population density has not been rigorously estimated in Sabah or elsewhere in the species' range.

Binturongs generally occur in lowland evergreen or seasonal forests but are thought to avoid wetland and peat areas (Willcox et al., 2016), though this is debated (Semiadi et al., 2016). The Binturong was never recorded in a camera-trapping survey conducted from June 2015 to May 2018 in the mangrove forest of Abai, located near the estuary of the Kinabatangan River (Bernard et al., 2021). The species is mainly found in lowland areas from sea level to ~400 m (Esselstyn et al., 2004; Rabor et al., 1986), though it has been detected over 1,000 m in Borneo (Hearn et al., unpub. data).

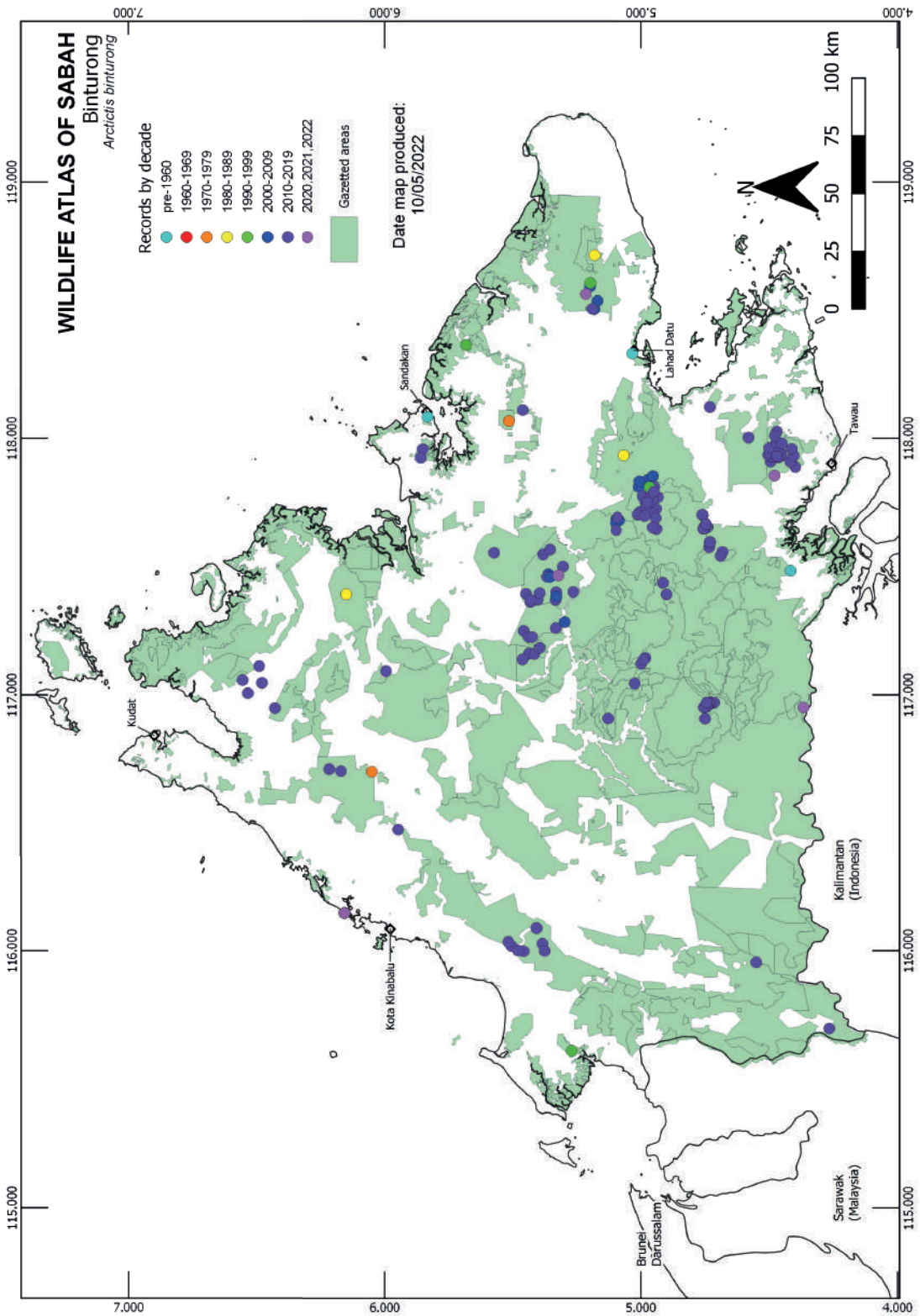


Figure 3. Records of Binturong

Threats

Impacts of Logging

Binturongs are thought to be strongly affected by logging, and absent from heavily degraded forests (Willcox et al., 2016). Detections of the species tend to be from large tracts of intact, evergreen forest (Duckworth et al., 1999). Nevertheless, Binturongs also occur in logged and secondary forests either where the logging was light, the logging occurred long enough ago that forest conditions had recovered somewhat, or where logged areas are interspersed with unlogged forest (Azlan, 2003; Brodie et al., 2015b; Esselstyn et al., 2004; Mathai et al., 2010; Meijaard et al., 2008; Samejima et al., 2012).

Records from Sabah confirm Binturongs in both logged and unlogged forests (Hearn et al., unpub. data; Brodie et al., 2015b), but not in oil palm plantations. In a camera-trapping study in Imbak Canyon Conservation Area, Binturongs were detected in unlogged but not logged forest sites (Bernard et al., 2013). In Tabin Wildlife Reserve, camera-trapping surveys in logged forests (lowland mixed-dipterocarp rainforest, logged around 1974) and in three forest fragments (<30 ha) located within a large (5,200 ha), and mature oil palm estate (10–15 years after planting) did not capture any photograph of Binturong (Bernard et al., 2014a). The forest fragments inside the oil palm were located <1.7 km from the nearest forest boundary (Bernard et al., 2014a).

A camera-trapping survey conducted over ~13 months in intact and rehabilitated, formerly fire-damaged peat swamp forests in Klias Forest Reserve, western Sabah, did not record Binturong (Bernard et al., 2019c). In a rapid (2 weeks) but extensive camera-trap survey covering both the Danum Valley Conservation Area (DVCA) and the greater Danum ecosystem (i.e. including the buffer zones outside of the DVCA) conducted in August 2016, Binturongs were detected at only one site in unlogged forest near Mt. Tribulation in the southwest of the conservation area. A large-scale Bayesian multi-species occupancy modeling analysis across Sabah and Sarawak showed that Binturong occurrence was strongly reduced in recently logged areas; but in areas that had been logged ≥10 years previously, Binturong occurrence was not significantly different from in unlogged forests (Brodie et al., 2015b).

Impacts of Agriculture and Infrastructure

In general, the species is thought to be intolerant of forest loss such as conversion to monoculture plantations; camera-trapping and other surveys have not recorded the species from rubber or oil palm estates (Willcox et al., 2016). Binturongs were not detected in a camera-trapping study of oil palm plantations near the DVCA in Sabah (Yue et al., 2015), though they were also not detected in that study in the DVCA itself, despite occurring there.

Impacts of Hunting and the Pet Trade

Binturongs are hunted throughout their historical range, which may have contributed to their current absence from many parts of northern Southeast Asia (Willcox et al., 2016). The species is hunted for food and traditional medicines, both for personal consumption and for markets (Bell et al., 2004; Corlett, 2007; Datta, 1999; Naniwadekar et al., 2013; Roberton, 2007; Shepherd, 2008; Shepherd & Shepherd, 2010). In China, Lao PDR, Vietnam, and parts of India, the meat of Binturongs and other civets is sought after as a delicacy (Bell et al., 2004; Roberton, 2007; Willcox et al., 2016). Binturongs are also frequently taken in non-targeted snaring to which they are susceptible, despite

largely being arboreal, when they move on the ground (Duckworth et al., 1999; Naniwadekar et al., 2013; Willcox et al., 2016). Binturongs are common in the pet trade in countries such as Lao PDR, the Philippines, Vietnam, and, potentially to a lesser degree, Indonesia (Willcox et al., 2016). The species is also captured for use in the production of *kopi luwak* (civet coffee) in Sumatra, Indonesia (M. Nakabayashi, pers. obs.; Willcox et al., 2016).

In Malaysian Borneo, a Bayesian multi-species occupancy analysis suggested that Binturongs were strongly negatively impacted by hunting; predicted occurrence across camera-trapping sites was much lower when detection of human hunters or their dogs was high (Brodie et al., 2015b). Interestingly, the effect of hunting on predicted Binturong occurrence was about as strong as the effect of recent selective logging though, as noted above, the impacts of logging on Binturong occurrence attenuated after about a decade (Brodie et al., 2015b).

Impacts of Climate Change

The Binturong is primarily a lowland species, while much of the remaining intact or lightly logged forests in Sabah are in hilly and sub-montane areas. If Binturongs are susceptible to rising temperatures, they therefore have a reasonable amount of higher-elevation forested areas to move into, as long as suitable corridors are maintained to allow these elevation range shifts (Williams et al., 2020b). Many lowland mammals in Malaysian Borneo appear minimally affected by recent temperature fluctuations (Brodie et al., 2017), though temperatures are now beginning to rise beyond historical ranges. But climate change adaptation in this (and other) species may not be as easy as simply 'relocating uphill'. As a primarily frugivorous species, Binturongs will depend on their preferred fruit plants either already being present at higher elevations or else being able to shift their ranges upwards at the same rate as the animals themselves. Such shifts in plant distributions could be hindered by edaphic changes at higher elevations (Ashton, 2014) and by altered precipitation patterns, which are difficult to predict. Moreover, climate change could alter fruiting phenology, potentially exacerbating periods of food scarcity for frugivorous animals such as the Binturong.

Conservation

Given that crop monocultures and urban areas are not viable habitats for Binturong, the expansion of these areas will negatively impact the species. There may be little additional forest clearance for oil palm expansion in Sabah because the state is striving towards jurisdictional certification from the Roundtable on Sustainable Palm Oil, which would prohibit forest clearance for plantation development. Increasing size of urban areas and other settlements is a concern, as is the expansion of the road network, for example with the Pan-Borneo Highway and its feeder roads, which will certainly fragment and destroy Binturong habitat.

Malaysia's commitment to the Convention on Biological Diversity (1992) and the tri-national Heart of Borneo Conservation Initiative, along with the state's intention to protect 30% of its land as Totally Protected Area, mean that a higher proportion of forest cover could be retained in Sabah than in many other parts of Southeast Asia. Moreover, with the explicit focus on habitat connectivity embodied in all of these agreements, the forest cover that is retained should hopefully be relatively well-connected. For example, in a state-contracted effort to prioritize new areas for elevated conservation status to achieve the 30% protection goal, a focus was made on securing areas

that enhanced connectivity between existing protected areas and that linked lowland and highland areas to facilitate climate-induced species range shifts (Williams et al., 2020b). This improved connectivity could be supplemented with enrichment of degraded habitats with planting of fig trees.

Without robust estimates of Binturong population density in different forest types, and lacking information on their dispersal behaviour and meta-population structure, it remains impossible to assess precisely how changes in forest cover and conservation status across Sabah will affect the long-term viability of Binturongs. Nevertheless, given their relatively small home ranges and short movement distances, Binturongs probably exist at higher densities than many larger mammals in Sabah, and could be expected to have a low risk of near-term extinction unless other unforeseen threats emerge.

Acknowledgements

Permissions for the various research projects in Sabah reported upon here were granted by the Sabah Biodiversity Centre and, in the case of earlier studies, the Economic Planning Unit of Malaysia. Most studies also depended on support from agencies such as the Sabah Forestry Department, Yayasan Sabah, the Sabah Wildlife Department, and/or Sabah Parks as well as local communities. Most of the projects reported on herein are also indebted to numerous field technicians and guides in the forests and communities where they worked. We are grateful to Maddy, Kon, Azz, Kenneth, Albert, Farizal, Taufiq, P. Salutan, and O. Helmy for their assistance in the field. Thanks also to Glyn Davies and Mohd-Azlan Jayasilan for editorial and peer review of this manuscript.

Data Sources

Individuals / organizations (Number of records): Brodie, Jedediah (13); Dee Arnielia Gundeh (15); Gardner, Penny (2); Haysom, Jessica (105); Hearn, Andrew (51); Guharajan, Roshan (12); 1StopBorneo Wildlife (2); Forest Solution Malaysia (4); Sabah Forestry Department (1); Sabah Museum (1); WWF-Malaysia (7). *Open source database (Number of records):* eMammal (5). *Publications (Number of records):* Abdullah et al., 1995 (1); Bernard et al., 2013 (2); Bili, 2014 (1); Boned et al., 2016 (1); Boonratana & Sharma, 1993 (1); Davis, 1962 (3); Dawson, 1992 (1); Deere et al., 2017 (3); Heydon, 1994 (1); Kee et al., 2018 (1); Lim, 1996 (1); Nagano et al., 2019 (1); Nakabayashi et al., 2014 (1); Nakabayashi et al., 2016 (1); Onoguchi & Matsubayashi, 2008 (2); Samejima & Ong, 2012 (9); Samejima et al., 2012 (1); SFD, 2017 (3); SFD, 2018 (1); SFD, 2019 (1); Wilting & Mohamed, 2010 (1); Wilting et al., 2010 (1); Wong, 2011 (1).



A male Sunda Clouded Leopard photographed by camera trap in the Tawau Hills Park © A. J. Hearn/WildCRU

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Sunda Clouded Leopard (*Neofelis diardi*)

Andrew James Hearn

Introduction

The Sunda Clouded Leopard, *Neofelis diardi*, is a medium sized wild cat found only on the islands of Borneo and Sumatra, where they are closely associated with forest habitats. The species is infrequently observed, a reflection of both its cryptic nature and its rarity, and remains as one of the world's least known and most threatened felids. On Borneo, in the absence of tigers, *Panthera tigris*, and leopards, *Panthera pardus*, this felid is the apex predator, and likely exerts important top-down regulatory pressures on the wider ecosystem. The Sunda Clouded Leopard is highly charismatic and requires extensive tracts of prey-rich forest to survive, and thus has the potential to be a powerful ambassador species (Macdonald et al., 2017).

Also referred to as Diard's Clouded Leopard, the local names for this felid vary greatly among the diverse communities in Sabah, and include *tananansad* (Dusun), *duarong* (Orang Sungai), *engkuli* (Iban), and *harimau dahan* (Bahasa Malaysia) or branch tiger, reflecting their arboreal tendencies. The species' English common name stems from both their Sunda shelf distribution and the distinctive cloud shaped markings on their coats. The insides of these marking, which are partially edged in black, are darker than that of the pelage's base colour, which is typically grey to tawny in colour. Melanistic and pale coloured animals have been reported from Borneo (e.g. Davies & Payne, 1982; Payne et al., 1998; Rabinowitz et al., 1987), but photographic evidence is lacking, despite the increasingly extensive camera-trapping effort throughout the species' range, which strongly suggests these colour forms are very rare.

The limbs are relatively short, whereas the tail is exceptionally long. The canines are longer relative to skull size than any other living felid (Guggisberg, 1975). The Sunda Clouded Leopard is highly sexually dimorphic. The males appear far more robust, typically weighing around 24–25 kg, which is more than double that of the females (Figure 1), which weigh around 11–12 kg (Hearn et al., 2018a; Nájera et al., 2017). Interestingly, detailed observation of camera-trap images indicates that the hair on adult males' tail is sleek, giving the appearance of a proportionately thinner tail, when compared to the apparently thick and fluffy tail of females and sub-adult males (A. J. Hearn, pers. obs.), which may be a mechanism to facilitate identification and to reduce aggressive encounters between male and females.

Taxonomy

The clouded leopards belong to the genus *Neofelis* (Gray, 1867) and are members of the subfamily Pantherinae (Pocock, 1917). Clouded leopards represent the earliest divergence from this lineage and are thought to have shared a common ancestor approximately 5.67 million years ago (Li et al., 2016). Until 2006 it was regarded as a monospecific genus (Wozencraft, 2005). However, studies have revealed that populations on the Sunda islands are genetically and morphologically distinct from those on the mainland, and two clouded leopard species – *N. diardi* (Cuvier, 1823) on Borneo and Sumatra and *N. nebulosa* on mainland Southeast Asia – are now recognized (Buckley-Beason et al., 2006; Christiansen, 2008; 2009; Kitchener et al., 2006; Wilting et al., 2007). The island and mainland forms are estimated to have split during the Mid-Pleistocene, approximately 1.4–2.0 million years ago (Buckley-Beason et al., 2006; Li et al., 2016; Wilting et al., 2011). An analysis of the genetic, skull and pelage characteristics of Sunda Clouded Leopards concluded that there are two distinct subspecies (Wilting et al., 2011), the Sumatran Clouded Leopard, *N. d. diardi,* and the Bornean Clouded Leopard, *N. d. borneensis* (Kitchener et al., 2017).

Natural History

The Sunda Clouded Leopard is one of the least studied of the world's larger felids (Brodie, 2009). Much of our knowledge of this species stems from an increasing body of camera-trap studies, especially from Sabah. In particular, three long-term and ongoing studies undertaken in the Lower Kinabatangan, Deramakot Forest Complex and the Tawau Highlands.

To date no study has quantified this felid's diet. Incidental observations of predation indicate that their prey is diverse and includes porcupines (Gordon & Stewart, 2007), Proboscis Monkeys



Figure 1. A female Sunda Clouded Leopard photographed by camera trap in the Ulu Segama Forest Reserve © A. J. Hearn & J. Ross.

(Matsuda et al., 2008b; Otani et al., 2012), orangutans (Kanamori et al., 2012; Sunderland-Groves et al., 2021), Bearded Pigs and Sambar (Davis, 1962; Mohamed et al., 2009; Rabinowitz et al., 1987). Ross et al. (2013) showed that Greater Mousedeer and Bearded Pigs exhibited shifts in temporal activity in the absence of the Sunda Clouded Leopard, suggesting that these may be principal prey species. Noting the species' substantial sexual dimorphism (Carbone et al., 1999), Hearn et al. (2018a) hypothesized that male and female's prey base is likely to differ greatly, with females focusing on prey <6 kg in size and males able to take prey that exceeds their own weight of 25 kg, but this remains to be tested.

The Sunda Clouded Leopard has remarkable arboreal talents, aided by their short limbs, long tail and flexible ankle joints (e.g. Kitchener et al., 2010). The species has been observed successfully hunting arboreal prey and resting in trees and is often described as an arboreal specialist. In an early account of this species' behaviour, however, Selous and Banks (1935) questioned this specialism, noting that hunting dogs chase and kill these cats on the ground, and data from camera traps have since shown that terrestrial activity is indeed common and that males are positively associated with logging roads and forest trails, which they likely use to facilitate travel, whereas females avoid these features, possibly to reduce encounters with males (Hearn et al., 2018a; Wearn et al., 2013). Haysom et al. (2021) deployed camera traps in pairs, with one camera set in the canopy and one on the ground, and recorded Sunda Clouded Leopards on only the terrestrial cameras. The Sunda Clouded Leopard can be active at any time of day but is primarily active throughout the night and during crepuscular periods (Hearn et al., 2018a; Ross et al., 2013).

Distribution in Sabah

Recent research in Sabah suggests that the Sunda Clouded Leopard is closely associated with forest but that it is also highly adaptable and able to utilise a range of forest habitats, including those modified by anthropogenic disturbance. In Sabah, the species has been recorded in primary (Brodie & Giordano, 2012) and selectively logged (Hearn et al., 2016; 2017; Wilting et al., 2006; 2012;) lowland dipterocarp forests, including highly disturbed areas (Wearn et al., 2013), hill dipterocarp and sub-montane forest (Hearn et al., 2017), and mangroves (Davis, 1962; Davies & Payne, 1982). While Sunda Clouded Leopards appear to tolerate forest disturbance, forest patch size appears to be important. Bernard et al. (2014a) did not record this species in a number of small forest patches embedded within an oil palm plantation, despite recording their presence in the adjacent Tabin Wildlife Reserve, and an absence of camera-trap detections from Sepilok (4,294 ha) led Hearn et al. (2017) to conclude that this forest may no longer support the species. Hearn et al. (2018a) reported that Sunda Clouded Leopards were detected over much of the elevational range that they surveyed, with records from 17 m in Kinabatangan to 1,452 m in Crocker Range, and it is likely that the species is found at even higher elevations in Kinabalu Park. Recent multi-scale analyses of the habitat associations of these felids in Sabah (Hearn et al., 2018a) and across their Bornean range (Hearn et al., 2016; Macdonald et al., 2018), showed this species selected areas with high levels of dipterocarp forest at relatively fine spatial scales, within broad landscapes with low levels of human footprint, plantations and scrub lands.

Whilst relatively understudied in comparison to forest habitats, camera-trap surveys of oil palm landscapes in Sabah did not detect this species (Hearn et al., 2017; Ng et al., 2021; Ross et al., 2013; Yue et al., 2015). The movements of four satellite collared animals in the Lower Kinabatangan

Wildlife Sanctuary (LKWS) were closely associated with forest habitats and strongly resisted by oil palm areas, although one individual male traversed several sections of a plantation as a shortcut between contiguous areas of forest, or to temporarily visit an isolated forest patch (Hearn et al., 2018b). Collectively, these observations indicate that oil palm plantations are not widely used by Sunda Clouded Leopards but may not necessarily form a hard barrier to their movement.

In their faunal survey of Sabah, Davies and Payne (1982) compiled reliable observation records of the species and conducted their own pugmark surveys and, while records were sparse, reported that the species was widely distributed across the state in the early 1980s. The increasing use of automatically triggered camera traps across Sabah in the 2000s, including a number of felid-specific, systematic surveys, has greatly increased the number of recent records of this species, which is reflected in our recent effort to compile information (Figure 2). Recent species distribution modelling efforts have capitalised on this increasing body of records and have attempted to predict the current distribution of the species across Borneo (Hearn et al., 2016; Macdonald et al., 2018) and Sabah (Hearn et al., 2018a). These predictive models support earlier suggestions that the Sunda Clouded Leopard is widespread across the state but highlight that their distribution has been greatly reduced as forest cover has declined.

Camera-trap surveys of eleven forest areas in Sabah have confirmed earlier assumptions that the species is rare, with population density estimates ranging from 0.84 to 3.10 individuals per 100 km² (Brodie & Giordano, 2012; Hearn et al., 2017; Mohamed et al., 2021; Wilting et al., 2012; Table 1). By extrapolating these estimates to the remaining area of forest, Hearn et al. (2017) developed a very approximate population size of 750 (95% posterior interval 300–1,300) individuals in Sabah. Low detection rates obtained during these intensive surveys, particularly for females, reduce the reliability of these estimates and result in relatively high confidence intervals, and as a result, Mohamed et al. (2021) caution that some of these estimates may be biased low.

Such uncertainty in population density limits our ability to compare abundance among sites in Sabah and in turn hinders understanding of how anthropogenic disturbance influences these felids. The first insight into the responses of these felids to such habitat disturbance came from Brodie et al. (2015c), who used camera traps to survey several forested areas in Sarawak and Sabah and showed that Sunda Clouded Leopards' local scale abundance was lower in logged forest sites compared to unlogged sites. Hearn et al. (2017) recorded their highest density in the logged forest of Ulu Segama (Table 1), and suggested that, among selectively logged sites, time since logging activities may be

Table 1. Population density estimates derived from Spatially Explicit capture recapture analysis of camera-trap data, from a range of forest types in Sabah. Densities (individuals per 100 km²) represent means and associated upper and lower 95% confidence intervals. CA: Conservation Area; FR: Forest Reserve; WR: Wildlife Reserve. Source: [1] Hearn et al., 2017; [2] Wilting et al., 2012; [3] Brodie et al., 2012; [4] Mohamed et al., 2021.

	Crocker Range Park[1]	Danum Valley CA[1]	Deramakot FR[2]	LKWS[1]	Maliau Basin CA[3]	Northern Kuamut FR[4]	Segaliud Lokan FR[2]	Tabin WR[1]	Tangkulap-Sungai Talibu FR[2]		Tawau Hills[1]	Ulu Segama FR[1]
Year(s) surveyed	2011/12	2012	2014/15	2010	2010	2016	2009	2009/10	2010	2015	2013	2007
Density	1.39	1.73	2.82	1.54	1.90	2.41	1.04	2.66	0.84	1.27	2.23	3.10
Lower CI	0.77	0.81	1.34	0.41	0.70	1.05	0.29	0.79	0.25	0.47	1.35	1.26
Upper CI	2.21	2.78	5.93	2.90	5.40	5.61	2.55	4.74	1.83	3.41	3.27	5.32

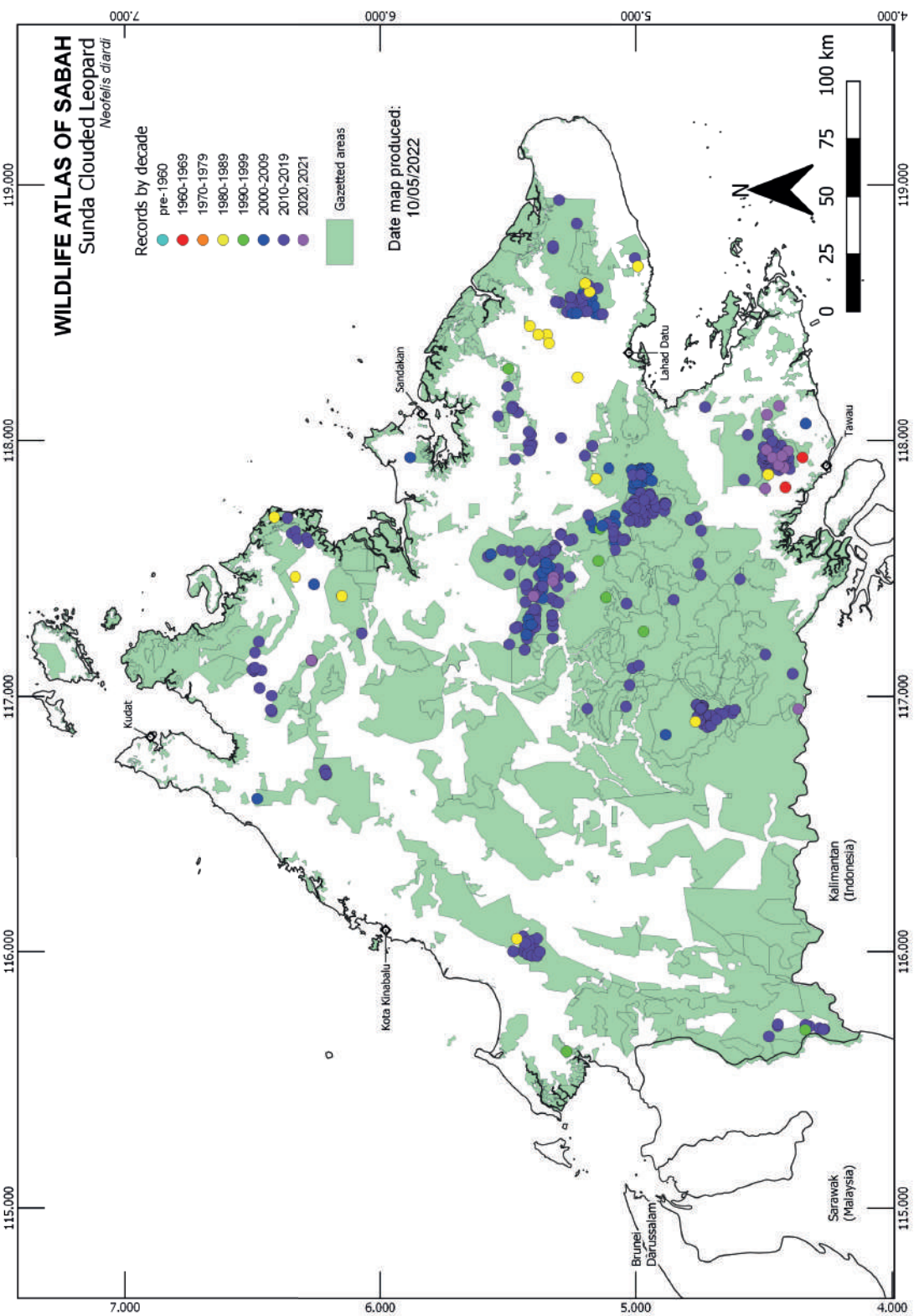


Figure 2. Records of Sunda Clouded Leopard

positively associated with higher density. Further, Mohamad et al.'s (2021) recent work supported that well-managed forests using Reduced Impact Logging techniques may support higher Sunda Clouded Leopard densities, even if logging is continuously ongoing, compared to forest reserves that experienced conventional logging followed by natural regeneration for more than 15 years.

Threats

In the Sunda Clouded Leopard Action Plan, the Sabah Wildlife Department (SWD) identified and discussed the main threats to the species in Sabah (SWD, 2019c). The most significant threat stems from the species' exceptionally low population size, which is predicted to be further diminished by the loss, degradation and fragmentation of their forest habitat, and with losses associated with the illegal killing of the animals themselves, and of their prey. The latter problem is exacerbated by the substantial losses of Bearded Pigs as a result of African Swine Fever sweeping through Borneo since 2020.

From 1973 to 2010, Sabah's forest cover declined from 78.6% to 47.5% (Gaveau et al., 2016; 2019), resulting in approximately proportional declines in the Sunda Clouded Leopard population (Hearn et al., 2015). These declines are set to continue as forest cover is further reduced across the state. The threats associated with a low population size are further exacerbated by forest fragmentation impacting the capacity for Sunda Clouded Leopards to move across the landscape, resulting in reduced gene flow. The available evidence suggests that Sabah's populations may now be fragmented into several sub-populations, which based on a model developed from satellite tagged animals in the Lower Kinabatangan (Hearn et al., 2018b), Hearn et al. (2019) predicted that a number of important protected areas, including the LKWS, Tabin Wildlife Reserve and Tawau Hills Park, may no longer be contiguous from the core Sunda Clouded Leopard populations in Sabah's central forests. This highlights the importance of forested corridors to facilitate population connectivity. Kaszta et al. (2019) explored how future development in the state, set out on the Sabah Development Plan, may further impact the population connectivity of this felid.

The low population density and population size of Sunda Clouded Leopards render them at particular risk from illegal wildlife trade for body parts and pets, but very little is known of the illegal trade in this species in Sabah, although even low rates of killing could have significant impacts on the population. Informal interviews with local hunters in the late 1980s suggested that that hunters only rarely encountered and did not specifically hunt Sunda Clouded Leopards. Rabinowitz reported in 1987 that the animals were encountered and killed, and the carcass was typically left where it fell, leading him to conclude that there was "virtually no market for the skin or body parts" at that time. In November 2007 the carcass of a male Sunda Clouded Leopard was left where it was apparently shot by poachers on a logging road in the Ulu Segama FR, again suggesting that this species was not targeted. In November 2015, however, a man was caught in possession of a young Sunda Clouded Leopard and was prosecuted and fined RM50,000, so there is a risk that a trade may be beginning.

Brodie et al. (2015c) found that local abundance of Sunda Clouded Leopards was negatively related to poacher presence, and Hearn et al. (2017) demonstrated that their population density in Sabah was lower in more heavily poached areas, even where Sunda Clouded Leopards were not apparently targeted. Indeed, the abundance of Sunda Clouded Leopards is directly affected by prey density, and since ungulates are a favoured quarry of hunters and important prey for Sunda Clouded Leopards, the felid will be negatively impacted by hunting that depletes their prey. Of particular

concern is the dense network of logging roads and tracks present in logged forests, which facilitates greater access and thus hunting opportunities for poachers. Based on the results from different commercial forest reserves in Sabah, Hearn et al. (2017) concluded that the overriding priority is to reduce poaching pressure, both on Sunda Clouded Leopards and their prey, by reducing access to the forest interior along logging roads.

Domestic dogs and cats are potential carriers of some important infectious diseases such as feline panleukopenia virus, canine distemper virus and canine parvovirus, all highly contagious and able to cause mortality in Sunda Clouded Leopard populations. Land use changes in Sabah have increased the potential risk of contact between domestic and wild carnivores, including many dogs in logged forests, and research is needed to assess these risks to Sunda Clouded Leopard populations.

Conservation

In isolation, Sabah's protected areas (Parks, Wildlife Sanctuaries and Class 1 Forest Reserves) while extensive (1.9 million ha) are insufficient to support a large population of Sunda Clouded Leopards; the commercial forest reserve system is thus also critical to this species' survival.

In the most recent IUCN Red List of Threatened Species assessment, the Sunda Clouded Leopard was designated as 'Vulnerable', due to a presumed small (<10,000 individuals) and declining population size across both Borneo and Sumatra (Hearn et al., 2015). In an earlier assessment, the Bornean subspecies was assigned as 'Endangered', as early data indicated that the population size across Sabah, Sarawak, Brunei and the Kalimantan provinces likely fell below the 2,500 mature individual threshold, with no sub-population having an effective population size greater than 250 (Hearn et al., 2008). Although fraught with uncertainty, the very approximate population estimate for Sabah ranges from 300 to 1,300 individuals (Hearn et al., 2017), which indicates that the Sunda Clouded Leopard is one of Sabah's most threatened species.

The Sunda Clouded Leopard is listed on Appendix 1 of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, which prohibits all international commercial trade. In Sabah, the species is listed as Totally Protected under Schedule 1, Section One of the Wildlife Conservation Enactment 1997, which criminalizes hunting and/or possession of listed species' body parts. The legislation predates the species split in 2011, and so the species is currently listed under "Clouded Leopard (*Neofelis nebulosa*) Harimau Dahan", and thus requires updating.

The Sunda Clouded Leopard Management Plan for Sabah (SWD, 2019c) identified four priority conservation actions: (i) Combat wildlife poaching and eradicate wildlife trafficking; (ii) Prevent any further loss and degradation of suitable habitat for the Sunda Clouded Leopard. Any of the key conservation areas for Sunda Clouded Leopards must be managed sustainably; (iii) Identify potential connectivity within and between Sunda Clouded Leopard habitats and establish connectivity within and between regional management units; and (iv) Disseminate awareness materials on Sunda Clouded Leopard to relevant stakeholders in the vicinity of the protected areas (local communities, oil palm workers). Ongoing research into all these issues is needed to monitor and adapt conservation policy and practice.

Local communities can be a key component to manage and conserve Sunda Clouded Leopard and other wildlife outside protected areas. However, some investment will be required to build capacity and influence wildlife use in favour of conservation objectives. For example, education programmes to raise hunters' respect for wildlife protection laws is necessary. It is unknown if Sunda Clouded

Leopards in Sabah are currently traded or consumed at the local scale, as is the case with many other wildlife species in the region, but proactive monitoring and awareness efforts should be undertaken. Social media can play an important role as an awareness and hunting monitoring tool. More efforts should be expended into raising awareness, through social media, school programmes (Sabah Environmental Education Network) and education centres (such as Bornean Sun Bear Conservation Centre) to educate the public on Sunda Clouded Leopards. Companies (logging, plantation and mining) need to be engaged as they are in charge of the management of the areas; thus, they are the ones which, if they want, can make their managed areas better for Sunda Clouded Leopards.

Acknowledgements

Thank you to Andreas Wilting for peer review and to the editors for their support.

Data sources

Individuals / organizations (Number of records): Brodie, Jedediah (80); Gardner, Penny (47); Haysom, Jessica (605); Hearn, Andrew (544); Guharajan, Roshan (64); Forest Solution Malaysia (188); 1StopBorneo Wildlife (3); Forest Solution Malaysia (19); Sabah Forestry Department (3); Sabah Museum (1); WWF-Malaysia (54). *Open source database (Number of records):* eMammal, 2021 (9). *Publications (Number of records):* Abdullah et al., 1995 (1); Bernard et al., 2013 (3); Bernard et al., 2014 (1); Bernard et al., 2016 (1); Bili, 2014 (1); Boonratana, 1997 (4); Boonratana & Sharma, 1993 (1); Chung et al., 2019 (1); Davies & Payne, 1982 (22); Davis, 1962 (1); Dawson, 1992 (1); Deere et al., 2017 (4); Fernando et al., 2013 (1); Hearn et al., 2017 (7); Ishige et al., 2017 (1); Kee et al., 2018 (1); Kehoe, 2011 (1); KOPEL, 2016 (1); Lim, 1996 (1) Lim, 1993 (1); Mohamed et al., 2009 (2); Nakabayashi et al., 2014 (1); Onoguchi & Matsubayashi, 2008 (1); Payne et al., 1989 (1); Ross et al., 2013 (5); Samejima & Ong, 2012 (14); Samejima et al., 2012 (1); SFD, 2016 (1); SFD, 2017 (1); Webb, 2016 (2); Wilting & Mohamed, 2010 (2); Wilting et al., 2006 (1); Wilting et al., 2012 (32); Wong, 2011 (1); Yasuda et al., 2007 (6).

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Sunda Pangolin (*Manis javanica*)

Elisa Panjang and Benoit Goossens

Introduction

The Sunda Pangolin, *Manis javanica* (Desmarest, 1822), also known as the Malayan Pangolin and Javan Pangolin, is one of the eight living pangolin species in the world; four of which are found in Asia. Other names are scaly anteater and *tenggiling* in Bahasa Malaysia.

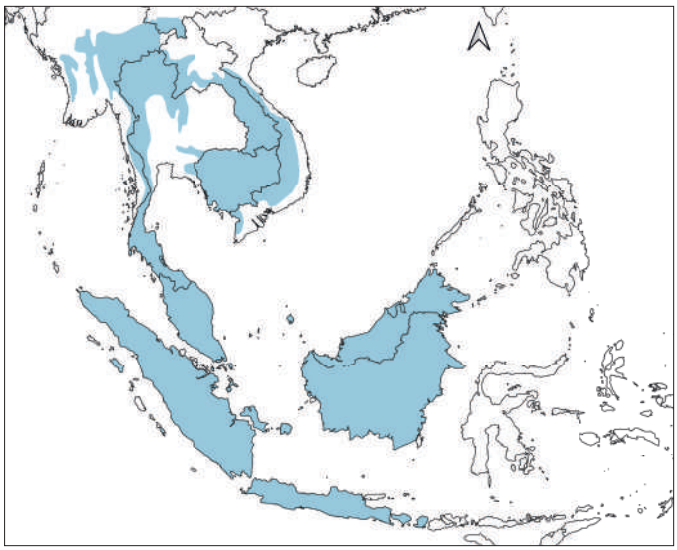


Figure 1. Sunda Pangolin distribution (Source: IUCN SSC Pangolin Specialist Group, 2019)

Reports show that the species is distributed widely in Southeast Asia and is native to Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Singapore, Thailand, and Vietnam (Challender et al., 2019; see Figure 1). The species is not present in the Philippines (Corbet & Hill, 1992). The distribution of Sunda Pangolin in China could not be ascertained (Wu et al., 2005), and also its altitudinal limits are poorly understood (Chong et al., 2020). There is poor understanding of its conservation needs, including identifying priority sites for its conservation.

Taxonomy

The Sunda Pangolin is a medium-sized mammal that generally can reach a weight of 4–7 kg, and its total length is up to 140 cm (Chong et al., 2020). There have been reports of much larger individuals; Sulaiman et al. (2017) recorded a 13.5 kg male, and a 19.3 kg male pangolin being monitored with a radio tracker in Kinabatangan (Panjang, unpub. data), as well as records from the logbooks of



Figure 2. Scales cover most of the Sunda Pangolin's body © Jia Zhen Lim

trafficking syndicates in Sabah that suggest the species can reach a weight of up to 21 kg (Pantel & Anak, 2010). There is a positive correlation between the species' body mass and overall length (Sulaiman et al., 2017; Yang et al., 2010), with males larger and heavier than females. Yang et al. (2010) and Lim (2007) estimated individuals of >3 kg to be adults, <3 kg considered as juveniles, and individuals weighing 1.5–3 kg are classified as sub-adults.

The most prominent feature of a pangolin is its scales (Figure 2). The scales cover most of its body except the face and undersides. The scales are hard, keratinous, and roundish in shape with a sharp edge (Jentink, 1882), and its colouration may not be uniform, ranging from light to dark brown (Chong et al., 2020). The species has a prehensile tail which is long and sturdy (Pocock, 1924), often used with its sharp hooked claws when climbing, and sometimes used to steer through the water when swimming (E. Panjang, pers. obs.). The species' head to snout ratio is short and looks V-shaped. The eyes and ears are small, and it has five digits with claws in each. The Sunda Pangolin lacks teeth, but has a long tongue with sticky saliva that can be extended to 25 cm to capture and consume prey (Nowak, 1999).

The species is classified in the Order Pholidota, Family Manidae and the genus *Manis* based on morphological (Gaudin et al., 2009) and genetic evidence (Gaubert et al., 2018; Hassanin et al., 2015). The *Manis* genus comprises four Asian pangolins: the Chinese Pangolin (*M. pentadactyla)*, the Indian Pangolin (*M. crassicaudata)*, the Philippine Pangolin (*M. culionensis)*, and the Sunda Pangolin. Pangolin populations in the Philippines were previously considered to be Sunda Pangolin. However, the morphological studies by Feiler (1998) and Gaubert and Antunes (2005) later classified it as a distinct species based on discrete morphological characters, and genetic analyses by Gaubert et al. (2018) further supported this classification.

Recent research has discovered that three previously unknown genetic lineages of Sunda Pangolins may be from Borneo, Java, and Singapore or Sumatra (Nash et al., 2018). Given the wide

geographic distribution of the species, potentially, there exists cryptic diversity across the range. As such, detailed research on genetic and morphology would allow us to have a better understanding of the Sunda Pangolin taxonomy.

Natural History

The Sunda Pangolin is semi-arboreal (Figure 3) and seems to live in stable home ranges. Lim (2007) tracked five adult pangolins on an island (ca. 24 km^2) in Singapore and estimated a mean home range of 41 ha for four males, and 7 ha for one female with an infant. In the Lower Kinabatangan Wildlife Sanctuary (area ca. 260 km^2), Panjang et al. (unpub. data) estimated the home range of one female pangolin to be 21 ha, and for one male to be 116 ha. In addition, Lim (2007) observed aggressive behaviour and a stand-off between two males. Evidence from camera traps also showed that male pangolins fight with other males: a) to defend their shelters, with the stronger male staying in the sleeping site and replacing the weaker male; and b) for the prize of a female (Panjang, unpub. data). These recent findings indicate that the males may be territorial.

The Sunda Pangolin uses diverse structures as shelters or sleeping sites, and these include tree hollows (either standing tree, fallen tree, and either live or dead), burrows (newly dug or modified existing structures) and tall grasses (e.g. *Imperata cylindrica)* (Lim & Ng, 2008a). Other structures include the branches of trees (e.g. *Ficus*, Bornean ironwood), the tree crown of oil palm trees (*Elaeis guineensis*) in commercial plantations, and narrow parts of buttress roots, as well as underneath Napier grasses along the riverbank (Panjang, unpub. data). Structures utilised by the species generally have one or more entrances, for example in tree hollows (Lim & Ng, 2008a; Panjang, unpub. data). In captivity, the species dig burrows (Save Vietnam Wildlife, unpub. data). The species has been found sleeping in large pipes in Singapore City (Lim & Ng, 2008a), and both in large pipes and under bridges in oil palm plantations (Panjang, unpub. data). Lim and Ng (2008a) report that a male pangolin stays in the same sleeping site for 1–2 consecutive days, while a female with young stays longer in the same sleeping site. Recent research has shown that pangolins can continue to sleep in their same sleeping sites for up to six days before moving on to new sleeping sites. Pangolins were also observed to frequently reuse their old sleeping sites (Panjang, unpub. data).



Figure 3. The Sunda Pangolin is an adept climber © Dan Challender

Several small mammals, including bats, Malay Badger (*Mydaus javanensis*), moonrat (*Echinosorex gymnura*), Malayan Porcupine (*Hystrix brachyura*), and Malay Weasel (*Mustela nudipes*), have been documented living alongside Sunda Pangolins in their sleeping sites

(Panjang, unpub. data) and several reptiles, e.g. python, monitor lizard (*Varanus* sp.) and tortoise, have been observed using old pangolin sleeping sites (Trageser, unpub. data).

The species' diet consists of ants and termites, although ants are preferred (Lim, 2007), with a wide range of ant species consumed (Lim, 2007; Nguyen et al., 2014; Wilcox et al., 2017). Species that prey upon them in Sabah, include humans, Sunda Clouded Leopard (*Neofelis diardi*) (Grassman et al., 2005a; Kawanishi & Sunquist, 2004), Reticulated Python (*Malayopython reticulatus*) (Lim & Ng, 2008b; Shine et al., 1998), Bornean Sun Bear (*Helarctos malayanus*) (Hedges & Aziz, 2013) and feral dogs (Chong et al., 2020). The defence mechanism pangolins use when threatened include freezing (N. Lim, & E. Panjang, pers. obs.), quickly moving into tree hollows, or curling up into a ball and not moving (E. Panjang, pers. obs). Sometimes, the tail grips a small tree, tree branch or the leg of a table (during handling) and is difficult to uncurl (Lekagul & McNeely, 1988; E. Panjang, pers. obs.).

All pangolins are solitary, with females sometimes observed with young (Lim & Ng, 2008a). Social interaction relies on scent marks from urine and secretions. The species is mainly nocturnal in the wild (Lim & Ng, 2008a) and in captivity (Challender et al., 2012; Nguyen et al., 2014). The only known vocalisation of the species is the sound of "hisses" or "puffs" (Chong et al., 2020).

Zhang et al. (2015) reported that mating occurs many times when a female is in oestrus. The gestation period is 168–188 days, about six months (Nguyen et al., 2014; Zhang et al., 2015). Typically, only one young is born, but twins have been reported (Payne et al., 1998; Prater, 1971). Maternal care lasts for 3–4 months (Lim & Ng, 2008a; Nguyen et al., 2014). Knowledge of sexual maturity is limited. In males, sexual maturity may occur when they are 1.5 years old (Kurniawan, unpub. data). Females may reach sexual maturity when they are around a year old (Zhang et al., 2015). The species is thought to be able to breed all year round (Lim & Ng, 2008a; Nguyen et al., 2014) and is aseasonal while in captivity (Zhang et al., 2015). It is assumed that males find females through their scent.

Distribution in Sabah

There are recent records of the species obtained in protected areas, e.g. Maliau Basin and Imbak Canyon (Benard et al., 2013), Tangkulap Forest Reserve and Sipitang Forest Reserve (Gardner, unpub. data), Danum Valley (Wai, unpub. data), Lower Kinabatangan Wildlife Sanctuary (Panjang, unpub. data), as well as unprotected areas; e.g. forest adjacent to Universiti Malaysia Sabah (Panjang, unpub. data) and surrounding islands, including Gaya Island (Sompud et al., 2019) and Labuan (Panjang, unpub. data). The Sunda Pangolin records in Sabah are further shown in Figure 4.

The Sunda Pangolin is present in many habitat types ranging from the primary (Figure 5) and secondary tropical forest (including dipterocarp), evergreen and hill forest, peat swamp forest, grasslands, and monoculture (e.g. oil palm and rubber plantations), gardens, and urban areas (Azhar et al., 2013; Ketol et al., 2009; Khwaja et al., 2019; Lim & Ng, 2008a; Payne et al., 1985; Wearn, 2015). The species can be found in agricultural landscapes and degraded forest (e.g. in Singapore) (Lim & Ng, 2008a), where it breeds and reproduces.

The Sunda Pangolin may be well-adapted to the wetland and riverine ecosystem; based on the records in Vietnam where the species was seen in *Phragmites reeds* and Melaleuca Forest (Willcox et al., 2017). In Kinabatangan, radio-tagged pangolins were observed utilising shelters along the riverbank and sometimes crossing the Kinabatangan River >100 m wide (Panjang, unpub.

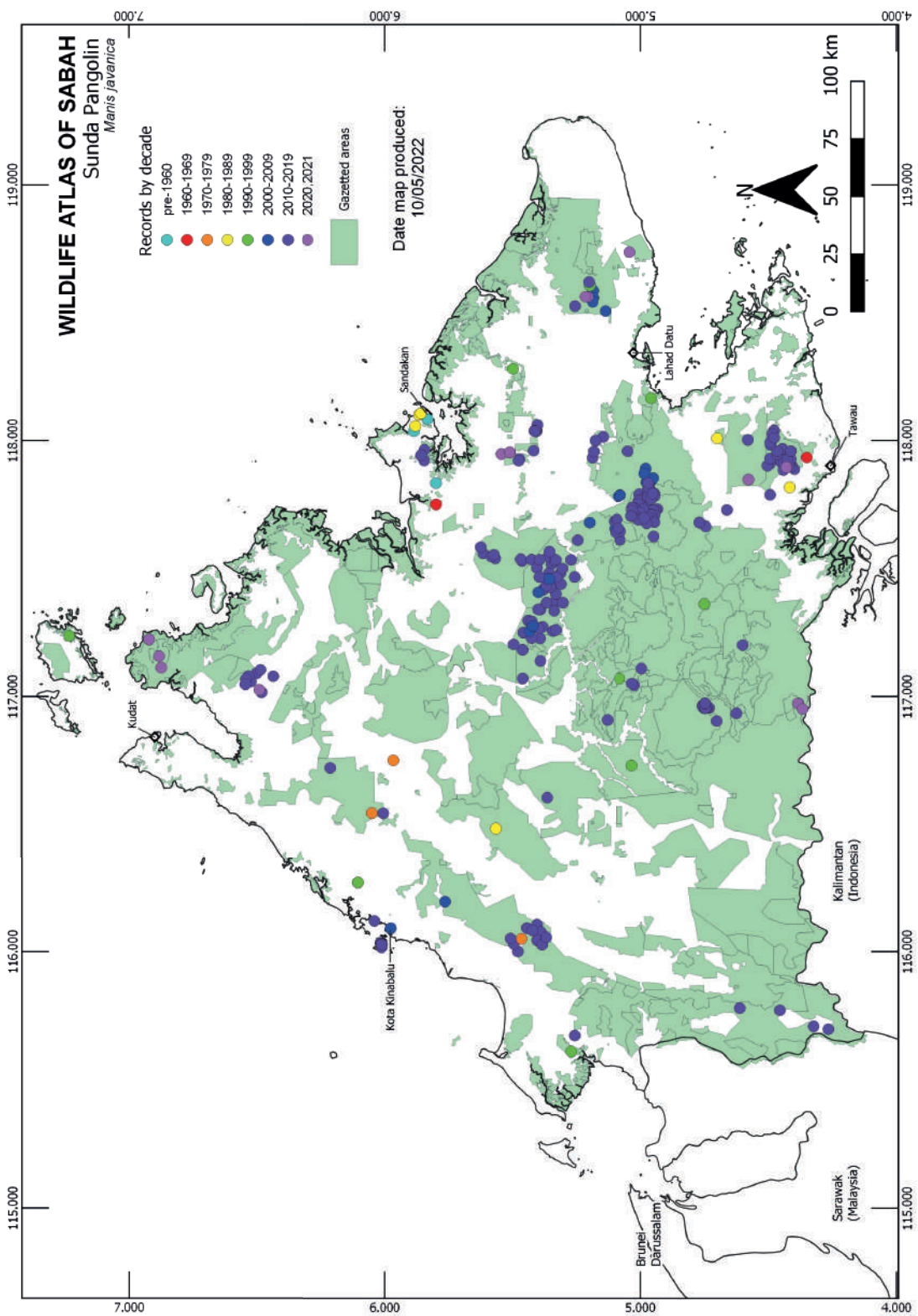


Figure 4. Records of Sunda Pangolin

data), swimming between flooded drains and canals (H. C. Nash, pers. obs.), and swimming in the sea from one island to another (S. Cheema, pers. obs.). In captivity, the species use pools of water for bathing and defecating (Nguyen et al., 2014). The species is not able to endure cold temperatures (Save Vietnam Wildlife, unpub. data).

Although there is a lack of quantitative data on the population sizes in Sabah, evidence from Singapore suggests that availability and quantity of ants and termites, large trees and structures providing shelter for pangolins, predation and exploitation are crucial factors affecting the species' abundance (Lim & Ng, 2008a).

Cultural Significance

In Asia, pangolins occupy a special place in the people's beliefs and rituals. Most of the reports focus on pangolin products, especially scales, in traditional medicine and magical belief. Recent studies primarily focus on the trade and trafficking in pangolins and their scales. The Sunda Pangolins were featured in several local folktales. Studies have shown that the Sunda Pangolin plays important roles in the religion (i.e. animism) and cultures, especially for protection, procreation and health maintenance as described in the Orang Asli groups in Peninsular Malaysia (Benjamin, 2014; Hafiz & Chong, 2016; Karim, 1981; Tacey, 2013; Yahaya, 2014) and Indigenous people in Sabah and Sarawak (Chong & Panjang, unpub. data).

In Sabah, the Kadazans use dried pangolin scales to deter crocodiles while in the river (Chong & Panjang, unpub. data). The Indigenous people consume pangolin meat to cure asthma and drink pangolin blood as a tonic. Around 50–100 years ago, Indigenous people of Sabah (e.g. Kadazan, Dusun, Murut and Rungus) used pangolin scales to make vests for their warriors and belts to cure arthritis (Panjang, unpub. data). Some of these are exhibited in local museums and are still kept by older generations, usually displayed during the *Kaamatan* or Harvest Festival in Sabah.

Nowadays, the Sunda Pangolin is subject to heavy illegal international trade in live animals and



Figure 5. Sunda Pangolin in forest habitat © Laura Benedict

their scales (used in traditional Chinese medicine) from Peninsular Malaysia, Sabah and Sarawak, mainly for East Asia (e.g. China) (Challender & Waterman, 2017; Pantel & Anak, 2010).

Conservation

Due to past and ongoing population declines through overexploitation, the Sunda Pangolin was listed as 'Critically Endangered' on the IUCN Red List of Threatened Species (Challender et al., 2019). In 2016, CITES uplisted all eight pangolin species to Appendix I, which means international trade for commercial purposes is prohibited by law. In all range states, pangolins are protected by their national legislation, which typically means exploitation for personal and commercial purposes is prohibited. The Sunda Pangolin is listed in Schedule 1 of the Sabah Wildlife Conservation Enactment 1997 as 'Totally Protected', hence no hunting is permitted. Possession of a live pangolin, as well as pangolin meat or body parts, is punishable by a fine of up to RM250,000 and imprisonment for up to five years. Pangolins were previously (and until very recently) listed in Schedule 2 as 'Protected', which meant that hunting with a permit was still allowed.

Overexploitation is the main threat to the remaining Sunda Pangolin populations in all its range states, including Sabah. The exploitation is mainly driven by the demand in China and Vietnam for the traditional Chinese medicine industry and as luxury products in high-end urban restaurants, and local demand (e.g. villages living near protected forests). For centuries, the Indigenous people and local communities in Sabah and elsewhere have consumed the Sunda Pangolin for subsistence purposes (e.g. as a source of protein; Corlett, 2007), and the scales for use in various applications (Hafiz & Chong, 2016).

The species has been caught opportunistically using various hunting methods, including snares, nets and dogs (Gray et al., 2017; Newton et al., 2008), and evidence indicates that people now chose to sell pangolins instead of consuming them due to the high prices they fetch (MacMillan & Nguyen, 2014; Pantel & Anak, 2010; Semiadi & Panjang, unpub. data). In some parts of Southeast Asia (e.g. Sabah), selling a pangolin can provide the equivalent of several months' income (Challender & Panjang, unpub. data).

The scale of the commercial, international trade has greatly expanded compared to the early and mid-20th century, when an average of 2,300 pangolins killed each year between 1912–1935, so that their scales could be exported from Sabah (Burgess, 1961). In recent times Pantel and Anak (2010) report that >22,000 individuals from Sabah were exported between 2007–2009. A shipment of more than eight tonnes of scales worth more than RM100 million was seized in Sabah in 2017. Authorities seized approximately 29.8 tonnes of pangolins in 2019, which included frozen meat, scales, and live pangolins. All of these items were thought to have been sourced locally and from neighbouring countries, as well as exported from Africa to China. Since 2017, Sabah has been linked to over 40 tonnes of pangolin smuggling, including 13 tonnes of African Pangolin scales (TRAFFIC, 2019). There is growing interest in Sabah's emerging role as both a source and a transit point in the global trafficking of pangolin scales.

In 2019, a coronavirus disease (COVID-19) caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has been designated as a zoonotic disease. SARS-CoV-2 has been discovered in bats, and pangolins may have acted as an intermediate host and infected humans (Lam et al., 2020; Wacharapluesadee et al., 2021). However, a total of 45 confiscated and rescued pangolins from Sabah were recently screened (out of 334 individuals from Malaysia), and all samples

tested negative (Lee et al., 2020).

The highest priority is to eliminate the illegal trade in endangered species, and there is a growing attention on the trafficking of pangolins and greater interest in funding pangolin conservation among international donors. Nevertheless, the lack of coordination and cooperation among different stakeholders within and between range states, and the lack of agreed priority conservation actions hamper conservation effort. Moreover, there is limited evidence that demand reduction efforts are effective in consumer countries (Veríssimo & Wan, 2019).

Habitat loss is an indirect threat to Sunda Pangolins due to the opening up of previously inaccessible areas, making the species more susceptible to hunting and poaching. The same applies to mining, the creation of dams, logging concessions and the expansion of road and oil palm plantations, and the increased risk of roadkill and feral dog attacks. There is a need for a comparative study to understand densities of the Sunda Pangolin in artificial and modified landscape (e.g. oil palm plantations) and natural habitats (Davies & Payne, 1982).

Ex-situ conservation (captive breeding) is challenging for the species. Captive pangolins face high mortality rates. Therefore, maintaining healthy captive pangolin populations over the long term remains a challenge (Chin & Tsao, 2015; Mohapatra & Panda, 2014). However, as illegal trade continues to threaten wild pangolins, there is a need to develop evidence-based protocols for the care and conservation breeding of pangolins in captivity. Most rescue centres experience problems in providing complete nutritional foods to pangolins. The species has a highly specialised diet, which includes ants and termites. Apart from captive nutrition, the enclosure and suitable captive environment design, monitoring the species behaviour and veterinary care are essential aspects in developing a successful pangolin husbandry. In Sabah, confiscated and rescued pangolins are kept temporarily in Sepilok Orangutan Rehabilitation Centre (for East Sabah) and Lok Kawi Wildlife Park (for West Sabah) before being released in the wild.

Acknowledgements

We thank the editors for the invitation to contribute to the Atlas, and for peer review from Chong Ju Lian. We also extend our gratitude to contributors and reviewers for providing information, feedback and advice. Pangolin research at Danau Girang Field Centre is funded by Houston Zoo, USA and Ocean Park Conservation Foundation, Hong Kong.

Data Sources

Individuals/organizations (Number of records): Brodie, Jedediah (22); Elisa Panjang (27); Gardner, Penny (10); Guharajan, Roshan (23); Haysom, Jessica (43); Hearn, Andrew (114); Lim, Angela (1); 1StopBorneo Wildlife (1); Forest Solution Malaysia (13); Sabah Forestry Department (3); Sabah Museum (4); WWF-Malaysia (20). *Open-source database (Number of records):* eMammal (1). *Publications (Number of records):* Bernard et al., 1997 (1); Bernard et al., 2013 (2); Bernard et al., 2019 (1); Boonratana, 1997 (2); Boonratana & Sharma, 1993 (1); Bornion Timber, 2021 (1); Bunya et al., 2010 (1); Chasen & Kloss, 1931 (1); Chung et al., 2019 (2); Davies & Payne, 1982 (6), Davis, 1962 (2); Dawson, 1992 (2); Deere et al., 2017 (1); Harris et al., 2012 (1); Harrison, 1998 (1); Ishige et al., 2017 (1); Ketol et al., 2009 (1); KOPEL, 2016 (1); Lim, 1996 (1); Mingueza, 2018 (1); Mullin & Colley, 1972 (1); Murphy, 2007 (1); Samejima & Ong, 2012 (21); Samejima et al., 2012 (1); SFD, 2016 (1); SFD, 2019 (1); Sheldon & Francis, 1985 (1); Shukor, 1996 (1); Sollmann et al., 2017 (3); Sompud et al., 2019 (9); Wilting & Mohamed, 2010 (1).

Flying Squirrels & Squirrels

Jessica Haysom

Introduction

The island of Borneo is home to an extremely high number of squirrel species, with 35 non-flying tree and ground squirrels, of which 14 are endemic to the island (Phillipps & Phillips, 2018), making it a global centre of squirrel and flying squirrel diversity (Thorington et al., 2012). However, the vast majority of these species are understudied and poorly-known. Indeed some Bornean flying squirrels are known from only one or two historical records (IUCN, 2021; Payne & Francis, 2007; Thorington et al., 2012).

All extant (currently living) squirrel species belong to the family *Sciuridae*, of the order *Rodentia*, and Sabah squirrels fall into three subfamilies: *Ratufinae* — the Oriental giant squirrels; *Callosciurinae* — the Asian ornate squirrels; and *Sciurinae*, which is further sub-divided into a) tree squirrels, and b) flying squirrels plus the Tufted Ground Squirrel. All are descendants of a common ancestor that lived between 30–40 million years ago (Thorington et al., 2012). In fact, comparison of the anatomy of extant and fossil squirrels shows that some tree squirrels have changed very little over 30–35 million years (Emry & Thorington, 1982). Similarly, flying squirrels, whose skeletons have tiny specialised wrist bones that support cartilage extensions for the gliding membrane, have undergone little morphological change since at least 11.6 million years ago (the age of the oldest known flying squirrel fossil; Casanovas-Vilar et al., 2018). Both groups may therefore be considered as 'living fossils'.

The great height of Borneo's forests means that arboreal (tree-dwelling) animals are challenging to study. Most squirrels are fast-moving, small-bodied, cryptically-coloured and, in the case of flying squirrels, nocturnal. Recently, motion-triggered camera traps have been successfully trialled in the canopy of Sabah's rainforests (Haysom et al., 2021), and it is hoped that future canopy camera trapping will provide much more in-depth information on squirrel behaviour and ecology.

For the six species of flying and non-flying squirrels covered in detail in this Wildlife Atlas, existing information comprises either simple records of presence in particular locations in Borneo, or ecological studies from other countries within the species' range. To date, it appears that there have been no detailed studies on the behaviour or ecology of any of these species in Borneo.

Gliding

Although commonly called 'flying' squirrels, these species do not use a flapping motion to generate thrust or lift. Instead, 'flying' squirrels have a gliding membrane, or patagium, which extends between the fore and hind limbs on either side to increase their body surface area and enable them to maintain enough lift to glide from one point to another, sometimes across distances of 100 m or more. Larger-bodied flying squirrels such as the three described in the following chapters also have a uropatagium, which is an extension of the gliding membrane that reaches from the knees to the tail, increasing the total gliding surface area, helping to overcome the increased weight of these

larger species. Here, the terms flying and gliding are used interchangeably.

The initial part of the glide is usually steep and probably represents the period when the squirrel is reaching optimum velocity. When this velocity is reached, the squirrel then flattens its glide to maximise the horizontal distance to be covered. At the end of the glide it increases the angle, resulting in an upward swoop and allowing it to land with head facing up on tree trunks. The swoop reduces air speed, thereby softening the landing. However, when necessary, flying squirrels can reportedly execute a 'semi-stall' for a hard and fast landing, or carry out a 'parachute landing' in emergencies (Thorington & Heaney, 1981).

Gliding between treetops means that an animal does not have to descend and ascend individual trees, which allows it to conserve energy. Not having to descend to the ground also avoids the risk of encountering ground-dwelling predators, and gliding may facilitate rapid escape from arboreal, non-flying predators (such as martens or snakes). The energetic advantages of gliding have been shown to be greatest for smaller-bodied flying squirrels. Large-bodied species need to undertake continuous glides of 45 m or more in order to benefit energetically (Dial, 2003; Scheibe & Robins, 1998).

Flying squirrels are unusual because, unlike most species where genders are different sizes, female flying squirrels are larger than males. This difference is associated with a gliding lifestyle (Nandini, 2011), because increases in weight and changes in the body shape during pregnancy will alter the flying squirrel's centre of gravity and reduce its speed, manoeuvrability and overall glide performance. Larger size may help females to cope with these changes, for example with longer tails providing an increased lift surface to help maintain glide distances and control over direction (Hayssen, 2008a). A similar longer tail in female non-flying squirrels may help pregnant individuals to stabilise and balance while travelling along branches high in the canopy (Hayssen, 2008a). This theory is supported by the fact that ground-dwelling squirrels tend to have much shorter tails in relation to body size than their arboreal and gliding cousins (Scheibe & Robins, 1998).

In general, flying squirrels bear only one offspring at a time (Goldingay, 2000), which is fewer than tree squirrels (Holmes & Austad, 1994). This means they can invest increased resources into the development of the young to improve that individual's chances of survival (Fokidis & Risch, 2008). Flying squirrels also tend to be longer-lived than tree squirrels. This combination of traits suggests that the ability to glide may reduce mortality due to predation, allowing for the slower development rates and smaller litter sizes seen in flying squirrels. Longer lactation and dependence on the mother in flying squirrels may also give the young more time to learn to glide — likely a harder skill to master than climbing alone (Hayssen, 2008b). While reproduction in tree squirrels may be governed by external factors such as climate, habitat and resource availability, reproduction in flying squirrels is likely limited by internal constraints of physiology and morphology (Hayssen, 2008b).

Forest Strata

The dipterocarp-dominated lowland rainforests in Sabah are the tallest tropical forests in the world, where the average canopy height is 35–50 m and emergent trees commonly reach 60 m or more (Ashton, 1988; Dudley & DeVries, 1990), with giants of up to 100 m recorded (Shenkin et al., 2019). Their great height results in a very large volume of three-dimensional habitat space and thus many ecological niches available within the vertical column. This facilitates the co-existence of a

high diversity of animal species, as they are effectively able to spread out across both vertical and horizontal space (Nakamura et al., 2017), limiting competition with other species for food resources and shelter.

Data from Sabah forest surveys in 1979–1981 (Davies & Payne, 1982), recording direct observations of diurnal squirrels during transect walks, do give some indication of how this ecological separation may occur (Figure 1). The two largest species (Giant Squirrel (1.2 kg) and Prevost's Squirrel (375 g) were found at all levels, up to the highest canopy and emergent trees; the two middle-sized squirrels (Plantain — 215 g and Horse-tailed — 312 g) were more commonly in the lower canopy, although the latter occasionally did occur above 20 m; the smallest species (Low's — 78 g and Pygmy — 17 g) were largely in the understory, with some surprising occasional records of Pygmy Squirrels up above 25 m.

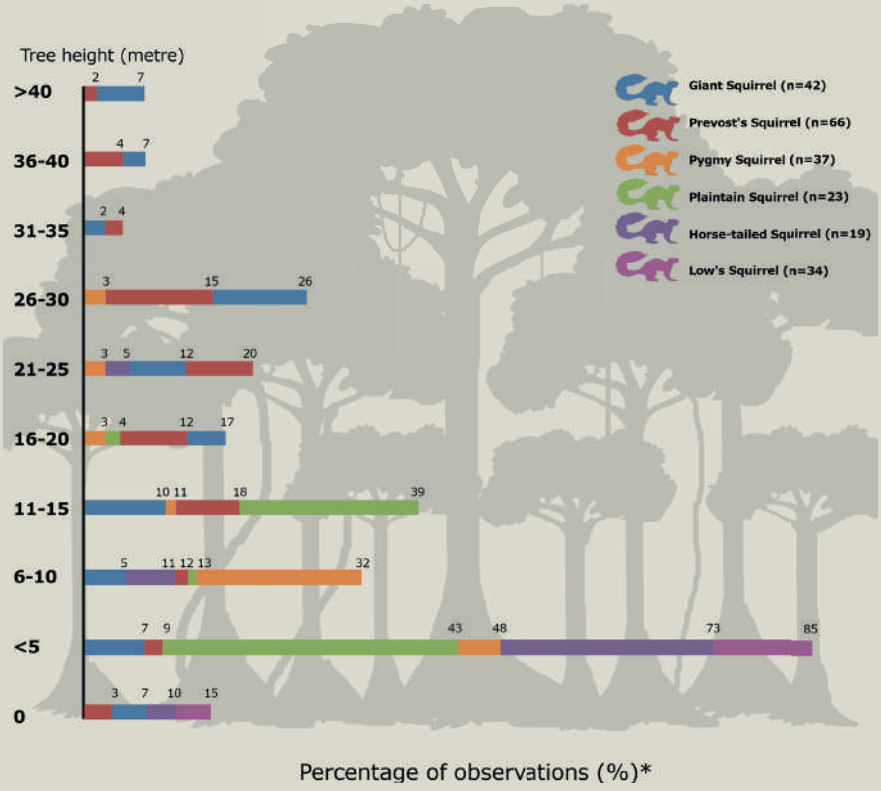


Figure 1. Squirrels species and tree heights where they are commonly recorded, based on WWF-Malaysia field records (Davies & Payne, 1982)

Acknowledgements

Canopy camera-trapping was kindly supported by the Sabah Biodiversity Centre, Maliau Basin Management Committee, SEARRP, University of Kent (UK) and with a funding grant from the Natural Environment Research Council (UK). Fieldwork was ably assisted by Almius Jupri, Fredino John, Mohd Sabri bin Bationg, Arnold James, Sabidi Mohd Rizan, Anis-Ampat Siliwong, Masliadi bin Asri, Masdi bin Asri, David Paul and Jamiluddin bin Jami.



Red Giant Flying Squirrel with tail down ready to launch gliding at Tabin Wildlife Sanctuary © William W. W. Wong

23

Red Giant Flying Squirrel (*Petaurista petaurista*)

Jessica Haysom

Taxonomy

The common names for this species are Red Giant Flying Squirrel and Common Giant Flying Squirrel.

Eighteen subspecies are recognised from across South and Southeast Asia (Duckworth, 2016). The subspecies present in Sabah, *P. p. nigrescens*, has dark cinnamon brown-red colouration all over, with a distinctive black tip to the tail, black feet and hands, and black facial markings including around the eyes, on the nose and the ears (Thorington et al., 2012). Its head to body measures 34–37 cm and tail 37–49 cm, and it weighs 1.3–2.9 kg. The most closely related species, the Spotted Giant Flying Squirrel (*Petaurista elegans*), can be distinguished by its thicker, darker-coloured tail, with no black tip, and a darker-coloured dorsum (back) speckled with white spots (Payne & Francis 2007).



Figure 1. Red Giant Flying Squirrel recorded by a canopy camera trap set at 40.5 m height in Maliau Basin, Sabah, an area of unlogged primary forest. For identification purposes, this species can be distinguished by its black tail tip, feet & hands, and facial markings, which are obvious even in black-and-white images © Jessica Haysom/DICE

Natural History

The Red Giant Flying Squirrel is highly folivorous, with leaves making up a major part of the diet (Payne & Francis, 2007). It also eats seeds, fruits, flowers, buds, bark and lichens (Thorington et al., 2012). Nine specimens collected in Malaysia had an average of 85%



Figure 2. Red Giant Flying Squirrel gliding mid-air at Sepilok Forest Reserve © George J. D. Stambul

fruit and 15% leaves in the stomach, and no insects (Harrison, 1961). Red Giant Flying Squirrels may act as pollinators within the forest ecosystem, having been observed consuming flowers of *Madhuca* sp. (Sapotaceae), with pollen remaining attached to fingers and fur around the mouth (Yumoto et al., 2000).

The digestive systems of Red Giant Flying Squirrels have a longer fermentation chamber relative to body size than smaller-bodied flying squirrels, which have lower fibre diets of fruit and seeds compared to the larger species' main diet of leaves (Mitsuzuka & Oshida, 2018). This is thought to be an adaptation to facilitate the digestion of a high fibre, nutritionally poor diet, allowing these large-bodied, mainly folivorous species to extract the maximum energy possible from their food.

They are nocturnal, with activity beginning just before dusk, but occasionally also seen during daylight hours resting on exposed parts of trees until around mid-morning, or peering out of the tree holes used as daytime shelters (Payne & Francis, 2007). Red Giant Flying Squirrels have a *tapetum lucidum* behind the retina of the eyes, which helps with night vision by reflecting light and also causes the 'eye-shine' seen in torchlight (Meijaard et al., 2006).

They are highly arboreal (tree-dwelling), with no known records of activity at ground level. They can make continuous glides of at least 100 m (Payne & Francis, 2007), and reportedly as far as 300 m where conditions allow — in this example, from the top of a limestone bluff to the canopy of fruiting trees, dropping approximately 125 m in height during the glide (Thorington & Heaney, 1981).

Social Behaviour

Red Giant Flying Squirrels give a species-specific call, often at dusk (Thorington et al., 2012). Leaf nests are occasionally used for shelter, but more often tree cavities, usually at heights of at least 10 m above the ground (Krishna et al., 2019; Payne & Francis, 2007; Thorington et al., 2012).

One individual was recorded nesting under a giant tree fern at approximately 70 m height in the canopy of an emergent yellow meranti (*Shorea faguetiana*) in primary forest in Sabah. The dark facial markings and camouflage with its surroundings are clear (see Figure 3a). The individual was discovered during research to set canopy camera traps, and the team took great care to work quickly and minimise any disturbance caused.

Red Giant Flying Squirrels are usually found alone or in small groups (Payne & Francis, 2007; Thorington et al., 2012). Males reportedly enter reproductive condition earlier than females and around 50% of females are thought to reproduce each season (Thorington et al., 2012). It is not known whether females can have more than one litter per year. When breeding, the nest is apparently occupied by mated pairs and 1–2 young are born, which take around 3–4 months to develop to independence (Nowak, 1999).

In Borneo, the Red Giant Flying Squirrel occurs in primary, logged and secondary forest up to 900 m elevation (Kee et al., 2018; Payne & Francis, 2007). It has also been reported from open areas, which have a few tall trees, gardens and plantations. There is possible migration in spring of individuals living above 900 m elevation to lower altitudes in order to take advantage of young leaves and flower buds that develop earlier at lower elevations (Meijaard et al., 2005). However, these represent observations of a limited number of individuals and it is not clear whether this is a trend that is consistent across populations and years.

The species' tolerance to habitat disturbance is poorly understood (Payne & Francis, 2007; Thorington et al., 2012). In Peninsular Malaysia, some transect surveys reported that population density did not change significantly six months after logging but did decrease in older logged forest, possibly as a result of fewer tree holes available and/or increased predation or hunting (Meijaard et al., 2005). Similarly, research in Sabah noted that larger flying squirrels in general were recorded less often from areas which had suffered heavier logging activities, and suggest this may be linked to the more open canopy and lower numbers of large trees (for launching glides and which provide holes for nesting) in logged forest (Wilting & Mohamed, 2010).



Figure 3. a) Red Giant Flying Squirrel photographed in its daytime resting place, a hole underneath a giant tree fern © Jessica Haysom/DICE; b) Another individual looking out from a tree cavity at Sepilok Forest Reserve © William W. W. Wong

Distribution in Sabah

Red Giant Flying Squirrels are reportedly found across the state of Sabah, although there are few records from the central mountains or the west. This may be due to elevation restrictions, as in montane areas above around 1,000 m elevation, Red Giant Flying Squirrels are replaced by the similar Spotted Giant Flying Squirrel (*Petaurista elegans*). It may also reflect a lack of surveys from western lowland areas.

Conservation

Red Giant Flying Squirrels may suffer population declines after logging, or may be able to adapt to maintain their populations if the tall trees that are used as nesting sites are retained (Meijaard et al., 2005; Muul & Lim, 1978, Syakirah et al., 2000). The species is patchily recorded in Sabah and, like other Bornean flying squirrels, is relatively under-studied and poorly-known. More detailed information about this species' ecology, distribution and habitat tolerances would help inform future conservation efforts and management plans.

Throughout their wide range, Red Giant Flying Squirrels are of 'Least Concern', because the species is widespread and abundant in suitable habitat, occurs in protected areas, and its populations are not thought to be experiencing significant decline (Duckworth, 2016). In Sabah, the species is classified under Schedule 2 of the Wildlife Conservation Enactment 1997, which means that hunting and collection is allowed only under licence.

24

Black Flying Squirrel (*Aeromys tephromelas*)

Jessica Haysom

Taxonomy

The common names for this species are Black Flying Squirrel and Large Black Flying Squirrel.

Two subspecies are recognised from Borneo (Sabah, Sarawak, Kalimantan & Brunei Darussalam), Peninsular Malaysia, Penang Island, Sumatra, and southernmost Thailand (Lee, 2016). The subspecies present in Sabah, *A. t. tephromelas*, has black colouration all over, whereas the less common *A. t. phaeomelas*, found in Kalimantan, is orange-red (Thorington et al., 2012). Recent camera trap images from Sabah suggest that some individuals may have a patchy, intermediate colouration (see Figure 1), although the images are black-and-white so this has not been confirmed. This individual was recorded on a canopy camera trap at 23.5 m height in the Mt. Louisa Forest Reserve, Sabah, a previously-logged forest. The Black Flying Squirrel can be identified by its very dark colouration, which is apparent even in black-and-white images, and furless ears and nose-tip, which appear pink in coloured images or pale/white in black-and-white images. Its head to body measures 35–43 cm and tail 41–47 cm, and it weighs 0.9–1.3 kg.

Natural History

Black Flying Squirrels are herbivores, feeding on seeds, fruits, nuts, leaves and other plant material (Lekagul & McNeely, 1988; Thorington et al., 2012). They are nocturnal; tending to emerge only after dark and remaining active throughout the night (Phillipps & Phillipps, 2018). Like the Red Giant Flying Squirrel, the Black Flying Squirrel has a *tapetum lucidum,* behind the retina of the eye, which helps with night vision by reflecting light and also causes the 'eye-shine' seen in torchlight (Meijaard et al., 2006).

They are highly arboreal (Lee, 2016), with no known records of activity at ground level and they nest in tree cavities when available (Thorington et al., 2012). In Sabah, the Black Flying Squirrel occurs in primary and secondary forests (Payne & Francis, 2007), as well as in gardens where it inhabits tree hollows (Lee, 2016).



Figure 1. Black Flying Squirrel showing apparent patchy colouration. The pale nose and ears are still distinct and overall colouration is still darker than other, similarly-sized flying squirrel species in the region © Jessica Haysom/DICE



Figure 2. Black Flying Squirrel at Tabin Wildlife Sanctuary © Cosmo Phillipps

Distribution in Sabah

According to the IUCN Red List, the Black Flying Squirrel is found across the western, central and northern parts of Sabah, but not in the east or south-east. However, available information includes confirmed records from the east and south-east, but distribution data are patchy and from scattered locations.

The Black Flying Squirrel appears to be widespread but occurring in relatively low numbers, and it may be that it naturally occurs at low density (Lee, 2016; Thorington et al., 2012). Along with other large-bodied flying squirrels, this species may occur in lower numbers after logging, possibly due to the more open canopy and lower numbers of large trees (for launching glides and which provide holes for nesting) in logged forest (Wilting & Mohamed, 2010).

Conservation

Black Flying Squirrels are listed as a Protected Species under Schedule 2 (Section 25 (2): Protected Animals) of the Sabah Wildlife Conservation Enactment 1997, meaning that hunting and collection in Sabah is only allowed under licence.

This species is thought to be adaptable and able to persist in disturbed forest, unless the forest is completely cleared (Lee, 2016). However, the lack of research prevents firm conclusions being drawn (IUCN data deficient). It is likely that, along with other flying squirrel species, it is threatened by habitat loss and fragmentation. In Peninsular Malaysia, this species is believed to be restricted to lowlands and foothills (Medway, 1983) and, if this elevation restriction is found in the rest of its range, it will increase the threat level to the species as lowland forest is more at risk of logging and conversion than hilly or montane areas (Lee, 2016).

25

Thomas's Flying Squirrel (*Aeromys thomasi*)

Jessica Haysom

Taxonomy

Thomas's Flying Squirrel, *Aeromys thomasi* (Hose, 1900), is endemic to Borneo and present across Sabah, Sarawak, Brunei Darussalam and Kalimantan, except the south-east (Gerrie et al., 2016).

It can be distinguished from the similarly-sized Red Giant Flying Squirrel, *Petaurista petaurista*, by its entirely reddish-brown colouration, with no black patches anywhere on the body, and from the Black Flying Squirrel, *Aeromys tephromelas*, by its overall lighter colouration and lack of pale, furless patches on the nose and ears. Its head to body measures 35–40 cm and tail 34–43 cm, and it weighs 1.1–1.5 kg.



Figure 1. Thomas's Flying Squirrel at Mt. Hatton, Tabin, without black markings on the tail tip or feet © William W. W. Wong

Natural History

Thomas's Flying Squirrels are herbivores, feeding mainly on fruits (Payne & Francis, 2007; Thorington et al., 2012). They are nocturnal and are active throughout the night **(**Payne & Francis, 2007). Like many other nocturnal mammals, they have a *tapetum lucidum* behind the retina of each eye, which helps with night vision by reflecting light and also causes the 'eye-shine' seen in torchlight (Meijaard et al., 2006).

This species is highly arboreal, but may occasionally descend to ground level as suggested by a very rare set of camera-trap images of what, at the time was thought to be a new species of Bornean carnivore but was later determined to most likely be a terrestrial record of Thomas's Flying Squirrel (Meijaard et al., 2006). A similar set of images recording likely ground travel of this species was captured by camera traps in Maliau Basin in 2019 (J. Haysom, pers. obs.). In Sabah, Thomas's Flying Squirrel occurs in primary, secondary and logged forest from the lowlands to around 1,600 m elevation (Payne & Francis, 2007). It may be more common in primary forest than disturbed areas, but this needs confirmation by further research as the habitat preferences of this species are not well-documented (Gerrie et al., 2016).



Figure 2. Thomas's Flying Squirrel recorded by a canopy camera trap at 40.5 m in Maliau Basin. Note the patagium, visible as folds of skin on the fore-arms of this individual © Jessica Haysom/DICE

Distribution in Sabah

Thomas's Flying Squirrels are reportedly found across the state of Sabah (Gerrie et al., 2016). The species has been recorded more frequently across Sabah than the Black Flying Squirrel, but is encountered much less frequently in the Rainforest Discovery Centre, Sepilok (G. Davies, pers. comm.). However, distribution data are patchy and from scattered locations (Kee et al., 2018).

The very limited available information indicates that Thomas's Flying Squirrel may be locally common, but there is a recognised lack of information (Thorington et al., 2012). This species may occur in lower numbers after logging, possibly due to the more open canopy and lower numbers of large trees (for launching glides and which provide holes for nesting) in logged forest (Wilting & Mohamed, 2010).

Conservation

Thomas's Flying Squirrel is Schedule 2 in Sabah's Wildlife Conservation Enactment 1997, allowing hunting and collection of the species only under licence.

This species is likely to be threatened by habitat loss, but very little information is currently available (Thorington et al., 2012). It is categorised as 'Least Concern', and was last assessed by IUCN in 2016. This categorisation was given as the species is widespread across a wide elevation band, found within protected areas, and has been recorded from both primary and secondary forest (Gerrie et al., 2016).

Data Sources

Black Flying Squirrel

Individuals / organizations (Number of records): Haysom, Jessica (71); Wong, William (1); 1StopBorneo Wildlife (1); WWF-Malaysia (3). *Publications (Number of records):* Webb, 2016 (2).

Thomas's Flying Squirrel

Individuals / organizations (Number of records): Haysom, Jessica (176); Wong, William (1); 1StopBorneo Wildlife (1); Sabah Museum (1); WWF-Malaysia (3). *Publications (Number of records):* Bili, 2014 (2); Boonratana, 1997 (2); Chasen & Kloss, 1931 (1); Kee et al., 2018 (1); Kehoe, 2011 (1); Ketol et al., 2009 (1); Rahman & Abdullah, 2002 (1); SFD, 2017 (2); SFD, 2018 (2); Webb, 2016 (3); Wilting & Mohamed, 2010 (1).

Red Giant Flying Squirrel

Individuals / organizations (Number of records): Haysom, Jessica (104); Wong, William (2); 1StopBorneo Wildlife (1); Forest Solution Malaysia (1); Sabah Museum (4); WWF-Malaysia (8). *Publications (Number of records):* Bili, 2014 (1); Boned et al., 2016 (1); Boonratana, 1997 (2); Davies & Payne, 1982 (4); Davis, 1962 (2); Ishige et al., 2017 (1); Kee et al., 2018 (1); Kehoe, 2011 (3); SFD, 2017 (5); SFD, 2018 (1); Shukor, 1996 (3); Webb, 2016 (2); Wilting & Mohamed, 2010 (1).

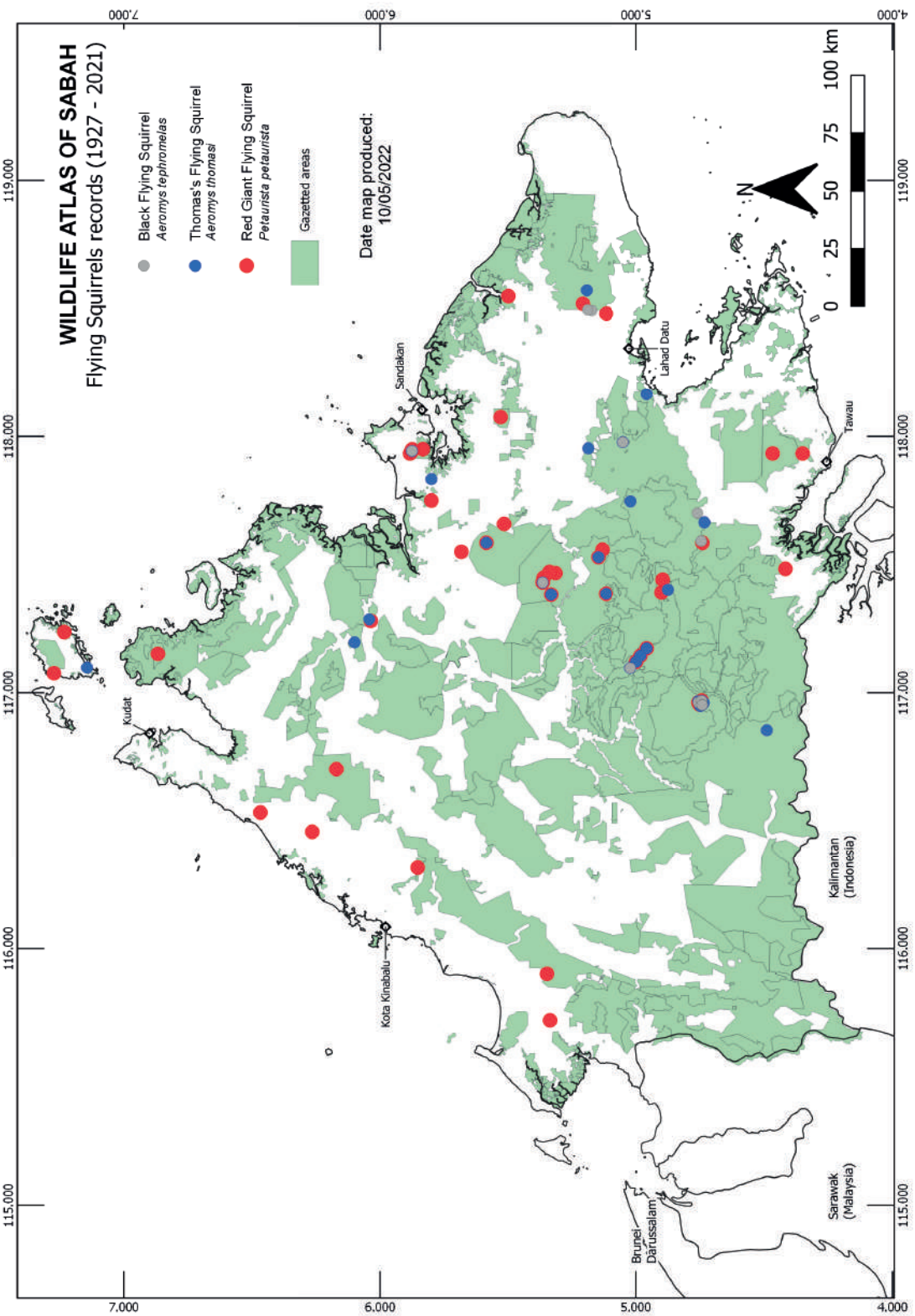


Figure 3. Records of Black Flying, Thomas's Flying and Red Giant Flying Squirrels

26

Giant Squirrel (*Ratufa affinis*)

Jessica Haysom

Taxonomy

The common names for Giant Squirrel, *Ratufa affinis* (Raffles, 1821), are: Giant Squirrel, Pale Giant Squirrel and Cream-coloured Giant Squirrel. At least nine subspecies are recognised (Payne & Francis, 2007), and the subspecies present in Sabah is *R. a. baramensis*, also found in Sarawak, north-east Kalimantan and Banggi Island (Thorington et al., 2012).

Giant Squirrels are the largest tree squirrel in Borneo (Phillipps & Phillipps, 2018). They have very variable colouration across the different subspecies. The subspecies present in Sabah is dark to very dark on the dorsum (back), particularly the midline, pale white to buff on the venter (underside) and pale orange on the face, cheeks and chest. The tail is dark above and paler below, sometimes appearing banded (Thorington et al., 2012). Its head to body measures 32–38 cm and tail 37–44 cm, and it weighs 0.9–1.5 kg.



Figure 1. Giant Squirrel recorded by a canopy camera trap set at 33.6 m height in Maliau Basin, Sabah, an area of unlogged primary forest © Jessica Haysom/DICE

Natural History

The Giant Squirrel's diet includes fruit, seeds, leaves, bark, sap, flowers, insects and eggs (Corlett, 1998; Meijaard, 2017; Thorington et al., 2012). One specimen collected in Malaysia had only fruit in the stomach (Harrison, 1961), and Payne (1979) examined the stomach contents of 40 *R. affinis* and 30 *R. bicolor* collected by Illar Muul in 1969–70 in Peninsular Malaysia, and found no signs of any animal material. Payne (1979) never saw *Ratufa* of either species (*R. affinis* and *R. bicolor*) in Krau Wildlife Reserve, Peninsular Malaysia, feed on anything other than plant materials during 22 months (1976–77) of direct observations, at least 15 days per month. 86% of feeding observations of *R. affinis* were of feeding on fruits, with seeds always the main part consumed. It is not clear whether Giant Squirrels are solely seed predators (i.e. destructively consume seeds) or also seed dispersers (i.e. either eating the pulp and discarding the seed, or consuming the seed whole, whereby it may be able to grow after excretion) (Becker & Wong, 1985). Giant Squirrels have been observed to give seeds to juveniles to eat, but whether they store (cache) seeds for later retrieval is unknown (Becker et al., 1985).

Ratufa squirrels in general, of which there are four species worldwide, have an enlarged part of the intestine known as the caecum (Borges, 2008). This adaptation facilitates the digestion of a nutritionally poor diet, and suggests that as a genus, the diet of *Ratufa* squirrels tends to be high in leaves and bark (see also chapter on Red Giant Flying Squirrel, *Petaurista petaurista*). It is thought that the ability to rely on this type of diet helps these large-bodied squirrels to cope with patchy fruit availability in their native forest habitat (Borges, 2008). In both Krau Wildlife Reserve and Sabah, there are several months every year where there are very few or no high-quality (i.e. large, high in protein and oil) seeds available, within the likely limits of the home range of *Ratufa* squirrels, and so they may be forced to live on a mix of very small seeds, leaves and bark cambium (Payne, pers. comm.).



Figure 2. a) Bark stripping observed in logged forest, Sabah © Jessica Haysom/DICE; b) Typical posture when feeding on laran fruit, looped over a small branch, in Sepilok © Glyn Davies



Figure 3. Canopy camera-trap image from 28 m in Maliau Basin, Sabah, showing an interaction between two individuals, which may have been a mating encounter © Jessica Haysom/DICE

Giant Squirrels are active throughout daylight hours, usually emerging from the nest well after dawn and returning before dusk (Payne & Francis, 2007). They are arboreal, only rarely descending to the ground to cross gaps in the canopy (Payne & Francis, 2007), or males following females during the breeding season (Nowak, 1999). Giant Squirrels are thought to use mainly the upper canopy layers (Meijaard et al., 2005), and the species has a longer tail in relation to body length than any other tree squirrel. This is likely to be an adaptation enabling such a large-bodied and highly arboreal squirrel to balance effectively at height (Thorington & Heaney, 1981).

Payne (1979) showed that both *Ratufa* species in Krau Wildlife Reserve have individual home ranges of at least 4 to 5 ha, and possibly up to 27 ha. Neither species defended a territory, and species showed home ranges that overlapped with conspecifics, with the degree of overlap in home range being at least five individuals in the case of *R. affinis*. Both species typically travelled within one-day distances equivalent to 200 to 300 metres in a straight line between the outermost points. The average active period for *R. affinis* was estimated at 550 minutes per day, with an average daily travel distance of 275 m. On one occasion, a male *R. affinis* was followed and travelled 900 metres in a more-or-less straight line within a few hours, but this observation was unique and did not represent routine daily behaviour. The period of inactivity between movement bouts varied from 1 to over 100 minutes, with a median of 8 minutes.

Social Behaviour

Giant Squirrels make a large, spherical nest of twigs and small branches in the crown of tall trees (Payne & Francis, 2007). Young are born and raised in the nests, usually with 1–2 young per litter. The reproductive strategy of Giant Squirrels is a low but continuous effort (Hayssen, 2008b), meaning that this species has a small litter size and each individual young is small (approximately 77 g) relative to parental size, but they have a relatively short gestation and lactation period and can breed throughout the year (Nowak, 1999).

Giant Squirrels are generally solitary although may sometimes be seen in pairs (Phillipps & Phillipps, 2018). It is not clear if these pairs are same-gender or male-female. Camera-trap images from Maliau Basin in Sabah recorded an interaction between two individuals, which may have been a mating encounter (see Figure 3). Scent-marking behaviour was observed in a male Giant Squirrel at Danau Girang Research Station in the Kinabatangan region (J. Haysom, pers. obs.). The individual urinated on a branch at approximately 8 m height, before rubbing its genital region in the

urine and along the branch. It could conceivably also be used as a way of advertising his presence to females, but without further study the exact use or uses of this behaviour can only be speculated.

Giant Squirrels have a loud, harsh alarm call, as well as a softer "hgip ... hgip" (Payne & Francis, 2007). When feeding in tree crowns, they are vulnerable to attack by airborne predators such as birds of prey. However, their large size and behaviour may help with defence, as they have been recorded reacting to the presence of eagles by, "dashing around with bristling fur, calling loudly" (Becker et al., 1985). In contrast, Giant Squirrels were also observed to be chased out of fruiting Meliaceae (*Aglaia* sp.) trees by the smaller, but apparently more aggressive, Prevost's Squirrel, *Callosciurus prevostii* (Becker & Wong, 1985).

Giant Squirrels inhabit primary, logged and secondary forests in the lowlands and hills to around 1,500 m elevation (Meijaard, 2017). They may have some tolerance to plantations, but are thought to rarely enter this highly-modified habitat (Payne & Francis, 2007).

Distribution in Sabah

Giant Squirrels have been recorded from across the state of Sabah (Meijaard, 2017). They appear to be fairly abundant in forest habitats and were frequently encountered during transects at various lowland primary forest sites; e.g. Ulu Muda Forest Reserve, Peninsular Malaysia (Saiful & Nordin, 2004), Barito Ulu, Kalimantan (McConkey & Chivers, 2004), Gunung Palung, Kalimantan (Marshall et al., 2014). Density estimates range from 1.3 indiv/km^2 in Ulu Muda Forest Reserve (Saiful & Nordin, 2004), to 11 indiv/km^2 in Kalimantan (MacKinnon et al., 1996).

Giant Squirrels are hunted for food across parts of their range (Fiedler, 1990; Meijaard, 2017), but no detailed information is available for Sabah.

Conservation

The Giant Squirrel is threatened by widespread forest habitat loss, possibly logging, but unlikely by hunting in Sabah. Indeed, the Sabah population may now be relatively stable, as most conversion of forest to oil palms in Sabah occurred prior to 2005, and some areas have since started to naturally regenerate (J. Payne, pers. comm.). It is also likely threatened by the fragmentation of remaining forest areas, including the intrusion of roads as these increase the risk of fatal collisions with traffic (Kasmuri et al., 2020).

As a native forest species, allowing the regeneration of previously logged forests, as well as protecting remaining forests, will aid conservation of the Giant Squirrel. Like most Bornean squirrels, it is relatively understudied and poorly-known. Further research into this species' ecology, distribution and habitat tolerances would help inform future conservation efforts and management plans.

Giant Squirrels in Sabah are listed as Schedule 2 under the Wildlife Conservation Enactment 1997, which means that hunting and collection of this species is allowed only under licence. Throughout Southeast Asia it is categorised as 'Near Threatened', on the basis that it is likely to be in significant decline due to habitat loss and hunting (Meijaard, 2017), although specific conditions in Sabah (likely low hunting pressure and relatively large area of remaining forest) may mean that the population in this state is relatively stable. It is listed under CITES Appendix II, meaning that international trade of this species is controlled.

27

Prevost's Squirrel (*Callosciurus prevostii*)

Jessica Haysom

Taxonomy

There are forty-seven subspecies of Prevost's Squirrel, *Callosciurus prevostii* (Desmarest, 1822), recognised from across the geographic range of Southeast Asia and Peninsular Malaysia (Corbet & Hill, 1992; Oshida et al., 2001), and it has been introduced into northern Sulawesi (Musser, 1987). In Borneo and its small coastal islands, there are eleven subspecies. The only subspecies present in Sabah is *C. p. pluto*, which is not found elsewhere (Thorington et al., 2012).

The many subspecies of Prevost's Squirrel have highly variable colouration. The subspecies present in Sabah usually has an entirely black dorsum (back) and tail, an entirely orange-red venter (underside, see Figure 2) and no white lateral (side) stripe. However, some individuals recorded



Figure 1. Sabah subspecies of Prevost's Squirrel (*C. p. pluto*) observed at Maliau Basin. Note the distinctive black dorsum and lack of white lateral stripe © Jessica Haysom/DICE



Figure 2. Prevost's Squirrel with obvious orange-red venter at Tabin Wildlife Sanctuary © William W. W. Wong

by canopy camera traps at the Mt. Louisa Forest Reserve do show a faint white lateral stripe. The subspecies present in Borneo with a white lateral stripe are known to occur in Sarawak and West Kalimantan, both areas that are distant from Mt. Louisa FR. This highlights how little is known about the geographical variation within the species.

The Prevost's Squirrel's head to body measures 20–27 cm and tail 20–27 cm, and it weighs 0.25–0.5 kg.

Natural History

Prevost's Squirrel is reported to eat mainly fruits, especially those with sweet or oily flesh (Corlett, 1998), as well as bark, sap, leaves, shoots, flowers and eggs. It will extract and eat insects, such as ants, termites and beetle larvae, from dead wood (Lurz et al., 2017). Payne (1979) examined the stomach contents of 10 *C. prevostii* collected by Illar Muul in 1969–70 in Peninsular Malaysia, and found insects, mainly ants and termites, as well as fruits and leaf shoots. In a captive zoo setting,



Figure 3. Probable scent-marking behaviour by a Prevost's Squirrel at 23.5 m in logged forest © Jessica Haysom/ DICE

this species ate feral mice (Xanten et al., 1988). When feeding in fruiting trees, Prevost's Squirrel has been observed to frequently remove seeds and fruit and carry them elsewhere (Becker et al., 1985). One individual was observed wedging a ripe fruit in the crack of a tree branch at 40 m height, approximately 50 m away from the source tree, a behaviour suggesting arboreal caching (Becker et al., 1985). This may be to feed juveniles still in the nest, to cache in a safe place for later consumption, or as a way of avoiding arboreal predators, such as the Yellow-throated Marten (*Martes flavigula*), or birds of prey, such as the Crested Serpent Eagle (*Spilornis cheela*). Prevost's Squirrels have been observed to dive for cover at the sight or sound of an eagle (Becker et al., 1985).

Prevost's Squirrels have been observed to often drop seeds after feeding on fruits (unlike some other species in the genus *Callosciurus*), suggesting that they may act as seed dispersers in the forest ecosystem (Thorington et al., 2012). They may also act as pollinators, having been observed consuming flowers of *Madhuca* sp. (Sapotaceae), with pollen remaining attached to fingers and fur around the mouth. Pollen transfer from tree to tree was not confirmed, but is plausible (Yumoto et al., 2000).

Prevost's Squirrels are diurnal/crepuscular, with the greatest amount of activity in the early morning and late afternoon (Thorington et al., 2012). They are not active at night. Payne (1979) managed to follow one individual for most of one day and recorded the following percentages of time on each activity: inactive, 63%; searching for food, 19%; feeding, 11%; travelling, 5.5%; calling, 1.5%.

Prevost's Squirrels are arboreal, descending to the ground only occasionally either to forage or to cross large gaps in the canopy (Cassola, 2016; Thorington et al., 2012). From his detailed study of squirrels in Peninsular Malaysia, Payne (1979) saw Prevost's Squirrels throughout the forest canopy layers, and mainly at mid-levels at Krau Wildlife Reserve, while in Kalimantan Meijaard et al. (2005) suggest they use mainly the upper layers of the forest. Surveys in Sabah (see introduction to this section: *Flying Squirrels and Squirrels*) recorded this species most commonly between 10–30 m, with a smaller proportion of sightings down to ground level, and up to emergent trees (40 m).

Social Behaviour

When breeding, Prevost's Squirrels build a loose nest of gnawed sticks lined with shredded bark and grasses with the entrance usually low on one side (Banks, 1931). They usually have 1–3 young and a gestation period of 46–48 days (Hayssen, 2008; Hayssen, et al. 1993). The young are carried in the mouth by the scruff of the neck (Banks, 1931).

Prevost's Squirrel may behave aggressively when competing for food. It was observed to chase members of its own species, as well as Black Hornbills (*Anthracoceros malayanus*) and Giant Squirrels (*Ratufa affinis*) out of the crowns of fruiting *Aglaia* sp. (Meliaceae) trees, sometimes with multiple individuals cooperating to chase away other animals (Becker & Wong, 1985).

Distribution in Sabah

Prevost's Squirrel is recorded across the state of Sabah and thought to be fairly common throughout its range (Cassola, 2016). It inhabits primary, logged and secondary forests in the lowlands and hills to around 1,200 m elevation (Payne & Francis, 2007; Thorington et al., 2012). This species is known to tolerate forest habitat modification; it will live in gardens, plantations and fruit orchards and has been recorded from several logged forest locations (Lurz et al., 2017).

Prevost's Squirrel appears to be fairly abundant in forest habitats and are frequently encountered during transects at various lowland primary forest sites. The species occurs on Signal Hill and Bukit Padang in Kota Kinabalu, but sightings in comparison with the secondary growth specialist, the Plantain Squirrel (*Callosciurus notatus*), are about forty times less frequent (J. Payne, pers. comm.). This may be as a result of Plantain Squirrels commonly using lower heights than Prevost's Squirrel, but currently the habits of both species are not well-known. Density estimates range from 38+ indiv/km^2 at Kuala Lompat, Krau Wildlife Reserve (Payne, 1979), 2.98 indiv/km^2 in Nanga Gaat, Sarawak (Dabahan et al., 1996), 3.29 ±1.54 indiv/km^2, in Ulu Muda Forest Reserve, Peninsular Malaysia (Saiful & Nordin, 2004), to 7.3 indiv/km^2 in Danum Valley, Sabah (Norhayati, 2001). The much greater estimated population density at Kuala Lompat is striking, but not implausible. Population density of leaf monkeys at Kuala Lompat is about ten times that of lowland dipterocarp forests in Sabah, while mammal population density in Sarawak is notoriously very low. Payne (1979) also noted a dominance of legumes in the diet of squirrels at Kuala Lompat, as is the case with leaf monkeys.

Population size likely fluctuates between years and seasons (Lurz et al., 2017), and may peak after peak fruit production, especially in unlogged dipterocarp-dominated forests (Nakagawa et al., 2007).

Cultural Significance

Prevost's Squirrel is considered a pest of oil palm and coconut plantations (Lekagul & McNeely, 1988; Meijaard & Sheil, 2007), as well as other domestic fruit plantations. However, this species is rarely seen more than a few tens of metres from forest edge, unlike *C. notatus* and rat (*Rattus* sp.) species, which occur throughout plantations, irrespective of distance from forest edge (J. Payne, pers. comm.).

It is hunted for the pet trade in Sarawak (Cassola, 2016), and recorded as being hunted for food in Asia (Fiedler, 1990). The meat of Prevost's Squirrel is reportedly used by Orang Rimba in Jambi, Sumatra, as a remedy for asthma (Masy'ud et al., 2020), but no similar information is available for Sabah.

Conservation

Prevost's Squirrel may benefit from light forest disturbance and may increase in density in some areas post-logging (Meijaard et al., 2005). However, it is vulnerable to forest habitat loss, with much of its native lowland habitat having already been replaced by plantations (Cassola, 2016). It is also likely threatened by the fragmentation of remaining forest areas, in particular the intrusion of roads as these increase both access to the forest for hunters, and the risk of fatal collisions with traffic (Kasmuri et al., 2020). In parts of Sarawak, it is heavily hunted for sale as a pet (Cassola, 2016).

It is not listed as a protected species under the Sabah Wildlife laws, and is recorded as 'Least Concern' globally (IUCN, 2016). Prevost's Squirrel is common and widespread, occurs in a number of protected areas, is tolerant to some degree of habitat modification and is unlikely to be declining at the rate required to classify it as threatened (Cassola, 2016).

28

Tufted Ground Squirrel (*Rheithrosciurus macrotis*)

Jessica Haysom

Taxonomy

Tufted Ground Squirrel, *Rheithrosciurus macrotis*, is the only species within its genus, and is endemic to Borneo (Payne & Francis, 2007). It is most closely related to the *Sciurus* squirrels of the Americas and North Asia. Apart from *R. macrotis*, *Sciurus* squirrels are absent from Southeast Asia, indicating that this species has a relict distribution in Borneo and has become extinct in the rest of Southeast Asia (Pecnerova & Martinkova, 2012).

The Tufted Ground Squirrel is the largest squirrel in Borneo (Phillipps & Phillipps, 2018), with head to body measurements: 34–35 cm and tail, 30–34 cm, and it weighs 1.2–1.3 kg.

Two colour morphs of this species have been reported; one with uniform rusty-red colouration across the head and dorsum (back) and one with grey head and shoulders and rusty-red dorsum. Both colour morphs have prominent white and black lateral (side) stripes, creamy-white venter (underside), long and grey ear tufts which stand upright, and very large, light grey tails. It is not yet known how the two colour morphs are distributed geographically across Borneo (Payne & Francis, 2007).

Natural History

Tufted Ground Squirrels' diet is made up predominantly of fruits, thick-shelled nuts and seeds (Thorington et al., 2012). They show a high degree of ecological specialisation, consuming a small subset of available plants, with a disproportionate reliance on *Canarium* seeds (Blate et al., 1998). This corresponds with their powerful jaw muscles and saw-shaped incisors with deep ridges, which indicate an adaptation to feeding on large, hard thick-coated seeds (Marshall et al., 2020), such as *Canarium decumanum* and *Mezzettia leptopoda*. They may play an important role as seed predators and potentially also as dispersers, for example, where seeds are buried (cached) for later consumption but are not retrieved.

This species is active throughout daylight hours. Camera-trap records from Maliau Basin and Kalabakan show a clear peak in activity around midday (J. Haysom, unpub. data), but Tufted Ground Squirrels' activity patterns have yet to be studied in other locations.

Tufted Ground Squirrels are predominantly a terrestrial (ground-dwelling) species, found mainly on the ground or lower trunks, with occasional records in the canopy, including from canopy camera traps in Maliau Basin (Haysom et al., 2021).

Social Behaviour

Little information is available on the social behaviour of this species, including mating and nesting behaviour. Most records suggest it is usually solitary, although an observation at Mt. Lucia, Tawau Hills Park, recorded two individuals together in the canopy at 15–20 m height, eating *Irvingia* sp. seeds (S. Cheema, pers. obs.). In addition, camera-trap images from Maliau Basin recorded two individuals travelling together in the canopy at Maliau Basin (see Figure 2). It is not clear whether these pairs were same-gender or male-female. The sequence of photographs recorded them appearing to investigate the bark of the branch, before travelling together into the canopy and away from the camera.

Camera-trap footage from a separate location at Maliau Basin appears to show one individual scent-marking a branch, by rubbing its genital region along the surface (see Figure 3), an indication of some form of social communication. Tufted Ground Squirrels are rarely observed in the canopy, and almost nothing is known about their social behaviour or ecology. Canopy camera traps may offer us the opportunity to record unusual or previously unknown behaviours. Tufted Ground Squirrels will reportedly also forage in the same trees as macaques, and show little fear of these primates (Thorington et al., 2012).

The incredible large tail of the Tufted Ground Squirrel, at approximately 130% the volume of the body, is thought to be one of the most voluminous tails relative to body size of any mammal (Meijaard et al., 2014). The function of this tail is unknown. Given Borneo's year-round warm, humid climate, it is unlikely to be for heat retention purposes. It may have evolved as a response to predators, either to confuse potential predators to the squirrel's true size, or, if pounced upon, would provide a limited hold and possibly allow an opportunity for escape (Meijaard et al., 2014).

Distribution in Sabah

Tufted Ground Squirrels have been recorded from primary and selectively logged forest in lowlands and hills up to 1,100 m elevation, as well as from forested coastal flats (Meijaard, 2016), with some indications that they prefer hilly or steep terrain (Payne & Francis, 2007). They are occasionally observed in orchards and secondary forest (Thorington et al., 2012).

The Wildlife Atlas of Sabah database records would support the indication that this species occurs more in upland and highland areas, and according to some authors (Marshall et al., 2020; Meijaard, 2016) this species may be locally common, particularly around specific food trees such as *Canarium* sp. However, care needs to be taken not to confuse actual population density with observations of squirrels concentrating near fruiting trees, such as *Canarium*. Camera traps set in a widely-spaced design at Maliau Basin (primary forest) and Kalabakan (selectively logged forest) recorded this species from 14 and 5 locations, respectively (J. Haysom, Wildlife Atlas Database). This provides at least preliminary support for the idea that Tufted Ground Squirrels may be locally abundant, and may prefer primary forest to logged forest, but further research is needed before conclusions can be reached.



Figure 1. Tufted Ground Squirrel photographed on a tree trunk at Maliau Basin, an area of unlogged primary forest. This individual ran across the trunk for around a minute, before descending to the ground and disappearing into the undergrowth © Jessica Haysom/DICE



Figure 2. Two Tufted Ground Squirrels travelling together at 22.3 m in the canopy at Maliau Basin. It is possible that the individual in the foreground is a male, but this is not clear. The gender of the other is unknown © Jessica Haysom/DICE



Figure 3. Canopy camera trap in Maliau Basin recorded what appears to be scent-marking, on a branch at 28 m © Jessica Haysom/DICE

Cultural Significance

This species is seen as a pest in some areas as it causes damage to forest gardens (Salafsky, 1993).

Local folklore holds that Tufted Ground Squirrels will wait on low-hanging branches for muntjac (*Muntiacus* sp.) to pass below and will jump on the muntjac's back, bite the jugular vein, and wait for it to bleed to death, before consuming the stomach contents, heart and liver (Meijaard et al., 2014). There are also anecdotal stories of the species killing domestic chickens and eating only the heart and liver (Meijaard et al., 2014). These tales have earned it the nickname of the 'Vampire Squirrel', however these reports have yet to be confirmed or documented by photographs or video. To add further intrigue to the mystery, camera-trap images have recently emerged of a Tufted Ground Squirrel foraging peacefully alongside a male Red Muntjac (*Muntiacus muntjac*), its supposed prey species (see Figure 4). Clearly, there is much still to be discovered about this enigmatic squirrel; including verification of folk tales.

Tufted Ground Squirrels are traditionally hunted for meat and for the ornamental use of its tail, including to adorn *parangs* (machetes) (Banks, 1931). It is not known whether, or at what level, the species is still hunted across Sabah.

Conservation

The biggest threats to this species are thought to be habitat loss due to the conversion of forest to monoculture plantations, and the removal of large trees in all forms of forest exploitation, whether legal or illegal (Meijaard, 2016). It is also threatened by hunting, both directly as a target of hunters (Thorington et al., 2012), and indirectly, as it often forages on the forest floor and so is vulnerable to being caught in snares and traps set for other species (Meijaard, 2016). Tufted Ground Squirrels show some tolerance to habitat disturbance (Haysom et al., 2021; Meijaard et al., 2005), but it is not known whether the species can persist long-term in disturbed habitats or may eventually disperse away from them (Thorington et al., 2012).



Figure 4. A Tufted Ground Squirrel foraging peacefully alongside a male Red Muntjac, a species that it allegedly hunts, at Maliau Basin © Jessica Haysom/DICE

In Sabah, the species is listed under Schedule 2 of the Wildlife Conservation Enactment 1997, so it can be hunted and collected only under licence. The species is totally protected in Sarawak, but not in Kalimantan or Brunei Darussalam, and it is classified as 'Vulnerable' across its range in Borneo (IUCN, 2016). Although the Tufted Ground Squirrel is found in protected areas throughout its range, it may suffer from illegal hunting and the species is estimated to have undergone a population decline greater than 30% in three generations, which is approximately 15 years for this species (Meijaard, 2016). As with most other Bornean squirrels, however, it is understudied and poorly-known. Further research into the ecology, distribution and habitat tolerances of Tufted Ground Squirrels would help inform future conservation efforts and management plans.

Data Sources

Plantain Squirrel

Individuals / organizations (Number of records): Dee Arnielia Gundeh (7); Sabah Forestry Department (3); Sabah Museum (133); WWF-Malaysia (29). *Open source database (Number of records)*: eMammal, 2021 (1). *Publications (Number of records):* Davies & Payne, 1982 (26); Lim, 1993 (1); Murphy, 2007 (1); Rajaratnam, 1995 (1); Regip, 2003 (1); WWF-Malaysia, 1985 (3); Zakaria & Rajpar, 2015 (1).

Prevost's squirrel

Individuals / organizations (Number of records): Brodie, Jedediah (4); Gardner, Penny (2); Haysom, Jessica (4595); Hearn, Andrew (6); 1StopBorneo Wildlife (2); Forest Solution Malaysia (2); Sabah Museum (76); WWF-Malaysia (60). *Publications (Number of records):* Abdullah et al., 1995 (1); Ambu et al., 1984 (1); Bernard et al., 1997 (1); Bernard et al., 2014 (2); Boned et al., 2016 (2); Boonratana & Sharma, 1993 (1); Brunke et al., 2019 (4); Chasen & Kloss, 1931 (4); Chung et al., 2019 (1); Davies & Tan, 2019 (5); Davies & Payne, 1982 (68); Davis, 1962 (6); Hawkins et al., 2019 (1); Heany, 1978 (2); HUTAN KOCP, 2016 (1); Kehoe, 2011 (10); Lim, 1996 (2); Mahyudin et al., 2010 (1); Mullin & Colley, 1972 (1); Murphy, 2007 (1); Nakashima et al., 2008 (4); Payne et al., 1989 (1); Prudente et al., 2009 (1); Rajaratnam, 1995 (1); Rajaratnam, 1999 (2); Sheldon & Francis, 1985 (1); Shigeki et al., 2000 (2); Shukor, 1996 (2); Webb, 2016 (3); Wells et al., 2007 (2); Wells et al., 2014 (1); Whitehead, 1893 (1).

Tufted Ground Squirrel

Individuals / organizations (Number of records): Brodie, Jedediah (15); Gardner (4); Guharajan, Roshan (7); Haysom, Jessica (220); 1StopBorneo Wildlife (2); Forest Solution Malaysia (8); Sabah Forestry Department (4); Sabah Museum (4); WWF-Malaysia (20). *Open source database (Number of records):* eMammal, 2021 (22). *Publications (Number of records)*: Bernard et al., 2013 (1); Boonratana,1997 (1); Bornion Timber, 2021 (1); Davies & Payne, 1982 (4); Davis,1962 (1); Dawson,1992 (2); Deere et al., 2017 (3); Hawkins et al., 2019 (1); Lim, 1996 (1); Payne et al.,1989 (2); SFD, 2016 (1); Sollmann et al., 2017 (1).

Giant Squirrel

Individuals / organizations (Number of records): Gardner, Penny (1)*;* Haysom, Jessica (253); 1StopBorneo Wildlife (2); Forest Solution Malaysia (2); Sabah Museum (47); WWF-Malaysia (19). *Publications (Number of records):* Abdullah et al., 1995 (1); Bernard et al., 1997 (1); Bernard et al., 2014 (2); Boned et al., 2016 (1); Boonratana, 1997 (3); Bunya et al., 2010 (1); Chasen & Kloss, 1931 (3); Davies & Payne, 1982 (67); Davis, 1962 (6); Dawson, 1992 (1); Harrison, 1998 (1); Kehoe, 2011 (3); Lim, 1993 (1); Mahyudin, 2010 (1); Mullin & Colley, 1972 (1); Murphy, 2007 (1); Payne et al., 1989 (1); Rajaratnam, 1995 (1); SFD, 2016 (1); Sheldon & Francis, 1985 (1); Shukor, 1996 (2); Wong, 2011 (2).

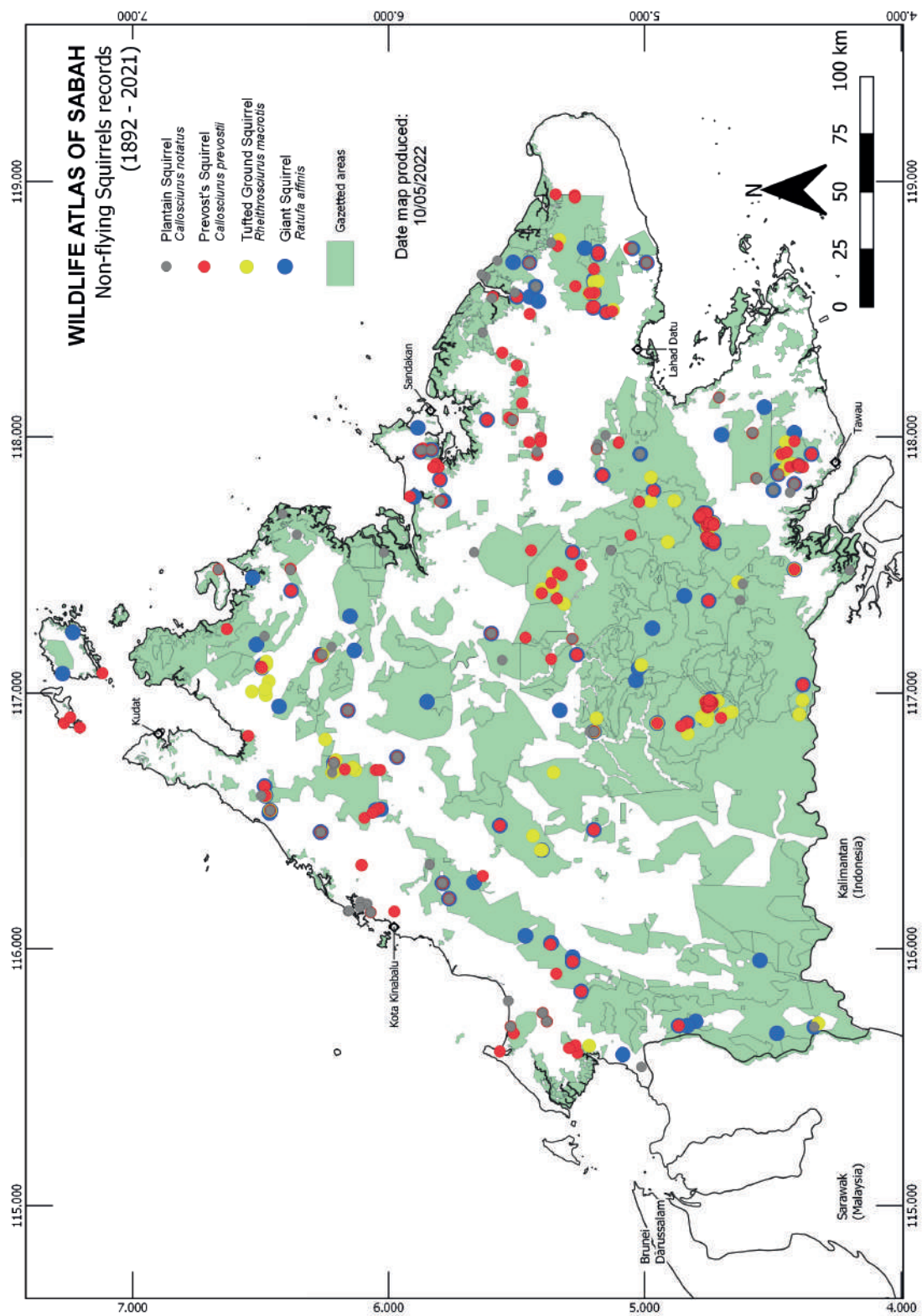


Figure 5. Records of Plantain, Prevost's, Tufted Ground and Giant Squirrels

Birds

Geoffrey Davison and Frederick Sheldon

Of some 849 species of birds ever recorded in Malaysia, about 619 species (73%) have occurred in Sabah. That is 93% of the 667 birds that have ever been recorded in the whole of Borneo, making Sabah the richest of all the Borneo territories. The 619 species from Sabah include 549 that have occurred in both Sabah and Sarawak, and 22 known from Sabah that have never yet been recorded either in West Malaysia or from any other part of Borneo. Those last few include mostly very rare vagrants, a handful of extreme endemics, and a couple of recent colonists from the Philippines.

These figures sound precise, but they shift as rare vagrants are discovered, or sometimes as populations that were thought to be one species are newly classified as two. The phrase "ever recorded" correctly gives the idea that the numbers are historical accumulations of records over time. It is much more difficult to keep track of losses over time, to realise that a species has been locally exterminated, or to determine that a species is less and less likely to occur as a vagrant. An example would be the Philippine Collared Dove, *Streptopelia dusumieri*, which has not been recorded in Sabah since 1962. With time it is becoming less and less likely to occur again, as its normal range within the Philippines has contracted and its abundance there has declined.

The international conservation status of Sabah's birds is as follows:

Critically Endangered	3	0.5%
Endangered	6	1.0%
Vulnerable	19	3.1%
Near-threatened	96	15.5%
Least Concern	495	79.9%

These numbers fluctuate, mostly trending towards greater endangerment. Remember, too, that Sabah populations of these birds can never be more secure than the global assessment, because they are only a subset of the total species. The Near-threatened, Vulnerable, Endangered and Critically Endangered species are overwhelmingly birds of the forest, especially in the lowlands. These species typically have small global ranges, and their habitat is rapidly declining everywhere. Birds that are of Least Concern are overwhelmingly those of open country, mixed habitat, and disturbed vegetation. Those species often have large global ranges, and in some cases their habitat is expanding.

The six birds discussed in the Wildlife Atlas of Sabah comprise less than 1% of all Sabah's birds, but they have been selected to highlight the kind of conservation issues faced by many species — loss of habitat, hunting, and pet-trading. They include four large species (Great Argus Pheasant, Storm's Stork and two hornbills) and two small (the Straw-headed Bulbul and the White-crowned Shama). The latter two are renowned songbirds, heavily poached because their virtuosity is prized by cage-bird enthusiasts. Their extremely recognizable songs also make them easy to locate and trap. Three of the four large birds (the pheasant and the hornbills) also have distinctive vocalisations, easily recognized from long distances. Storm's Storks are rarer and more challenging to detect, but quite

likely to be seen along rivers or soaring overhead when present. The conservation plight of these storks draws attention to the importance of rivers and wetlands for certain species.

These six bird species are iconic. They are characteristic of the forests of Southeast Asia (especially Malaysia, Brunei and Indonesia). They are spectacular and have interesting behaviour. They depend on the forests that are part of Sabah's natural heritage and are all culturally important. All six are declining, and several of them are in very serious trouble, especially the Straw-headed Bulbul and the Helmeted Hornbill — both of which are 'Critically Endangered' according to the IUCN. Storm's Stork is 'Endangered', and the Great Argus Pheasant and Rhinoceros Hornbill are considered 'Vulnerable'. Only the White-crowned Shama is currently considered 'Not Threatened', but that is a taxonomic and bureaucratic idiosyncrasy. In fact, this species is heavily depredated by pet-traders in Sabah and is now much rarer than it used to be near villages and towns.

Despite their decline, these six species are fairly easy to map for atlas purposes because of their loud vocalisations or, in the case of Storm's Stork, visibility. In these respects, they are similar to big mammals, such as gibbons and elephants. They are indicator species which vividly illustrate different conservation problems, especially the loss of nesting and feeding trees, hunting and pet-trading, loss of forest to agriculture, forest fragmentation, and forest fires.

Maps of forest cover, both logged and unlogged, are a reasonable proxy for the occurrence of all forest birds for which exact distributional data are scanty. The periodic mapping exercises of the Sabah Forestry Department are useful in tracking probable changes in bird distribution, but they need to be supplemented by a continuing stream of locality records provided by enterprising birdwatchers, photographers, and scientists to assess the birds' abundance as well as the area and quality of remaining forest.

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Great Argus Pheasant (*Argusianus argus*)

Geoffrey W. H. Davison

Introduction

The Great Argus Pheasant, *Argusianus argus* (Linnaeus, 1766), is a Sunda endemic occurring from the Thai-Malay Peninsula, just reaching into southernmost Myanmar at 10°20'N, southwards to Tebrau in Johor on the mainland and on the island of Pangkor, but never reliably recorded from Penang Island or Singapore; the whole of mainland Sumatra but none of its offshore islands; and the whole of Borneo including (historically) Pulau Laut, to about 4°00'S, and not on Java. The subspecies occurring in Borneo is the Bornean Great Argus, *Argusianus argus grayi* (Elliot, 1865).

The Great Argus Pheasant is the biggest of 14 species in the family Phasianidae in Borneo. Adult females weigh about 1.7 kg, and adult males weigh in the region of 2.2 kg, and are recognised for the magnificent wing feathers which have series of 'peacock eyes' along their length that are used in courtship displays. They also have characteristic very loud calls (see below), and the common names for this bird species in Borneo all derive from these calls: *Ruai, Haruai* (Banjar); *Tubou* (Dusun); *Ruai* (Iban); *Kavong* (Kenyah); *Tawau* (LunDayeh); *Tuwou* (Murut); *Kuang* and *Kuwau* (Malay).

Natural History

The species occurs in mixed dipterocarp forest from the extreme lowlands at or close to sea level, to a variable upper limit that usually lies between 500 and 900 m. There are hints that its upper limit may differ between the Malay Peninsula, Sumatra and Borneo, but the limits are very hard to be sure of because the loud calls carry long distances. Higher elevation records may therefore include gross estimates rather than exact points. More

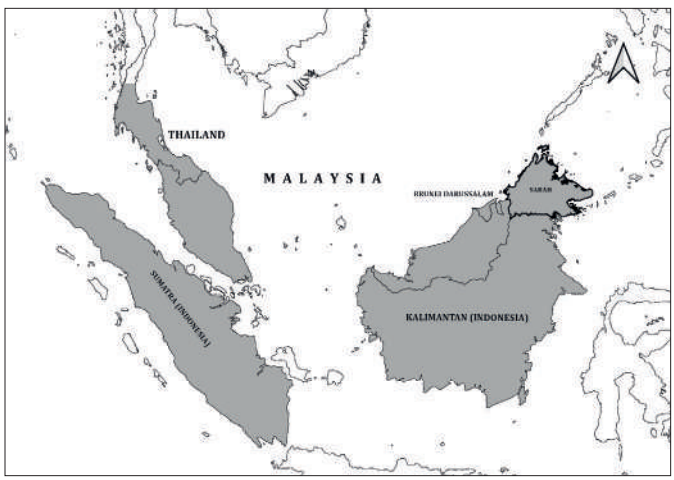


Figure 1. Global distribution of Great Argus Pheasant, Source: BirdLife International and Handbook of the Birds of the World (2016)

important than determining an exact limit, the abundance of Great Argus tails off from mid elevations (ca. 500 m asl) upwards. Therefore lowland and foothill populations are the most important for conservation, and sparse individuals towards the upper limits have less relevance for its survival. There are records from peat swamp and freshwater swamp forest, but they are "more abundant away from the flat steamy swamps of coastal districts" (Smythies, 1981) and Zulfikri (2013) found them to be absent from areas that had been subject to fire. The dryland dipterocarp forest is by far their most important and extensive habitat.



Figure 2. Female Great Argus captured on camera-trap in Lingkabau FR © WWF-Malaysia

Where the land is hilly, males tend to call from ridge crests, spurs or shoulders on the slopes, wherever a small fairly flat spot can be located. There, each male in reproductive condition will clear the leaf litter and understorey growth from a space several metres in diameter. The rule of thumb is one cleared space per breeding male, but rare cases are known in which one male has more than one cleared space, and in which one cleared space is (at different times, outside the calling and breeding period) visited occassionally by more than one male. The spaces have been called dancing grounds, display grounds, calling sites, or leks.



Figure 3. Male Great Argus at Merotai, Tawau © WWF-Malaysia

Strictly, the word 'lek' refers to a cluster of displaying males, so the word cannot be applied to a single male Great Argus and his display ground. However, the distribution of male Great Argus through the forest is uneven, and there appear to be clusters of males in vocal contact but each separated from its nearest neighbours by a few hundred metres. Such a cluster can be thought of as an 'exploded lek' with the potential for a female to visit and compare separate males one after another.

The birds are diurnal, with calling throughout the day but concentrated largely in the morning (0700–1100) with a lesser peak in the afternoon (1500–1800). Calling also occurs at night, but much less, with birds replying to one another from their roost sites. It is assumed that males occupy

relatively small home ranges centred on their display sites, and that females occupy larger areas at least from time to time, visiting more than one calling male and mating with perhaps one. Camera trapping has revealed social units of one, two or three females visiting a male's display site but these could include mothers with female offspring that are not ready to breed. At the display site the male performs a prolonged and elaborate display. It is possible that females could mate with mature non-calling males elsewhere in the forest, but this is speculation. Most sightings are of solitary individuals, either male or female, but a male and female have been seen together away from any display site.

The diet consists mostly of fruits, fallen from the canopy or plucked from plants in the understorey, including fruits of figs and palms. Probably a wide range of fruit species is taken, but the number identified is very small. Big fruits can be swallowed whole, or pecked to pieces if soft. Smaller numbers of ants and other invertebrates are eaten.



Figure 4. The great tail- and wing-fanning courtship display of the male Great Argus to attract a female at Lingkabau FR © WWF-Malaysia

Calling Behaviour

Great Argus Pheasants call very loudly but are extremely hard to see. The huge majority of records are therefore based on hearing birds call, and more recently on camera trapping. There are at least three types of loud calls. One (Short Call) is a high-pitched two-syllable yell, "ku-wau!" (writers have given plenty of spelling variations on that) given once to several times, then a pause of several minutes before calling again. As far as known, the Short Call is given only by males that are in reproductive condition and own a display ground. The calls are given from the display ground by day, and sometimes from a roost perch during the night.

A second call type (Long Call) is a prolonged series of perhaps 15 to a maximum of more than 70 notes, beginning slowly with loud single yells that speed up into a regular series, and then the last 10 or so notes start to rise up the scale and become slightly disyllabic and slower before the series ends abruptly. It used to be thought that this call type was given by females, but it is now known to be given by both females and males, including at times of year when no males are advertising their display sites. It is possible that the Long Calls of males and females might be distinguishable (e.g. by total number of notes, frequency, amplitude) but this has been impossible to discover because the calling bird is never seen. If there are sexual (or age, or seasonal) differences, they are likely to be differences in averages, not absolute either/or differences. On current knowledge, Long Calls of males cannot be distinguished from Long Calls of females. Long Calls can be delivered by day and by night, at any time of year but more often during times when breeding males are giving Short Calls.

A third call type (Irregular Hoot) is a lilting series of syllables, "ooo, kaui-oo" of which the second part can be repeated (in Borneo up to three to five times, in the Malay Peninsula population usually



Scan for a collection of Great Argus calls in Sabah
© Department of Integrative Biology, Museum of Natural Science, Michigan State University, USA

not more than once or twice). Like the Short Call, this is thought to be given only by reproductive males holding a display ground, but its significance is unknown.

A loud series of barking calls is also heard occasionally. Sometimes this transitions into a Long Call, so it is unclear whether it is a functionally different call type or whether it is an aberrant form of Long Call (e.g. by young birds not yet fully capable of calling properly). It is unknown whether both males and females deliver such calls.

Distribution and Abundance in Sabah

The species is limited to forest, and its distribution must have contracted with land conversion to agriculture, even if this is not obvious from mapped records. Absences reflect forest loss; e.g. in the Kudat area, Klias Peninsula, west coast plains, and eastern Sabah where cocoa plantations removed forest cover even before the spread of oil palm, as indicated by old records marked in red dots on the distribution map where Great Argus is no longer present.

The distribution map suggests a very patchy distribution, but this might be misleading. There are obvious concentrations of recent records around camera trapping locations, including huge clusters of records by Brodie and Gardner (Danum Valley, Ulu Segama, Malua) 2010–2015, Haysom (Kalabakan and Maliau) 2017–2019, and Roshan (Deramakot and Tangkulap) 2018–2019. Together these account for more than 94% of all records.

The remainder of the records illustrate a retreat where land has been cleared, as noted above, because Great Argus can only survive in forest, but large areas of south-western Sabah without any records suggest that the map is strongly affected by birdwatchers concentrating on a few other areas. There are also suspiciously large gaps along the Crocker Range where Great Argus probably occur but are under-recorded. Altitudinal effects in south-west Sabah and Crocker Range, however, may help to explain some apparent gaps in distribution.

For population estimates, researchers have typically used Short Calls, because they are given from fixed locations (the display grounds) by day, one male per location. Nijman (1998; 2007) in Borneo, Thong-ari and Prasit (2002) in Thailand, O'Brien and Kinnaird (2008) in Sumatra, and Dawrueng et al. (2017) and Ong-In et al. (2021) in Thailand counted the calls heard while walking slowly along line transects through the forest, distinguished the number of individuals giving those calls, estimated their distance from the transect, and converted these to density estimates (distance sampling). Nijman (2007) also conducted point counts for periods of 5-minute per point, at hourly intervals and at chosen listening points; he estimated the number of calling males within an arc of 500 m radius. However, he found that density estimates derived from the point count method were consistently lower than those from the line transect method. When the 07.00–12.00 period was considered, estimates using point counts were 47% lower than from transects in 1996, and 69% lower in 2003.

Population densities range from zero to a maximum estimate of 8.08 males per km^2 (an oddly high figure at one site in Thailand). Most estimates are between two and four calling males per km^2 and the average across 12 sites is 3.03 calling males per km^2 (see Table).

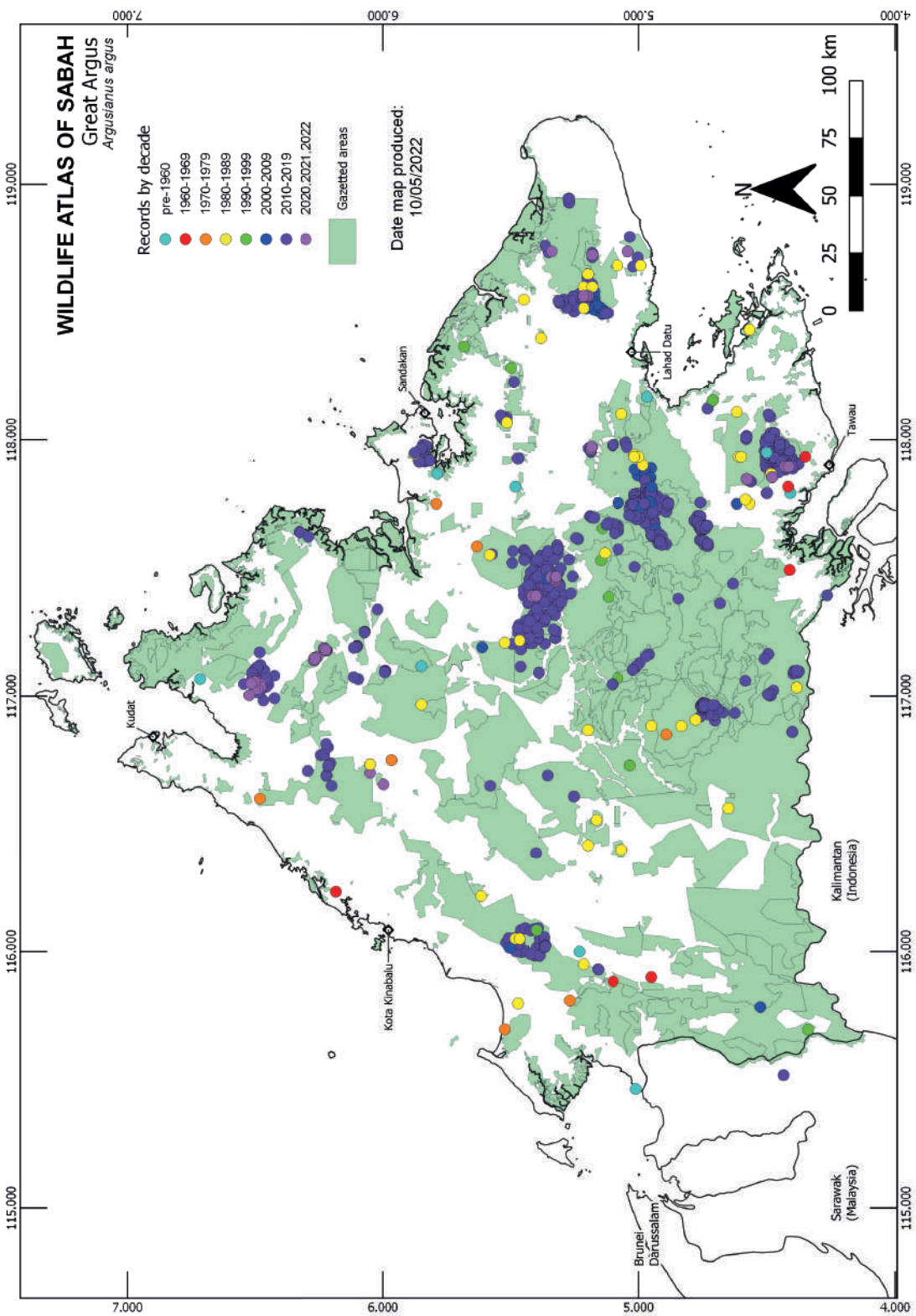


Figure 5. Records of Great Argus Pheasant

Table 1. Great Argus Pheasant population densities

Location		Population density	Habitat	Source
Borneo	**Lanjak Entimau, Sarawak**	1.5 calling Great Argus per km	unlogged hill forests	Bennett & Dahaban (1995)
	Kutai, East Kalimantan	2.3 calling Great Argus per km	unlogged forest	Wilson & Wilson (1975)
	Ulu Mentaya, Central Kalimantan	Not stated Absent	primary forest recently logged	Cleary et al. (2007)
	Kayan Mentarang	1.5 and 2.1 calling males/km 1.99 males/km^2; 1.66 males/km^2; 0.89 males/km^2; 0.23 males/km^2	primary forest old secondary forest young secondary forest riverine forest	Nijman (1998)
Peninsular Malaysia		1.1 calling Great Argus per km		Wilson & Johns (1982)
Peninsular Malaysia		3 birds/km^2; 2 birds/km^2; Too few to sample	Primary forest 10 year old secondary recently logged forest (five years)	Sengrath (2001)

Some authors do not explain precisely which calls they have used to estimate density. This is critical because of sex differences, annual differences and seasonality. Calls can be heard in any month but are influenced by rainfall and by drought. On the western side of Peninsular Malaysia males typically begin Short Calls in January or February and end any time between May and September. On the eastern side of Peninsular Malaysia the period of calling seems to be longer. In Borneo, including Sabah, seasonality seems to be much less pronounced, with Short Calls and Long Calls in nearly all months. Calling also varies between mass fruiting years (many birds giving many calls) and other years. Results by Nijman (2007) imply that in years with less calling, the number of males detected from Short Calls is similar to that in years with more calling, but each male calls less often. Aside from lack of clarity over which call types are being used to estimate density, another major uncertainty is the accuracy of estimating distances between observer and calling bird. Furthermore, sounds can be blocked or deflected by intervening ridges, or heard very long distances across valleys.

Nijman (1998) found that Great Argus Pheasant densities were positively correlated with increasing tree diameter, height, tree branching index, canopy cover, and increasing remoteness. Cleary et al. (2007) found an association with closed canopy conditions, amount of dead wood and abundance of ferns; the latter two factors likely being indirect.

Cultural Significance

Because of its loud calls, the species is known to many rural dwellers even if they have never seen it. The wing and occasionally tail feathers are used as hat ornaments by men of various tribal groups in Borneo. It has been hunted for food, either using ground snares or by shooting males at display sites. Focal areas of hunting have varied with forest removal, and in recent times have centred on the Murut heartlands. There are no data on the rate of offtake. In Malay culture, the bird features in a number of *pantuns* (oral poetry).

Conservation

The species is totally protected in Sabah and Sarawak although enforcement is challenging in remote areas. It is listed as 'Vulnerable' by IUCN, and it is on CITES Appendix II. The fundamental threat to the Great Argus is forest conversion, and increased hunting in forest areas that comes where logging roads allow greater access. The threats of habitat loss, fragmentation and degradation, including selective logging and forest fires will be influenced by climate change, which will affect the ecology of its habitat, for example, effects on dipterocarp mass fruiting years, frequency and intensity. Illegal trapping is usually not targeted at this species, there is no evidence of international trade in the species from Sabah, but it is caught among a range of ground-living forest animals by indiscriminate snares. Lowland and hill forest in protected and managed forests such as Danum Valley, Malua, Deramakot and Tabin will continue to be key to conservation.

Captive breeding is not a priority approach for conservation in view of very small clutch sizes and the longevity of individuals. It is not a substitute for conservation of wild populations and there has been no example of attempted reintroduction.

Acknowledgement

The text was kindly reviewed by Frederick H. Sheldon. Field data presented in this paper have come from numerous published sources, and records supplied to the Wildlife Atlas of Sabah.

Data Sources

Individuals / organizations (Number of records): Brodie, Jedediah (181); Davison, Geoffrey (1); Gardner, Penny (37); Guharajan, Roshan (467); Haysom, Jessica (5640); Hearn, Andrew (1924); 1StopBorneo Wildlife (1); Forest Solution Malaysia (68); Sabah Forestry Department (11); Sabah Museum (4); WWF-Malaysia (518). *Open source database (Number of records):* eMammal, 2021 (136). *Publications (Number of records):* Abdullah et al., 1995 (10); Bili, 2014 (18); Boonratana, 1997 (5); Boonratana & Sharma, 1993 (2); Bornion Timber, 2021 (3); Chung et al., 2019 (4); Davies & Payne, 1982 (44); Dawson, 1992 (1); Kehoe, 2011 (4); KOPEL, 2016 (2), Lim, 1993 (1); Payne et al., 1989 (1); Pieterse & Wielstra, 2009 (1); Rahman et al., 2002 (1); Samejima & Ong, 2012 (29); Samejima et al., 2012 (1); SFD, 2016 (4); SFD, 2017 (3); Sheldon et al., 2001 (35); Wilting & Mohamed, 2010 (1).



Storm's Stork © Biron Bong

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Storm's Stork (*Ciconia stormi*)

Frederick H. Sheldon

Introduction

Storm's Stork (*Ciconia stormi*) is one of two storks found in Sabah; the other is the Lesser Adjutant (*Leptoptilos javanicus*). Storm's Stork is a Sunda endemic, occurring on Borneo, the Thai-Malay Peninsula, Sumatra, the Mentawai and North Pagai islands, and formerly West Java (Elliott et al., 2020; Hancock et al., 1992; Robson, 2005). Prior to the 1990s, it was considered a subspecies of Wooly-necked Stork (*Ciconia episcopus*) (Kahl, 1979), but both taxa occur in Sumatra (Eaton et al., 2016; Holmes, 1977; Silvius & Verheugt, 1986) and Wooly-necked Stork used to occur on the Thai-Malay Peninsula (Wells, 1999). In addition to their sympatry, the two birds are distinct morphologically; Storm's Stork has an entirely orange-red bill, orange and yellow facial skin, and dark feathering that extends up the side of the neck (Eaton et al., 2016; Hancock et al., 1992; Wells, 1999). For these reasons, Hancock et al. (1992) recognised Storm's Stork as a separate species from Wooly-necked Stork, and that arrangement is now universally accepted (Clements et al., 2019; Gill & Donsker, 2019). The Malay name is *Karau*, an onomatopoetic rendering of its voice (Smythies, 1999).

Natural History

Storm's Storks occur at low elevation in primary and secondary forest along freshwater rivers, streams, lakes, and ponds, and in swamp and swamp-forest, tree-lined estuaries, and boggy forest gaps (BirdLife International, 2001; Nakhasathien, 1987; Smythies, 1999; Wells, 1999). They generally feed on the ground under forest cover in wet places, searching for fish, frogs, crabs, worms, and other aqueous and water-edge prey (Danielsen et al., 1997). But they have also have been observed feeding in more open areas, for example, in a field cleared for oil palm along the Sukau Road in 1983 (Sheldon et al., 2001), where they presumably were hunting insects, small rodents, lizards, snakes, and other dryland prey. Storm's Storks usually feed alone, but they will come together in small groups, especially to roost in tall trees (Danielsen et al., 1997). Larger numbers (up to 10) have been recorded when the birds are soaring (BirdLife International, 2001; Hancock et al., 1992).

Perhaps the most perplexing feature of Storm's Stork natural history is that the species has a reasonably broad distribution in Sundaland, but its populations are few and far between, and where

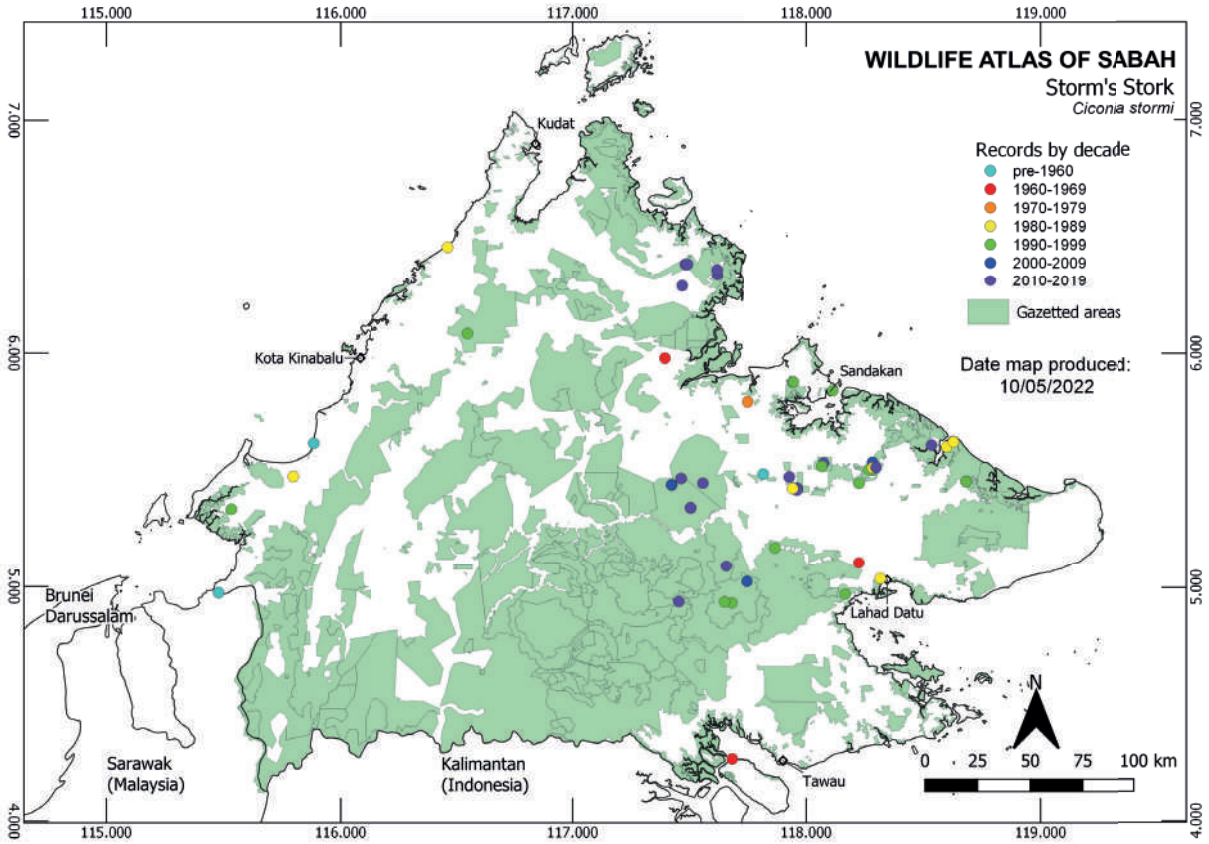


Figure 1. Distribution of Storm's Stork, additional records include Tabin Wildlife Reserve (BirdLife International, 2001; Mann, 2008)

it occurs its numbers are small. Next to the Greater Adjutant (*Leptoptilos dubius*), Storm's Stork is probably the rarest stork in the world (BirdLife International, 2001; Hancock et al., 1992). In 1989, the Indonesian population (Kalimantan and Sumatra) was estimated at 300, and even that appeared to be too high (Hancock et al., 1992). More recently the world population has been estimated at 260–330 individuals (BirdLife International, 2021). The rarity and spottiness of Storm's Stork occurrence may be attributed to its habitat requirements: fresh water in tall forest at very low elevation, usually in the floodplains of larger rivers (BirdLife International, 2001; Danielsen et al., 1997; Wells 1999). Such forest was the first habitat in Sundaland to be disturbed or destroyed by human exploitation and development, and nowadays it persists only in a few locations where remnants of the original habitat remain.

For such a large and easily recognised species, remarkably little is known about Storm's Stork life-history because of its rarity and disjunct distribution. Only three nests have been described; one in the early 1880s in Kalimantan (BirdLife International, 2001; Grabowski, 1885), one in 1986 in southernmost Thailand (Nakhasathien, 1987), and another in southeastern Sumatra in 1989 (Danielsen et al., 1997). Given that the largest population of Storm's Stork is probably in Sabah along the lower Kinabatangan River (BirdLife International, 2001), it is remarkable that nests have not yet been described in the state. No doubt, with the intensive research currently being conducted in that area (e.g., Evans et al., 2016; Matsuda et al., 2020a), nest descriptions will soon appear.

Distribution in Sabah

Historically, Storm's Stork was known from numerous localities around the edge of Sabah and up some of the larger rivers, but it was never common. Smythies (1999) described it as 'distinctly local'. Currently, it may be found reliably only along the lower Kinabatangan River and perhaps on the Klias Peninsula, Kulamba Wildlife Reserve, and in the Paitan-Sugut-Labuk wetlands (Figure 1).

Conservation

Storm's Stork is not listed in CITES appendices, but is ranked as 'Endangered' by the IUCN in its Red List, based on the species' small global population and declining population-size caused by the destruction of lowland forest by logging, dam construction, and conversion to oil palm (BirdLife International, 2021). In Sabah, Storm's Stork is a protected species under Schedule 2 (Section 2), Part 1 (Section 25 (2)) of the Wildlife Conservation Enactment 1997. The best hope for Storm's Stork in Sabah is the regeneration of wetland forest in the Sandakan-Tambisan corridor, with key centres at the Kinabatangan Wildlife Sanctuary and Kulamba Wildlife Reserve, and on the Klias Peninsula, for example, in the environs of the Klias Forest Reserve and Padas Damit Forest Reserve, and in the Paitan-Labuk-Sugut wetlands.

Acknowledgements

James Eaton kindly provided the photograph of Storm's Stork. Adi Shabrani helped extensively with historical records and mapping.

Data Sources

Individuals / organizations (Number of records): Guharajan, Roshan (4); WWF-Malaysia (16). *Publications (Number of records):* Boonratana, 1997 (1); Boonratana & Sharma, 1993 (2); Chung et al., 2019 (1); Davies & Payne, 1982 (1); Kehoe, 2011 (2); KOPEL, 2016 (3); Pieterse & Wielstra, 2009 (1); Rajaratnam, 1995 (2); SFD, 2019 (2); Sharma, 1992 (2); Sheldon et al., 2001 (20); WFVZ, 2021 (1); WWF-Malaysia, 1985 (1).



Figure 2. Storm's Stork © James Eaton



Helmeted Hornbill in Sabah
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Helmeted Hornbill *(Rhinoplax vigil)*

Jedediah F. Brodie, Ravinder Kaur and Marc Ancrenaz

Introduction

The Helmeted Hornbill is the largest Asian hornbill (Kinnaird & O'Brien, 2007). It is usually classified as the sole member of the genus *Rhinoplax*, which is the sister-genus of *Buceros* (containing the other large Asian hornbills such as the Rhinoceros Hornbill, *B. rhinoceros* and Great Hornbill, *B. bicornis*) within the Bucerotidae family (Gonzalez et al., 2013).

It is a striking animal with mostly black plumage, a bare throat patch, and two greatly elongated central tail feathers, though usually only one (and occasionally none) is present at any given time due to the moult cycle. It has among the most distinctive calls of any bird species in Southeast Asia, a series of loud hoots that accelerate into a raucous cackle. Like many large vertebrates, the Helmeted Hornbill is threatened by habitat loss. But the species is also particularly hard-hit by unsustainable hunting for its casque, which, unique among hornbills, is solid rather than hollow and therefore provides a medium widely used for artistic carvings and decorations. It is one of only a handful of Malaysian species listed as 'Critically Endangered' by the IUCN. The Helmeted Hornbill is important ecologically as a disperser of fig seeds and culturally significant to certain groups in the region.

Globally, the Helmeted Hornbill is restricted to the core of the region known as Sundaland, specifically Borneo, Sumatra, and Peninsular Malaysia. It does not occur in Java and Bali, which are drier and have been more extensively deforested (BirdLife International, 2020b). The Helmeted Hornbill does not currently occur in Singapore (BirdLife International, 2020b), though it is unclear whether it did in the past (G. Davison, pers. comm.). Within its range on Borneo, the species is found in undeveloped lowland areas in Kalimantan, Brunei, Sabah and Sarawak. On the mainland, the species range extends into southern Thailand, just north of the Isthmus of Kra and therefore slightly farther north than that of the Rhinoceros Hornbill (*Buceros rhinoceros*) (BirdLife International, 2020b). The species is considered by the IUCN to have a decreasing population trend (BirdLife International, 2020b), has been on CITES Appendix I since 1975, and has a range-wide conservation action plan (Jain et al., 2018).

Natural History

The Helmeted Hornbill is around 110–120 cm in length, mostly black or dark brown with a lighter underside and white tips to the wing feathers. Its casque is yellow at the front but often covered on the sides and top with red pigment from a gland near the tail, which the birds rub onto their casque and bill. The large, wrinkled patch of bare skin on the throat is bright red in males and pale blue in females. In the Penang Bird Park, the gular pouch of the only captive male Helmeted Hornbill was a much darker red shade than normal, perhaps due to its diet in captivity (Kaur, 2020a). The colour also varies in females, from bright blue to pale green, which could be related to health or breeding condition (G. Davison, pers. comm.). A female in Borneo was reported to exhibit red spots on the gular pouch, a feature absent in females in Peninsular Malaysia (Kaur, 2020a).

Males engage in territorial contests that include repeated noisy flights above and through the crowns of forest trees with rushing sounds and combat via crashing into each other in flight with their casques, an act known as aerial jousting (Kinnaird et al., 2003). The solid casque and skull together may account for up to 10% of the animal's total weight.

Helmeted Hornbills live in lowland evergreen or semi-evergreen forest up to ~1,500 m elevation, and may favour hilly terrain (BirdLife International, 2020b). They do not live in peat swamp or cleared areas (Kinnaird & O'Brien, 2007; Poonswad et al., 2013), though they do occur in logged forest.

Like all Asian hornbills, the Helmeted Hornbill is mostly frugivorous. While fruits of many species are consumed, figs (*Ficus* spp.) appear to be particularly important and may constitute the majority of the biomass consumed (Kitamura et al., 2011; Nakabayashi et al., 2019), especially the hemi-epiphytic 'strangler' species (Choo & Teresa, 2001; Nakabayashi & Ahmad, 2018; O'Brien et al., 1998). While all species of hornbill consume figs and many rely on them for a substantial portion of their diet, Helmeted Hornbills may be unique in the extremely high proportion of their diet made up by figs. Indeed, Helmeted Hornbill diets may be much more restricted to figs than the diets of other large, sympatric hornbills (Hadiprakarsa & Kinnaird, 2004). While Rhinoceros Hornbill diets include fruits from a variety of plant taxa, and the species may prefer large, lipid-rich fruits (e.g., from certain Myristicaceae and Meliaceae) to figs (Moraceae) (Leighton & Leighton, 1983), Helmeted Hornbills are nearly, though not fully, fig specialists (Hadiprakarsa & Kinnaird, 2004; Kemp, 1995; Leighton, 1986). Pairs have been observed consuming unripe figs by the hundreds (Kaur, 2020a). Figs are often abundant sources of energy for frugivores in the rainforest, tend to be available year-round (Terborgh, 1986), and are high in calcium (O'Brien et al., 1998), which is especially important for birds when they are producing eggs. Helmeted Hornbills also hunt and consume large arthropods and small vertebrates such as rodents, birds, lizards, and snakes (Chong, 2011; Kemp et al., 2014; Utoyo et al., 2017). Such animal foods may help supplement the diet while the chicks are developing, as most fruits are very low in protein. At least one pair that was observed in Peninsular Malaysia fed many stick insects to its chick (BirdLife International, 2020b). A pair delivered a total of 11 stick insects to chicks over the course of a six-month breeding period in the Kinabatangan beginning in May (Kaur, 2020a).

As with the *Buceros* hornbills, Helmeted Hornbill adults live in monogamous pairs (BirdLife International, 2020b). Helmeted Hornbills nest in natural cavities in tree trunks. Unlike other hornbills, the male does not cling onto the nest opening to pass food through to the female and chick, rather nests are selected at sites with a natural bump or protuberance below, above, or to the side of

the cavity opening, on which the male perches (Thiensongrusamee et al., 2002). The pair seals the female inside the cavity with a wall of debris and faeces, leaving a small hole through which the male can feed her and the chicks. Of the relatively few Helmeted Hornbill nests that have been observed, most were in large canopy or emergent trees such as dipterocarps (e.g. *Shorea pauciflora*; Kaur et al., 2018), with some also observed in *Dysoxylum* (Kaur et al., 2015) and *Koompassia parviflora* (Kemp, 1995). The typical Helmeted Hornbill nest cavity is where a major bough has failed — in big legume trees this tends to be upward-pointing and surrounded by a smooth rim of regenerated bark (G. Davison, pers. comm.). When the chicks are old enough, potentially over 160 days (Chong, 2011), they remove the wall and emerge. Only a single chick is usually produced at a time, which remains with the parents for ~6 months (BirdLife International, 2020b). In the Kinabatangan, a female Helmeted chick that fledged was photographed six months later still accompanying its parents (Kaur et al., 2018).

As of yet, the use of artificial nest boxes has not been observed in Helmeted Hornbills as it has in Rhinoceros and other hornbills in Sabah (HUTAN, 2018). In fact, no visits were recorded at the artificial nest boxes that were designed specifically for Helmeted Hornbills in the Lower Kinabatangan; i.e. with a protruding cavity entrance (Kaur, 2020a).

Helmeted Hornbill lifespan has been estimated at 40–50 years (Jain et al., 2018). Little is known about Helmeted Hornbill home ranges, movement patterns as they track food resources, or their natal dispersal. The species may be territorial while breeding, occupying an area up to 7.7 km^2 (Leighton, 1982), and nomadic during the non-breeding season (Poonswad et al., 2013).

Distribution and Abundance in Sabah

In Sabah, Helmeted Hornbills can be found in many large tracts of lowland and hill forest (Lim & Mojiol, 2018), particularly in the interior Heart of Borneo areas (Davies & Payne, 1982). Many of the recent records come from the eastern part of the state including the Danum-Maliau forest complex and Tabin Wildlife Reserve, as well as the Lower Kinabatangan (Figure 1). Helmeted Hornbill distribution and abundance have changed dramatically in Sabah over the past few decades, though there are no data quantifying such trends. As an anecdotal example, Helmeted Hornbills were detected in Sepilok in the early 1980s (Davies & Payne, 1982) but have not been recorded there recently by the members of the Borneo Bird Club (R. Ong, pers. comm. March, 2022). Hornbill population changes in the Kinabatangan are unclear; elders interviewed in Sukau reported that there were such large trees several decades ago that hornbills were much harder to observe, whereas it is easier now (R. Kaur, pers. obs.).

Helmeted Hornbills can be detected visually and by their calls, which may carry 2–3 km (Haimoff, 1987). Many studies on the ecology of the species in the wild have used either direct observations, for example to record feeding behaviour, or line transects to estimate population density (Hadiprakarsa & Kinnaird, 2004; Johns, 1997).

In a WWF-Malaysia survey of 12 sites in Sabah, listening for hornbill calls on ~2 km^2 belt transects from 2018–2020, Helmeted Hornbill densities tended to be much lower, often half or less, than those of Rhinoceros Hornbills at the same sites. (As a caveat, however, we note that differences in calling behaviour — the basis of most density estimates — and an incomplete understanding of movement behaviours in both species prevent precise interspecific comparisons of density (G. Davies & G. Davison, pers. comm.). The species was not detected at all in two areas where Rhinoceros

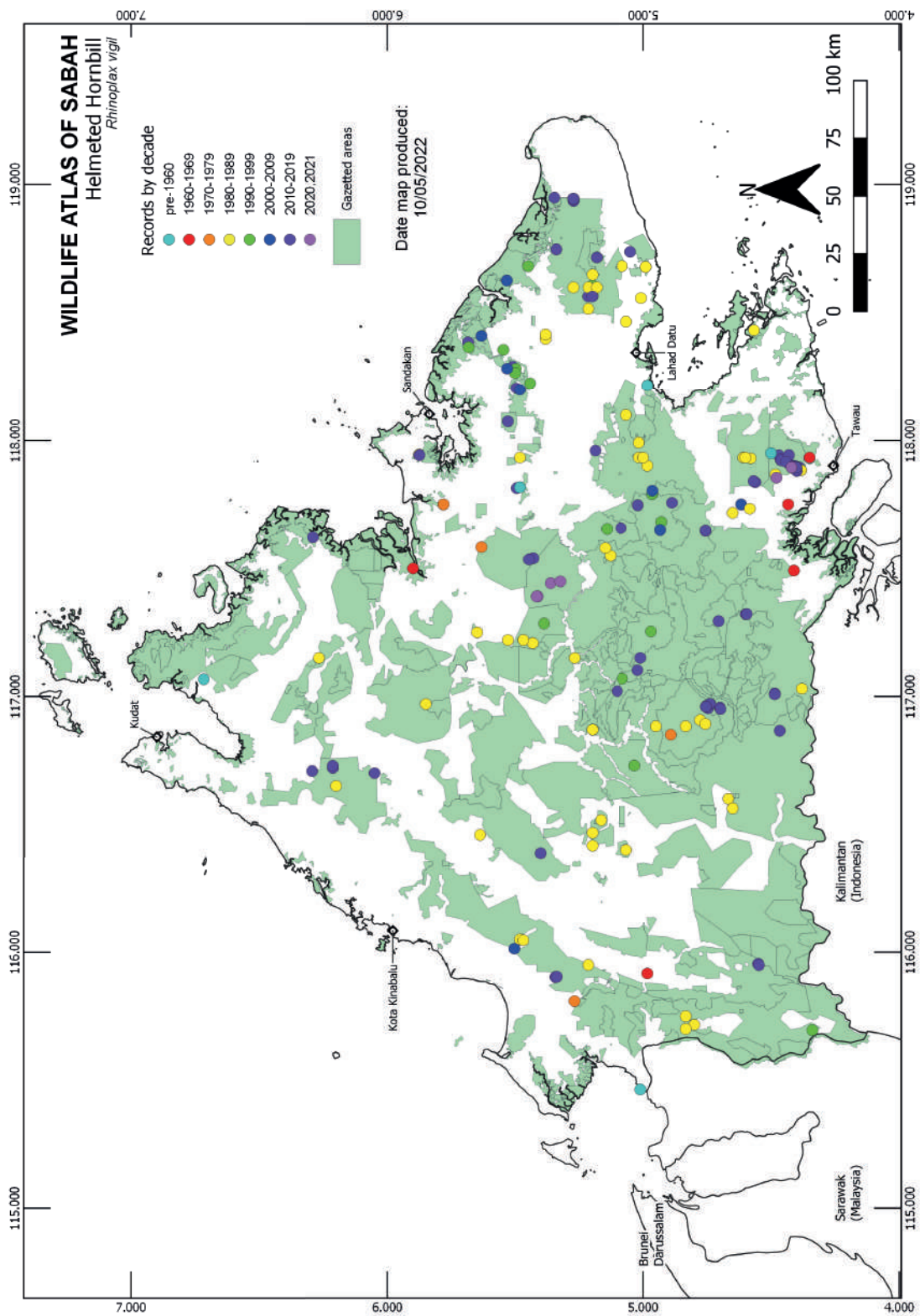


Figure 1. Locations of confirmed detections of Helmeted Hornbill

Hornbills were, including the heavily degraded forests of Sungai Melati (Ulu Kalumpang FR), and appeared most abundant at the lowest elevation sites (G. Davies, pers. comms.). Helmeted Hornbill population density estimates are presented in Table 1; densities are quite variable, from 0.2–2.6 km^2 in unlogged forest and 0.3–2.5 km^2 in logged forest. At least some of this variability is likely because the animals will stay in one area for weeks (e.g. if there are food sources) or months (e.g. during breeding), thus giving higher density estimates, and then move on, thus giving lower estimates (G. Davison, pers. comm.). Helmeted Hornbill densities as low as 0.05 km^2 have also been reported, even in optimal habitat (BirdLife International, 2020b).

Annual river surveys in the Kinabatangan have reported extremely low frequencies of Helmeted Hornbill sightings. Only a few resident pairs are known throughout the entire Lower Kinabatangan Wildlife Sanctuary, yielding an extremely low density and showing that the species cannot readily survive in heavily degraded and fragmented lowland habitat (Kaur, 2020a).

Table 1. Helmeted Hornbill population density estimates

Location	Forest type	Estimated density (individuals/km^{-2})	Source
Sabah			
Tabin Wildlife Reserve (4 sites)	Logged	0.5–1	WWF-Malaysia (2020; G. Davies, pers. comm.)
Deramakot Forest Reserve (2 sites)	Logged	0.5–1	
Ulu Kalumpang FR (2 sites)	Logged	0–0.5	
Tawau Hills Park	Unlogged	0.5	
	Unlogged	0.6	Lakim & Biun (2005)
Crocker Range Park	Unlogged	0.19	
Ulu Segama Forest Reserve	Logged	0.3–2.5	Johns (1997)
	Unlogged	1.4	
Danum Valley Conservation Area and	Unlogged	1.7–1.9	Bennett et al. (1997)
Long Pa'Sia	Unlogged	0.48	
Other areas			
Tekam Forest Reserve, Peninsular Malaysia	Logged	1.1–2.1	Johns (1997)
	Unlogged	2.6	
Hala Bala Wildlife Reserve, Thailand	Unlogged	1.2	Gale & Thongaree (2006)
Bukit Barisan Selatan National Park, Sumatra, Indonesia	Unlogged	2.1	Anggraini et al. (2000)

Threats

Impacts of Logging and Forest Clearance

Selective and conventional logging has been rampant across the forests of Sabah, and even more so in other parts of the Helmeted Hornbill's range (Tracewski et al., 2016), but the impacts of this forest disturbance on the species are poorly known. Helmeted Hornbills are thought to be less tolerant of human disturbance than Great and Rhinoceros hornbills. As mentioned above, the few estimates of Helmeted Hornbill population density are not necessarily consistently lower in logged than in unlogged forest. But estimates of population density could reflect foraging use by non-nesting adults. Given that Helmeted Hornbills have very particular nesting requirements and often select very large trees, logging may well reduce the availability of nest sites (BirdLife International, 2020b), ultimately lowering the carrying capacity of the environment for this species. One pair exhibited nest fidelity during three breeding cycles (Kaur, 2020a), suggesting that nest trees are highly valuable and should be protected. Logging will impact Helmeted Hornbills more heavily if the timber extraction also removes their preferred fruiting tree species and if it is associated (as it often is) with the removal or damage-induced mortality of strangler figs (Johns, 1987; Meijaard et al., 2005).

Other forest disturbances such as fire can also affect Helmeted Hornbills. The population density of the species in Bukit Barisan Selatan National Park, Sumatra, declined by 52% after forest fire (Anggraini et al., 2000).

Impacts of Hunting, the Pet Trade, and Tourism

Because the solid casque of the Helmeted Hornbill is so sought-after, the species has been hunted extensively and is now at much greater risk of extinction than the other Asian hornbills. This hunting pressure has been greatly exacerbated by the widespread logging across the species' range that has made formerly remote areas of forest much more accessible to hunters; therefore, while habitat loss and hunting are addressed separately here, it is critical to remember that they often interact synergistically (Brodie et al., 2012).

Helmeted Hornbill casques, skulls, and feathers are commonly found in the illegal wildlife trade in many countries. In China, the biggest market for Helmeted Hornbill casques, the yellow-white casque material (sometimes referred to as hornbill 'ivory', 'red ivory', or 'golden ivory') can be up to five times as expensive as elephant ivory (Hughes, 2015). The trade in Helmeted Hornbills is conducted by international organized crime syndicates — putting the species in the same plight as taxa like tigers (*Panthera tigris*) and pangolins (*Manis* spp.) (Beastall et al., 2016). Though a small trade in casques from Borneo to China may have occurred for hundreds of years (Bennett et al., 1997), in 1997 it was " ... illegal under national laws and CITES, and current exports are probably minimal" (Bennett et al., 1997). But by 2015, the trade was referred to as " ... the crisis that came out of nowhere" (Collar, 2015). So the advent of large-scale international trade in Helmeted Hornbill casques likely only started in the 21st century. The casques have also been traded locally for centuries as a part of traditional medicine; the solid material being attributed medicinal value by local communities in Borneo for a variety of ailments. In Terengganu, Indigenous people and the Malay community believed that Helmeted Hornbill casques, when worn as a ring, could detect poison; if one was served poison in a glass, dipping the ring into the liquid caused the glass to break (R. Kaur, pers. obs.).

Even before the advent of massive, illegal international trade, Helmeted Hornbill hunting for local use was unsustainable in many areas (Bennett et al., 1997). Throughout Borneo, Helmeted Hornbills were culturally important to many peoples and were hunted for meat and for their feathers (Bennett et al., 1997). Though not as prized as Rhinoceros Hornbill feathers for dances and ornaments, Helmeted Hornbill feathers were still used extensively and the species was declining in many areas (Bennett et al., 1997).

Helmeted Hornbills are not well-suited to being able to withstand such heavy hunting pressure. Their large body size and low reproductive rate (adult pairs usually produce a single chick every two years) are associated with very slow population growth. The unique breeding biology of all Asian hornbills further compounds their vulnerability, as the killing of a male while the female is sealed in the tree cavity could lead to the death of the female and chick as well (Collar, 2015). Overall, the high demand for Helmeted Hornbill body parts on the international black market has led to the species' disappearance from much of its range (BirdLife International, 2020b).

Tourism can also potentially affect the species. Recently, the sighting of a pair of Helmeted Hornbills in Pahang led to a frenzy of photography lasting over a month. Bird photographers and enthusiasts used playback calls incessantly, attempting to lure the birds closer to the road for a better view (Kaur, 2020b). The male responded to the callbacks and came closer to the photographers on a daily basis; this distracting use of callbacks may have prevented the pair from attempting to nest (Kaur, 2020b).

Impacts of Climate Change

In Thailand, mean daily temperatures inside a natural hornbill nest cavity were 21.9°C in February, 25.6°C in March, and 26.9°C in April (Poonswad, 1993), all much cooler than the ambient temperatures. A study on the microclimate conditions inside several natural hornbill nest cavities in the Kinabatangan also revealed low temperatures (25.8°–28.8°C) and high humidity (88.2%–99.8%) (Kaur, 2020a). Climatic changes leading to temperature increases even in canopy microsites could create sub-optimal nesting conditions for hornbills.

The Helmeted Hornbill is primarily a lowland species, while much of the remaining intact or lightly logged forests in Sabah are in hilly and sub-montane areas. If Helmeted Hornbills are susceptible to rising temperatures, they therefore have a reasonable amount of higher-elevation forested areas to move into, as long as suitable corridors are maintained to allow these elevational range shifts (Williams et al., 2020b). Many lowland vertebrates in Malaysian Borneo appear minimally affected by recent temperature fluctuations (Brodie et al., 2017), though temperatures are now beginning to rise beyond historical ranges. But climate change adaptation in Helmeted Hornbills (and other species) may not be as easy as simply 'relocating uphill'. As a primarily frugivorous species, Helmeted Hornbills will depend on their preferred fruit plants either already being present at higher elevations or else being able to shift their ranges upwards at the same rate as the animals themselves. Such shifts in plant distributions could be hindered by edaphic changes at higher elevations (Ashton, 2014) and by altered precipitation patterns, which are difficult to predict. Moreover, climate change could alter fruiting phenology, potentially exacerbating periods of food scarcity for frugivorous animals such as the Helmeted Hornbill.

Conservation

The conservation status of the Helmeted Hornbill deteriorated from 'Near Threatened' directly to 'Critically Endangered' based on the sudden rise of massive illegal trade. To prevent the species from going extinct, breaking these trade networks, reducing consumer demand, and enforcing the CITES restrictions that are already in place are paramount. The Helmeted Hornbill action plan lists a number of ways by which this might be achieved; the top goal is "to eliminate trade in Helmeted Hornbills, their parts and derivatives" (Jain et al., 2018).

Sabah is critical in stemming the Helmeted Hornbill decline. Most of the recent hunting to supply international markets has been in Indonesia. But with populations of the species crashing in that country due to overhunting (Krishnasamy et al., 2016), the killing is now turning to those parts of Malaysia where the species can still be found (Jain et al., 2018). Helmeted Hornbills are gone from most of Sarawak, leaving parts of Sabah as the last stronghold of the species in Borneo and East Malaysia. Stronger legislation, domestic enforcement, and international law enforcement coordination are critically needed in Sabah to address the illegal wildlife trade, as noted by *The Conservation of the Helmeted Hornbill Resolution* to the 2016 IUCN World Conservation Congress that was proposed by the Malaysian Nature Society (Jain et al., 2018).

Given that crop monocultures and urban areas are not viable habitats for Helmeted Hornbills, the expansion of these areas will negatively impact the species. There may be little additional forest clearance for oil palm expansion in Sabah because the state is striving towards jurisdictional certification from the Roundtable on Sustainable Palm Oil, which would prohibit forest clearance for plantation development. Expansions of urban areas and other settlements is a concern, however, as the human population of Sabah increases. The expansion of the road network, for example with the Pan-Borneo Highway and its feeder roads, will certainly fragment and destroy Helmeted Hornbill habitat.

Malaysia's commitment to the Convention on Biological Diversity (1992) and the tri-national Heart of Borneo Initiative, along with the state of Sabah's intention to protect 30% of its land as Totally Protected Areas, means that a higher proportion of forest cover could be retained in Sabah than in many other parts of Southeast Asia. Moreover, with the explicit focus on habitat connectivity embodied in all of these agreements, the forest cover that is retained should hopefully be relatively well-connected. For example, in a state-contracted effort to prioritise new areas for elevated conservation status to achieve the 30% protection goal, a focus was made on securing areas that enhanced connectivity between existing protected areas and that linked lowland and highland areas to facilitate climate-induced species range shifts (Williams et al., 2020b). Without robust estimates of Helmeted Hornbill occupancy and population density in different forest types, and lacking information on their dispersal behaviour and meta-population structure, it remains impossible to precisely assess how changes in forest cover and conservation status across Sabah will affect the long-term viability of the species in the state. Hunting, of course, will also likely remain a long-term threat to the population. As with all species of conservation concern in Sabah and elsewhere, conservation awareness and education efforts are needed to ensure that the impacts of hunting and habitat loss are reduced over time.

Cavity restoration has been an effective conservation method introduced by the Thailand Hornbill Project. Instead of providing artificial nest boxes for Helmeted Hornbills, which have so far not proven successful, locating tree cavities that can be enhanced through simple techniques

may be one way to create more breeding opportunities for these hornbills. Other successful hornbill conservation initiatives that have been used in Thailand include the employment of local villagers as hornbill nest guardians and nest adoption programmes. Former poachers benefit financially by becoming long-term nest guardians of hornbill nests and produce reports about the birds' well-being that are provided to the donors in the adoption programme. Over 16 years, 440 hornbill chicks have fledged safely under this programme (Poonswad et al., 2013).

Acknowledgements

Permissions for the various research projects in Sabah reported upon here were granted by the Sabah Biodiversity Centre and, in the case of earlier studies, the Economic Planning Unit of Malaysia. Most studies also depended on support from agencies such as Sabah Forestry Department, Yayasan Sabah, Sabah Wildlife Department, and/or Sabah Parks as well as local communities. Most of the projects reported on herein are also indebted to numerous field technicians and guides in the forests and communities where they worked.

Data Sources

Individuals / organizations (Number of records): Haysom, Jessica (14); 1StopBorneo Wildlife (16); Sabah Museum (1); WWF-Malaysia (58). *Publications (Number of records):* Abdullah et al.,1995 (2); Ancrenaz, 2011 (4); Boonratana, 1997 (6); Boonratana & Sharma, 1993 (2); Chung et al., 2019 (1); Davies & Payne, 1982 (56); Davies & Tan, 2019 (4); Dawson, 1992 (1); Kehoe, 2011 (5); Lim, 1993 (1); Payne et al., 1989 (2); Pieterse & Wielstra, 2009 (2); Rajaratnam, 1995 (1), Regip, 2003 (1); SFD, 2019 (1); Sharma, 1992 (3); Sheldon et al., 2001 (30); Wong, 2011 (2), Zahri & Ahmad, 2019 (1).



A pair of Rhinocerous Hornbills in Deramakot Forest Reserve © Brendan Ryan

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Rhinoceros Hornbill (*Buceros rhinoceros*)

Jedediah F. Brodie, Ravinder Kaur and Marc Ancrenaz

Introduction

The Rhinoceros Hornbill is one of the largest Asian hornbills, a striking animal with black and white plumage, a large bill, and a red-orange, up-curving casque. It is important ecologically as a disperser of many plant seeds and culturally significant to many people in the region. The Iban people in Sarawak, for example, construct *kenyalang*, magnificent wooden sculptures of Rhinoceros Hornbills used in sacred rites called *Gawai Kenyalang*; the carvings depict a hornbill with a fig fruit in its bill (Davenport, 2000). Images of Rhinoceros Hornbills are on Malaysia's five-Ringgit notes, and the species is the official emblem of the state of Sarawak.

The Rhinoceros Hornbill is in the genus *Buceros*, which contains three other species of large, arboreal hornbills in Asia, all of which have large, hollow, bony casques. Within the genus, the Rhinoceros Hornbill is the sister species of the Great Hornbill (*B. bicornis*) (Gonzalez et al., 2013), with which it is sympatric in Sumatra and parts of the mainland. There are three subspecies of Rhinoceros Hornbills: *B. r. rhinoceros* is found in southern Thailand, Peninsular Malaysia, and Sumatra; *B. r. silvestris* is endemic to Java; and *B. r. borneensis* is found in Borneo (Poonswad et al., 2013).

Globally, the species is restricted to the region known as Sundaland, comprising Borneo, Sumatra, Java, and Peninsular Malaysia. It is not known whether it natively occurred in Bali before that island was extensively deforested. The species extends into the far south of Thailand in the Hala Bala area (Trisurat et al., 2013) up to about the Isthmus of Kra. The Rhinoceros Hornbill has been extirpated from Singapore and some of the smaller (mostly deforested) states in Peninsular Malaysia, such as Melaka and Penang. The species is classified as 'Vulnerable' by the IUCN Red List, with a decreasing population trend, but lacks a range-wide conservation action plan (BirdLife International, 2020a).

Compared to the other large hornbills in Sabah, such as the Helmeted Hornbill (*Rhinoplax vigil*), the Rhinoceros Hornbill appears to be more adaptable to different habitats and more tolerant of forest disturbance such as logging. Because of this, and because it is not targeted by hunting nearly so heavily, the Rhinoceros Hornbill appears more abundant than the Helmeted in areas where they occur (G. Davies, pers. comm.). The ecology of the Rhinoceros Hornbill is also better known than that of the Helmeted because the former is more conspicuous — pairs generally associate together and use frequent loud 'call-reply' honks to communicate, which reveals the presence of the species even

from over half a kilometer away (G. Davies, pers. comm.). While Helmeted Hornbills also have very loud calls, they use them less frequently and are more likely to try to be inconspicuous around humans (Leighton, 1982).

Scan for a Rhinoceros Hornbill call from Sabah
© Jabanus Miun, formerly with WWF-Malaysia

Natural History

The Rhinoceros Hornbill is unmistakable due to its large size, colouration, and upturned casque. It is 80–90 cm long; females weigh 2–2.4 kg and males 2.4–3 kg. The plumage is mostly black and the vent and legs are white. The striking feathers of the tail, white with a black band, have historically been used as ornaments and decorations in the traditional attire and dances of Dayak tribes, particularly in Sarawak. A gland above the tail produces orange and red pigments that the animals rub onto their beak and casque to enhance their characteristic colouration. The sexes can be distinguished by eye colour; in males the eyes are red with black edges, while in females the eyes are white with red edges (Figure 1).

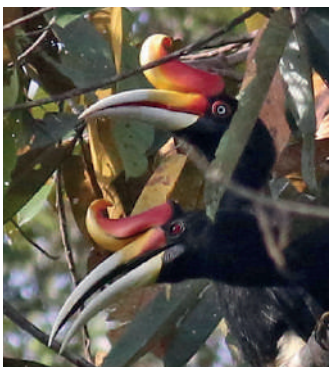


Figure 1. Female Rhinoceros Hornbill (above) and male (below) © Brendan Ryan

Rhinoceros Hornbills live in large tracts of lowland, hilly, and sub-montane rainforest up to ~1,400 m in elevation (BirdLife International, 2020a) with observations up to 1,760 m on Mt. Kinabalu (Smythies, 1999). They primarily feed on fruits. Trees producing large, lipid-rich arils, including taxa from a number of families, especially Meliaceae (particularly *Aglaia*) and Myristicaceae are used by Rhinoceros Hornbills, and just a small number of such arils can provide a significant proportion of the birds' energetic requirements (Johns, 1987; Leighton, 1982). Fruits from Lauraceae and Annonaceae are also utilised (Johns, 1987) and figs (*Ficus* spp.) are consumed in abundance, especially the hemi-epiphytic 'strangler' species (Choo & Teresa, 2001; Nakabayashi & Ahmad, 2018; O'Brien et al., 1998). Figs are an abundant source of energy for frugivore species in the rainforest, tend to be available year-round (Terborgh, 1986), and contain a high calcium content (O'Brien et al., 1998), which is especially important for birds when they are producing eggs. Rhinoceros Hornbills are often seen in pairs at the edge of the forest along the Kinabatangan River consuming *Ficus racemosa* (Kaur, 2020a).

However, Rhinoceros Hornbills are not fig specialists (as are some other birds, probably including the Helmeted Hornbill), and consume large amounts of figs mainly when other preferred fruits are unavailable (Leighton & Leighton, 1983). Rhinoceros Hornbills also consume large arthropods, such as giant millipedes or stick insects, and small vertebrates such as frogs, birds, lizards, and small mammals, as well as the eggs of other bird species (Kaur et al., 2015; Kemp & Boesman, 2018). One pair of Rhinoceros Hornbills and its juvenile were observed to consume Brahminy Kite eggs while perching inside the kite nest; the pair of kites merely watched (Mahathir Ratag, pers. comm.).

Rhinoceros Hornbill pairs have year-round home ranges within which they exhibit seasonal and shorter-term movements to track shifting fruit availability (Leighton & Leighton, 1983). But little is known about their degree of territoriality (e.g. home range overlap with other pairs) or their patterns of natal dispersal.

Rhinoceros Hornbill adults are often observed in pairs (Mohd-Azlan et al., 2016a). Larger groups of 15 (BirdLife International, 2020a) to 25 (Kemp, 1995) individuals may form, usually juveniles or sub-reproductive adults. Groups of more than 40 birds have very occasionally been spotted in the Lower Kinabatangan (M. Ancrenaz, pers. comm.).

Breeding is seasonal, with nesting in trees such as *Koompassia malaccensis* (Kaur et al., 2015) and dipterocarps such as *Dryobalanops lanceolata* and *Shorea atrinervosa* (Kaur, 2020a). As with other hornbills, Rhinoceros Hornbills nest in natural cavities in tree trunks, generally 9–15 m above the ground (Kemp & Boesman, 2018). The pair seals the female inside the cavity with a wall of debris, faeces, and reportedly giant millipedes (Kemp & Boesman, 2018), leaving a small slit through which the male can feed her and the single chick. When the chick is old enough, the adult female breaks the sealing and removes the wall.

Distribution and Abundance in Sabah

Rhinoceros Hornbills can be detected visually and by their calls, which may carry half a kilometer through the forest (Kemp & Boesman, 2018). Many studies on the ecology of the species in the wild have used either direct observations, for example to record feeding behaviour, or line transects to estimate population density (Johns, 1987). More recently, abundance and occurrence models have been tested in the field to estimate the proportion of forest containing tree cavities, an important resource for hornbills (Kaur et al., 2020).

In Sabah, Rhinoceros Hornbill can be found in many large tracts of lowland and hill forest (Lim & Mojiol, 2018), particularly in the interior Heart of Borneo areas (Davies & Payne, 1982). Many of the recent records come from the eastern part of the state including Ulu Segama, the Danum-Maliau forest complex, Tabin Wildlife Reserve, and the Kinabatangan River (Figure 1). The five most common species of hornbills sighted during annual boat surveys conducted by HUTAN-KOCP in the Kinabatangan were, in order of decreasing detection frequency: Oriental Pied (*Anthracoceros albirostris*), Black (*Anthracoceros malayanus*), Rhinoceros, Wrinkled (*Aceros corrugatus*), and Bushy-crested (*Anorrhinus galeritus*) hornbills (Kaur, 2020a; Kaur et al., 2020). Oriental Pied and Black are the only Malaysian hornbills not dependent on blocks of intact forest habitat (Chong, 1998).

WWF-Malaysia conducted hornbill sampling at 12 sites in Sabah, listening for hornbill calls on ~2 km² belt transects from 2018–2020. The density of Rhinoceros Hornbills was ~1–2 indiv/km² at most sites (Silabukan, Sungai Melati, Sungai Landau, Tawau Hills Park, Lingkabau Forest Reserve, Trus Madi, two sites in Deramakot, and three sites in Tabin), and up to 3 indiv/km² in the west of Tabin. These estimates tend to be approximately double the estimated density of Helmeted Hornbills at the same sites. G. Davies (pers. comm.) reports that, "Overall, two pairs (4 birds) in a 2-km² survey area seemed a common density for Rhinoceros Hornbill in all of these logged forest sites, dropping below this level in the badly degraded logged forest of Sungai Melati, degraded forests near Dagat in Tabin North, and at the higher elevation sites". Two decades ago, Lakim & Biun (2005) estimated Rhinoceros Hornbill densities in Tawau Hills and the Crocker Range parks at 5.7 and 0.94 indiv/km², respectively. The Tawau Hills Park estimate may be the highest estimated density for the species in its range. Density estimates from the Ulu Baram area and Batang Ai National Park in Sarawak were much lower, at <1 indiv/km² (Chin & Jantan, 1999; Meredith, 1995). In Kutai National Park, East Kalimantan, Rhinoceros Hornbill were estimated to be 2–3 indiv/km² (Smythies, 1999). In Kuala Lompat and Sungai Tekam Forestry Concession in Peninsular Malaysia

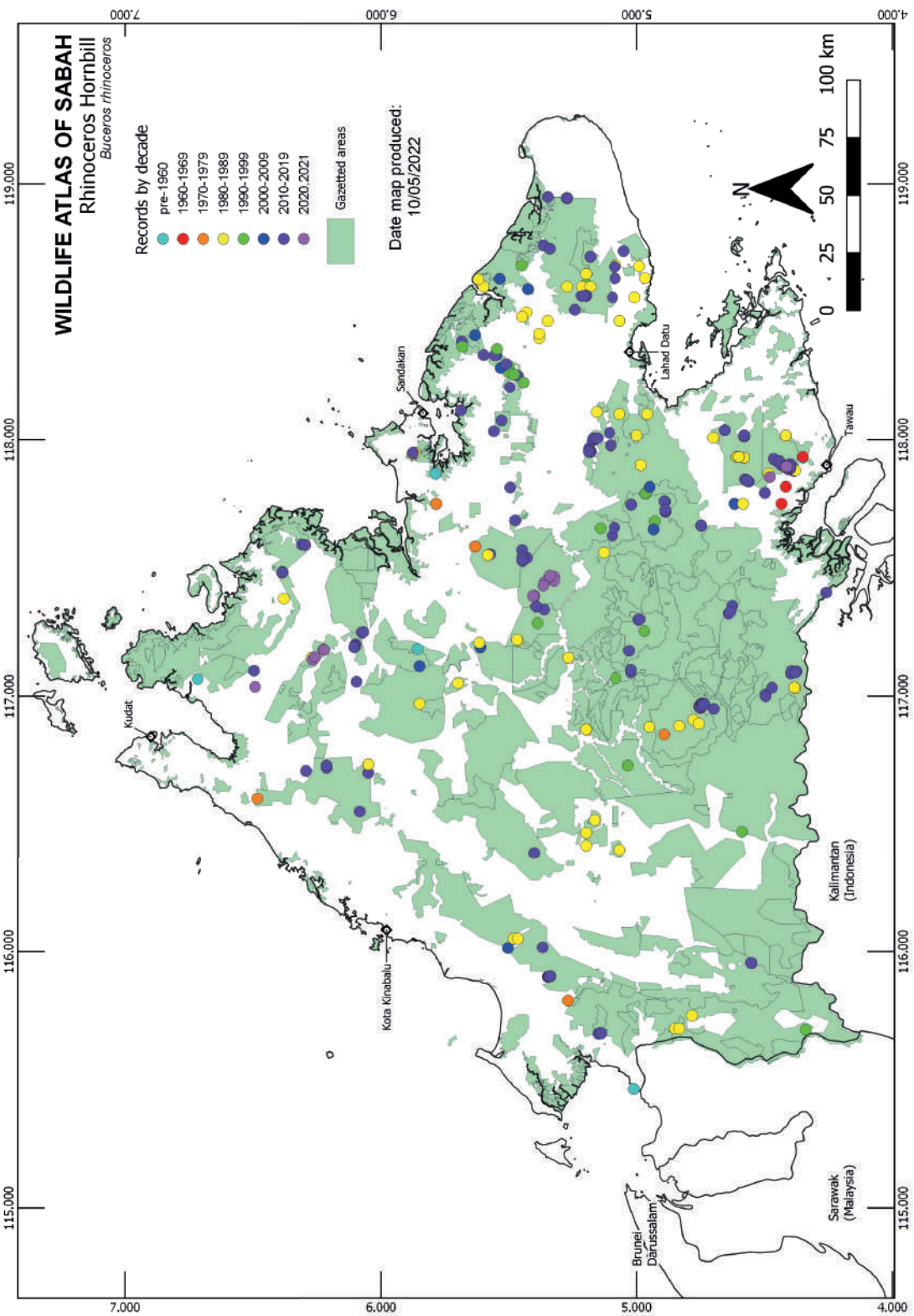


Figure 2. Locations of confirmed detections of Rhinoceros Hornbill

they were generally ≤2 indiv/km² (Johns, 1987; Medway & Wells, 1971) and in Aceh Province, Sumatra, densities were ~1.4 indiv/km² (Kamal et al., 2019). Rhinoceros Hornbills were the most abundant of nine hornbill species in the Hala Bala Wildlife Reserve, Thailand, with a density of ~2.7 indiv/km² (Gale & Thongaree, 2006).

Threats

Impacts of Logging and Forest Clearance

Selective logging has been rampant across the forests of Sabah over decades, and even more so in other parts of the Rhinoceros Hornbill's range (Tracewski et al., 2016). In general, the impacts of forest disturbance on Rhinoceros Hornbills are incompletely known. The species appears to be able to persist in more heavily degraded forests and near forest edges than the Helmeted Hornbill (G. Davies, pers comm.), though comparative density estimates are problematic because of both species' large-scale movement behaviours and differences in calling behaviour (which affect estimated density; G. Davison, pers. comm.). In the state of Pahang, population density was highly variable across different logged areas, without noticeable differences between logged and unlogged sites (Johns, 1987). Selective logging often targets large dipterocarp trees, which are important nest trees for hornbill species (Chuailua et al., 1998; Poonswad, 1995; Thiensongrusamee et al., 2002). The regenerating forests of the Kinabatangan are characterised by the absence of large dipterocarp trees following intense past logging activities; these forest patches lack the preferred cavity heights of the more endangered large-bodied hornbills such as Helmeted and Rhinoceros (Kaur, 2020a). The Rhinoceros Hornbills observed in much of the Kinabatangan are wandering birds who visit the area for a few days before leaving (that so many of the birds are migrants is one reason that estimating population density in the Kinabatangan is so difficult); in the Lower Kinabatangan there may be both a resident breeding and a nomadic population (M. Ancrenaz, pers. obs.). These wandering animals are likely flocks of young individuals that have not paired up yet and are travelling in search of fruit (R. Kaur, pers. obs.).

Logging will impact the species more heavily if timber extraction also removes their preferred fruiting tree species, and if it is associated (as it often is) with the removal or damage-induced mortality of strangler figs (Johns, 1987). The impacts of logging on hornbills can likely be at least partially ameliorated if (i) hunting is controlled (Kinnaird & O'Brien, 2007), (ii) strangler figs are retained or replanted (Pawar et al., 2020), and (iii) artificial nests are provided. Rhinoceros Hornbills have successfully used artificial nest boxes in the Kinabatangan, and this shows positive signs of adaptability in the species. A total of five nesting cycles have been recorded from 2017–2019 by two pairs of Rhinoceros Hornbills nesting in two artificial nest boxes that were erected through collaborative efforts with Sabah Wildlife Department, HUTAN-KOCP, the Chester Zoo, and the Beauval Zoo (HUTAN, 2018). Five Rhinoceros Hornbill chicks have fledged from these nest boxes from the five nesting cycles (Kaur, 2020a). In the Kinabatangan, breeding has been recorded from June through October (Kaur, 2020a). Elsewhere in Borneo the breeding season has been observed to begin in February, with the female leaving the nest by April (Leighton, 1982). In Peninsular Malaysia, nesting has been observed to begin in March (Johns, 1987) and April (Kaur et al., 2015).

While Rhinoceros Hornbills may be able to persist in selectively logged forest, and several other hornbill species forage in and even nest in agroforestry plantations (Pawar et al., 2020), areas cleared for oil palm plantations, human habitation, and infrastructure are not viable habitat.

Rhinoceros Hornbills are sometimes observed in monoculture tree plantations, but they are only passing through en route to adjacent forest (Poonswad et al., 2013). They have been seen feeding occasionally on oil palm fruits (Kaur, 2020a) and wild fruits (e.g. *anggur hutan*) that grow around plantations (Helson Abdullah, pers. comm.). Interestingly, the inside of an artificial nest box used by a Rhinoceros Hornbill in the Kinabatangan was lined with oil palm seeds (R. Kaur, pers. obs.).

Impacts of Hunting, the Pet Trade and Tourism

Rhinoceros Hornbills are hunted for food, for decorative objects (e.g. their skulls and casques), and, perhaps primarily, for their tail feathers that are used in traditional ceremonial attire and as hand-held fans in dances among various Dayak tribes (Kinnaird & O'Brien, 2007). Unsustainable hunting to meet these demands is likely responsible for the loss of Rhinoceros Hornbills across large parts of their range, particularly in Sarawak. It is also important to note that, while hunting and logging are treated separately here, the two are not independent — logging operations and associated road construction often increase forest accessibility and hunting pressure (Robinson et al., 1999). Hunting is lower in parts of Sabah than in most of Sarawak due to taboos of the Murut people (Bennett et al., 1997); there were 0.5–>2 Rhinoceros Hornbill sightings and calls per kilometre of survey trail at sites in Sabah compared to none in sites in Sarawak (Bennett et al.,1997). As a potential way to reduce the pressure on wild hornbills while maintaining cultural traditions, Dr. Elizabeth Bennett (Wildlife Conservation Society) has explored community attitudes towards using the imported white tail feathers of domestic turkeys, dyed black across the top, in lieu of Rhinoceros Hornbill feathers for traditional dances.

Rhinoceros Hornbills are also caught from the wild to be kept as pets locally (J. Brodie, pers. obs.), though the species does not appear to be prominent in the international pet trade (BirdLife International, 2020a) and is listed on CITES Appendix II.

In areas such as the Kinabatangan, Rhinoceros Hornbills are one of the species driving a blooming tourism industry. Indeed, these magnificent birds provide great opportunities for photographers. Artificial nests used by breeding pairs were able to attract the attention of many tourist boats (HUTAN, unpub. data). Whether this attention affects Rhinoceros Hornbill behaviour or population dynamics, however, remains unknown.

Impacts of Climate Change

The Rhinoceros Hornbill is primarily a lowland species, while much of the remaining intact or lightly logged forests in Sabah are in hilly and sub-montane areas. If Rhinoceros Hornbills are susceptible to rising temperatures, they therefore have a reasonable amount of higher-elevation forested areas to move into, as long as suitable corridors are maintained to allow these elevational range shifts (Williams et al., 2020b). Many lowland vertebrates in Malaysian Borneo appear minimally affected by recent temperature fluctuations (Brodie et al., 2017), though temperatures are now beginning to rise beyond historical ranges. But climate change adaptation in Rhinoceros Hornbills (and other species) may not be as easy as simply 'relocating uphill'. As a primarily frugivorous species, Rhinoceros Hornbills will depend on their preferred fruit plants either already being present at higher elevations or else being able to shift their ranges upwards at the same rate as the animals themselves. Such shifts in plant distributions could be hindered by edaphic changes at higher elevations (Ashton, 2014) and by altered precipitation patterns, which are difficult to predict. Moreover, climate change could alter fruiting phenology, potentially exacerbating periods of food scarcity for frugivorous animals such as the Rhinoceros Hornbill.



Figure 3. Rhinoceros Hornbill © Sanjitpaal Singh / jitspics.com

Conservation

Given that crop monocultures and urban areas are not viable habitats for Rhinoceros Hornbills, the expansion of these areas will negatively impact the species. There may be little additional forest clearance for oil palm expansion in Sabah because the state is striving towards jurisdictional certification from the Roundtable on Sustainable Palm Oil, which would prohibit forest clearance for plantation development. Forest clearance from expanding urban areas and other settlements is a concern, however, as the human population of Sabah increases. The expansion of the road network, for example with the Pan-Borneo Highway and its feeder roads, will certainly fragment and destroy Rhinoceros Hornbill habitat.

Malaysia's commitment to the Convention on Biological Diversity (1992) and the tri-national Heart of Borneo Initiative, along with the state of Sabah's intention to protect 30% of its land as Totally Protected Areas, mean that a higher proportion of forest cover could be retained in Sabah than in many other parts of Southeast Asia. Moreover, with the explicit focus on habitat connectivity embodied in all of these agreements, the forest cover that is retained should hopefully be relatively well-connected. For example, in a state-contracted effort to prioritise new areas for elevated conservation status to achieve the 30% protection goal, a focus was made on securing areas that enhanced connectivity between existing protected areas and that linked lowland and highland areas to facilitate climate-induced species range shifts (Williams et al., 2020b). Programmes such as nest guardianship and adoption (as have been successfully demonstrated in Thailand; Poonswad et al., 2013) and nest box construction (HUTAN, 2018; Kaur, 2020a) may also help support the species in Sabah. Ensuring that logging operations spare large, cavity-bearing trees may also be important for providing nest sites.

Without robust estimates of Rhinoceros Hornbill population trends and occurrence in different forest types, and lacking information on their dispersal behaviour and meta-population structure, it remains impossible to precisely assess how changes in forest cover and conservation status across Sabah will affect the long-term viability of the species in the state. Hunting in some areas will also likely remain a long-term threat to the population. As with all species of conservation concern in Sabah and elsewhere, conservation awareness and education efforts are needed to ensure that the impacts of hunting and habitat loss are reduced over time.

Acknowledgements

Permissions for the various research projects in Sabah reported upon here were granted by the Sabah Biodiversity Centre and, in the case of earlier studies, the Economic Planning Unit of Malaysia. Most studies also depended on support from agencies such as Sabah Forestry Department, Yayasan Sabah, Sabah Wildlife Department, and/or Sabah Parks as well as local communities. Most of the projects reported on herein are also indebted to numerous field technicians and guides in the forests and communities where they worked.

Data Sources

Individuals / organizations (Number of records): Haysom, Jessica (183); 1StopBorneo Wildlife (15); Forest Solution Malaysia (2); Sabah Museum (1); WWF-Malaysia (156). *Publications (Number of records):* Abdullah et al., 1995 (7); Ancrenaz, 2011 (9); Bili, 2014 (5); Boonratana,1997 (6); Boonratana & Sharma, 1993 (2); Chung et al., 2019 (2); Davies & Tan, 2019 (4); Dawson, 1992 (1); HUTAN KOCP, 2016 (2); Kehoe, 2011 (9); Lim, 1993 (1); Matsuda et al., 2014 (1); Payne et al., 1989 (2); Pieterse & Wielstra, 2009 (1); Rajaratnam, 1995 (1); Regip, 2003 (1); SFD, 2017 (2); SFD, 2019 (1); Sharma, 1992 (4); Sheldon et al., 2001 (27); Wilting & Mohamed, 2010 (1); Wong, 2011 (5).

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Straw-headed Bulbul (*Pycnonotus zeylanicus*)

Frederick H. Sheldon

Introduction

The Straw-headed Bulbul (*Pycnonotus zeylanicus*) is a large and moderately colourful member of the bulbul family, Pycnonotidae. It is most closely related to some other large species, including the Streak-eared Bulbul (*P. conradi/blanfordi*) and Stripe-throated Bulbul (*P. finlaysoni*), that occur from Peninsular Malaysia to India (Shakya & Sheldon, 2017). Historically, Straw-headed Bulbuls were found in Tanintharyi (Tenasserim, southern Myanmar), southern Thailand, Peninsular Malaysia, Borneo, Sumatra, the west Sumatran islands, and Java (Rand & Deignan, 1960; Robson 2005). However, because the species is prized as a cage bird, its range has been curtailed dramatically following over-exploitation by pet traders (Bergin et al., 2018; Eaton et al., 2015; Shepherd et al.,



Figure 1. Straw-headed Bulbul in Singapore © Tiah Khee Lee

2013). It probably has been extinct in Java since the 1940s (Van Balen, 1999) and more recently extirpated in southern Indochina, Sumatra, and most of the Malay Peninsula and Borneo (Chiok et al., 2019; Eaton et al., 2015; Shepherd et al., 2013). It may only persist in a few places in Peninsular Malaysia, Singapore, and Malaysian Borneo (Chiok et al., 2019; Yong et al., 2018).

Natural History

The Straw-headed Bulbul is most famous for its song, one of the most iconic sounds of the Sunda Islands. In his famous handbook, *The Birds of Borneo*, Smythies (1960) described the song as "a prolonged series of magnificently warbled notes, richer and more powerful by far than the songs of such celebrated performers as the Nightingale and Blackbird … ".

Until 25–30 years ago, Straw-headed Bulbuls were well-known even to casual birdwatchers because of their visibility along edges of rivers and other water bodies, their loud song, and their penchant for feeding in open areas on fruits, seeds, and insects, even hawking insects emerging from streams and ponds (Smythies, 1999).

Breeding of Straw-headed Bulbuls is not well studied, but enough information exists to say the species breeds on Borneo mainly from December to March (Mann, 2008; Sheldon et al., 2001; Smythies, 1999), but some populations probably also nest after March as well.

Distribution in Sabah

The Straw-headed Bulbul was one of the most common passerine species in Sabah. It occurred in trees and bushes along rivers, streams, drainage ditches, lakes, ponds, and paddy fields, from coastal areas up to 1,500 m on Mt. Kinabalu (Jenkins & de Silva, 1978; Sheldon et al., 2001; Smythies, 1999). It inhabited both primary and secondary forest, exotic tree plantation, edges of hill forest, and garden and beach scrub, as long as fresh water and adequate underbrush were nearby (Sheldon et al., 2001).

The Straw-headed Bulbul has been extirpated from essentially all parts of Sabah, except perhaps a few heavily protected areas and remote riverheads. The dramatic decline in this species has been caused to some extent by a loss of river-edge forest (Shepherd et al., 2013; Wells, 2007) and suburban development (e.g. in western Sabah, where extensive areas of rice paddy have been converted into housing tracts). But the real cause of decline in the wild has been the growing demand of the cage-bird market (Chiok et al., 2019; Eaton et al., 2015; Shepherd et al., 2013). With the regional epicenter of the pet-bird trade in Indonesia (Jepson & Ladle, 2005; Nijman, 2010), extreme pressure was exerted on Straw-headed Bulbul populations in Malaysian Borneo starting about 20–30 years ago as populations in Java, Sumatra, and Kalimantan were depleted (Brickle et al., 2010; Fischer et al., 2016; Holmes, 1997). In the Kelabit uplands of Sarawak, where the species was once ubiquitous, it is now extinct (Sheldon et al., 2013). In such a well-protected area as Mt. Mulu National Park headquarters, Straw-headed Bulbuls were extirpated between 2010 and 2014 (Burner et al., 2016; Yong et al., 2018). In Sabah, the demise of Straw-headed Bulbul's populations has been documented formally only a few times (Chiok et al., 2019; Sheldon et al., 2009; Sheldon et al., 2010), but the extensive breadth of its former range compared with its current status is evidence enough of its extreme decline.

Conservation

Chiok et al. (2019) reviewed the conservation history of the Straw-headed Bulbul. Serious concern about its exploitation started in the 1990s (Collar et al., 1994; Holmes, 1997; Nash, 1993). It was named as a CITES Appendix II species in 1997, but has not been upgraded yet to Appendix I despite being listed as 'Endangered' in 2016 and up-listed to 'Critically Endangered' in 2018 by the IUCN in its Red List (BirdLife International, 2018). That status remains in effect today because the "species is declining extremely rapidly across its range as a result of trapping of wild birds for the cage-bird trade, compounded by habitat loss within its rather specific habitat type" (BirdLife International, 2021). In Sabah, Straw-headed Bulbul is a protected species under Schedule 2 (Section 2), Part 1

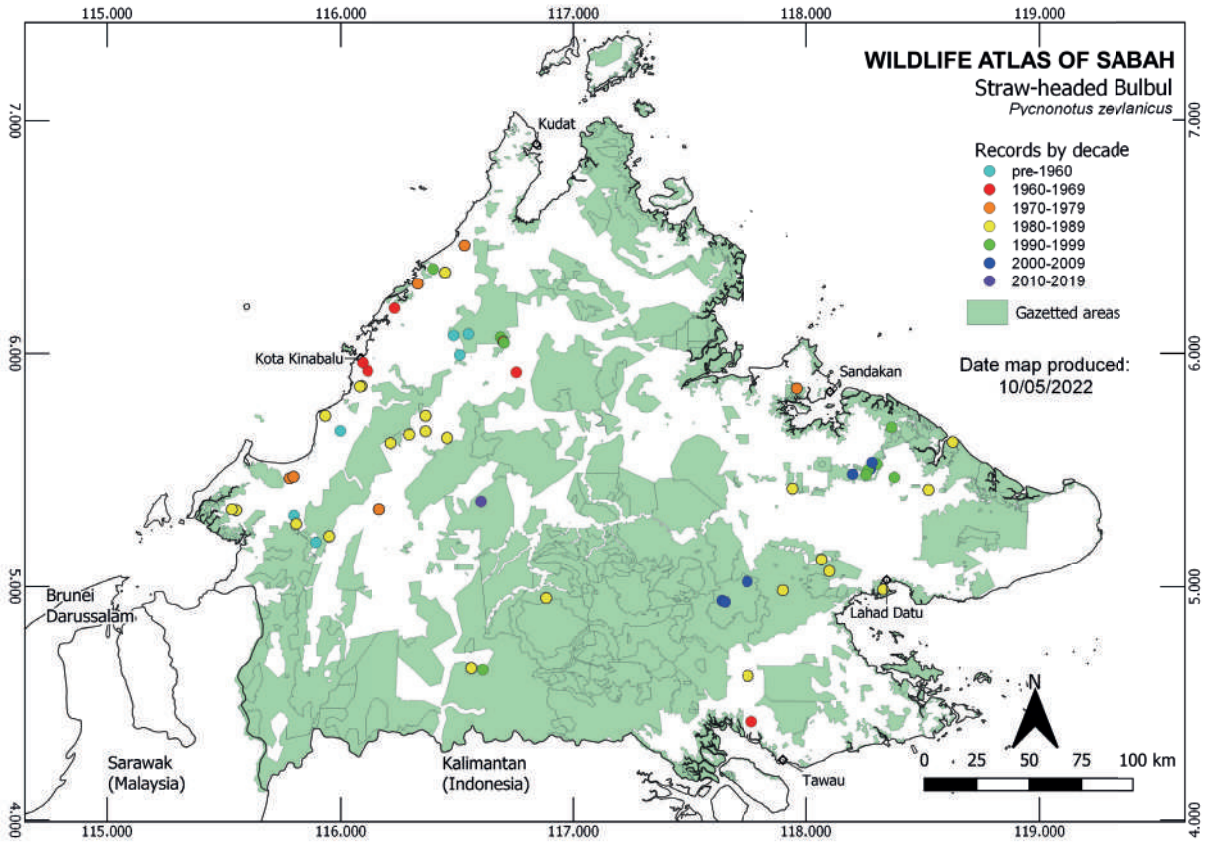


Figure 2. Published records of Straw-headed Bulbul occurrence include: Bole River, Danum Valley Conservation Area, Kabili-Sepilok Forest Reserve, the Kalabakan area west of Tawau (including Brumas, Merotai Besar, and Sabah Softwoods), Kinabalu Park including Tenompok to Kundasang and Poring, along the entirety of the Kinabatangan and Kuamut rivers, Kota Kinabalu suburbs, Klias Peninsula and along the Padas River to Tenom (including Padas Damit, Saliwangan and Rayoh), Pegalan River from Sinsuran and Tambunan through Keningau to Tenom, along the Segama River from Lahad Datu to the Segama headwaters, Sapulut River including Batu Punggul, Mt. Trus Madi at least to 750 m, and along rivers, streams, drainage, and paddy fields on the west coast from Sipitang (e.g. Lakutan and Menggalong rivers) to at least the Kota Belud Bird Sanctuary at Tempasuk Plain (Harris et al., 2012; Mann, 2008; Sheldon et al., 2001).

(Section 25 (2)) of the Wildlife Conservation Enactment 1997.

Despite plenty of warning from concerned conservationists and birdwatchers, the species has been steadily removed from most of its range. The impact of the cage-bird trade on Straw-headed Bulbul has been especially serious not only because of the species' desirability for its song but also because individuals of this species are particularly easy to capture. Unlike another remarkable singer, the White-crowned Shama (see Chapter 34), whose territories are dispersed throughout primary and secondary forest, Straw-headed Bulbuls are distributed linearly along water courses, lakes, and ponds. Thus, it is easy for pet traders to travel by boat, play recordings of their song, and capture entire flocks at a time.

The conservation issues pertaining to the Straw-headed Bulbul are unique in another respect as well. Unlike many endangered species whose habitat in Southeast Asia has been severely eroded and likely will never recover (see Storm's Stork Chapter 30), Straw-headed Bulbul habitat remains plentiful; there are literally thousands of kilometers of good Straw-headed Bulbul habitat in Sabah. Indeed, an ironic twist to the fate of this species is that its last major population stronghold is Singapore, a place with scarcely any native habitat (Yong et al., 2018). The reason that the bulbuls are doing well in Singapore is because they are better protected than in most other countries. Were adequate protection available to Straw-headed Bulbuls in the few remaining areas where populations persist, the species would undoubtedly rebound, probably as spectacularly as it has declined. In Sabah, the remaining wild populations should be able to spread widely without much trouble and eventually work their way into Kalimantan. Similar spread would likely occur on the Malay Peninsula. To seed a recovery of the original genotypes on Sumatra, however, might require reintroducing cage birds if there truly are no individuals left in the wild. Unfortunately, the original Javan population and those on many smaller islands are lost forever.

Acknowledgements

Ding Li Yong kindly commented on the manuscript before submission and provided the photograph of Straw-headed Bulbul by Tiah Khee Lee. Adi Shabrani helped extensively with historical records and mapping.

Field data presented in this paper have come from numerous published sources, and records supplied to the Wildlife Atlas of Sabah: BirdLife International (2001), Boonratana & Sharma (1993), Bornion Timber (2021), Pieterse & Wielstra (2009), Sabah Museum, Sharma (1992), Sheldon et al. (2001), Sheldon et al. (2009), Sheldon et al. (2014), Vermuelen (1996), WWF Davies & Payne (1982), WWF-Malaysia (1985).

Data Sources

Individuals / organizations (Number of records): Sabah Museum (2). *Publications (Number of records):* BirdLife International, 2001 (22); Boonratana & Sharma,1993 (1); Bornion Timber, 2021 (1); Davies & Payne, 1982 (5); Pieterse & Wielstra, 2009 (3); Sharma, 1992 (2); Sheldon et al., 2001 (20); Sheldon et al., 2009 (1); Sheldon et al., 2014 (1); Vermuelen, 1996 (1); WWF-Malaysia,1985 (1).

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White-crowned Shama (*Copsychus stricklandii*)

Frederick H. Sheldon

Introduction

The White-crowned Shama (*Copsychus stricklandii*) occurs in north-east Borneo and is commonly considered a Sabah endemic, although some individuals are found in northernmost Kalimantan (Smythies, 1999). It is a member of a small group of stout, long-legged, long-tailed passerines in the family Muscicapidae (Sangster et al., 2010; Zuccon & Ericson, 2010). Other members of this group from Sabah are the Oriental Magpie-Robin (*C. saularis*) and Rufous-tailed Shama (*C. pyrropygus*). The White-crowned Shama is most closely related to the White-rumped Shama (*C. malabaricus*), a widespread species that occurs from Borneo (outside Sabah) to India, and to the Maratua Shama (*C. barbouri*), which is restricted to Maratua Island off the northeast coast of Kalimantan (Chua et al., 2015; Lim et al., 2010).



Figure 1. White-crowned Shama © James Eaton

Because the White-crowned Shama replaces the White-rumped Shama geographically on Borneo and the two birds closely resemble each other in plumage and song, they are often considered conspecific, with the White-crowned Shama designated as subspecies *C. m. stricklandii* (Clements et al., 2019; Collar, 2004; Dickinson, 2003; Mees, 1996; Smythies, 1960). Until recently, only a few taxonomists treated White-crowned Shama as a distinct species (Inskipp et al., 1996; Ripley, 1964; Sibley & Monroe, 1990; Smythies, 1999). But careful consideration of specimen records (Davison, 1999) and genetic data (Lim et al., 2010; 2017) has demonstrated that White-crowned and White-rumped shamas are morphologically and genetically distinct. They almost certainly evolved in isolation from one another before coming into secondary contact near Sabah's border with Sarawak and Kalimantan, and the two appear not to interbreed to a significant extent where they meet.

Much of the conservation literature still treats White-crowned Shama as a subspecies of White-rumped Shama (e.g. Eaton et al., 2015; Leupen et al., 2018). Such treatment serves a useful purpose since both taxa are heavily sought by pet-traders. As a subspecies, White-crowned Shama falls under the protective umbrella of the White-rumped Shama, and concern about over-exploitation of the latter helps protect it. On the other hand, as a distinct species, White-crowned Shama likely suffers increased pressure from pet-traders because rarity and taxonomic uniqueness, in addition to song, are characteristics highly prized by cage-bird enthusiasts (Lee et al., 2016; Leupen et al., 2018; Nijman, 2010a; Nijman et al., 2019; Shepherd & Chng, 2017).

Natural History

White-crowned Shamas are famous for their loud and beautiful songs and ability to mimic other birds and sounds (Collar, 2005; Roberts et al., 2020; Smythies, 1999). For these reasons, they are well known to Sabahans, but unfortunately, they have not been well studied by ecologists, so very little information is available on their natural history.

Shamas nest in cavities, and in Sabah the main nesting season appears to be from January to June (Sheldon et al., 2001; Thompson, 1966). In the 1960s, nests were described from the Klias area. They were built in holes in trees from 2.5–4 m above the ground and constructed of fibres, rootlets, and dead leaves. Eggs (two or three) were described as pale greenish, heavily flecked with a few spots of lilac and purple (Sheldon et al., 2001; Smythies, 1999). WWF-Malaysia surveys recorded a newly fledged bird in Tawau Hills Landscape in August 2019 (G. Davies, pers. comm.).

White-crowned Shama food includes large ants, worms, centipedes, spiders, and berries (Smythies, 1999).

A collection of White-crowned Shama calls from Sabah
© Department of Integrative Biology, Museum of Natural Science, Michigan State University, USA

Distribution in Sabah

White-crowned Shama is a common inhabitant of primary and secondary forest as long as there is adequate undergrowth. Its habitats include mixed dipterocarp, kerangas, ultrabasic, freshwater swamp, and logged forest; also, scrub adjacent to mangrove, enclosed forest on islands, and exotic tree plantations adjacent to native forest, such as cocoa, overgrown rubber, mature *Acacia mangium*, and mature *Albizia* — but notably not oil palm (Mann, 2008; Sheldon et al., 2001; 2009;

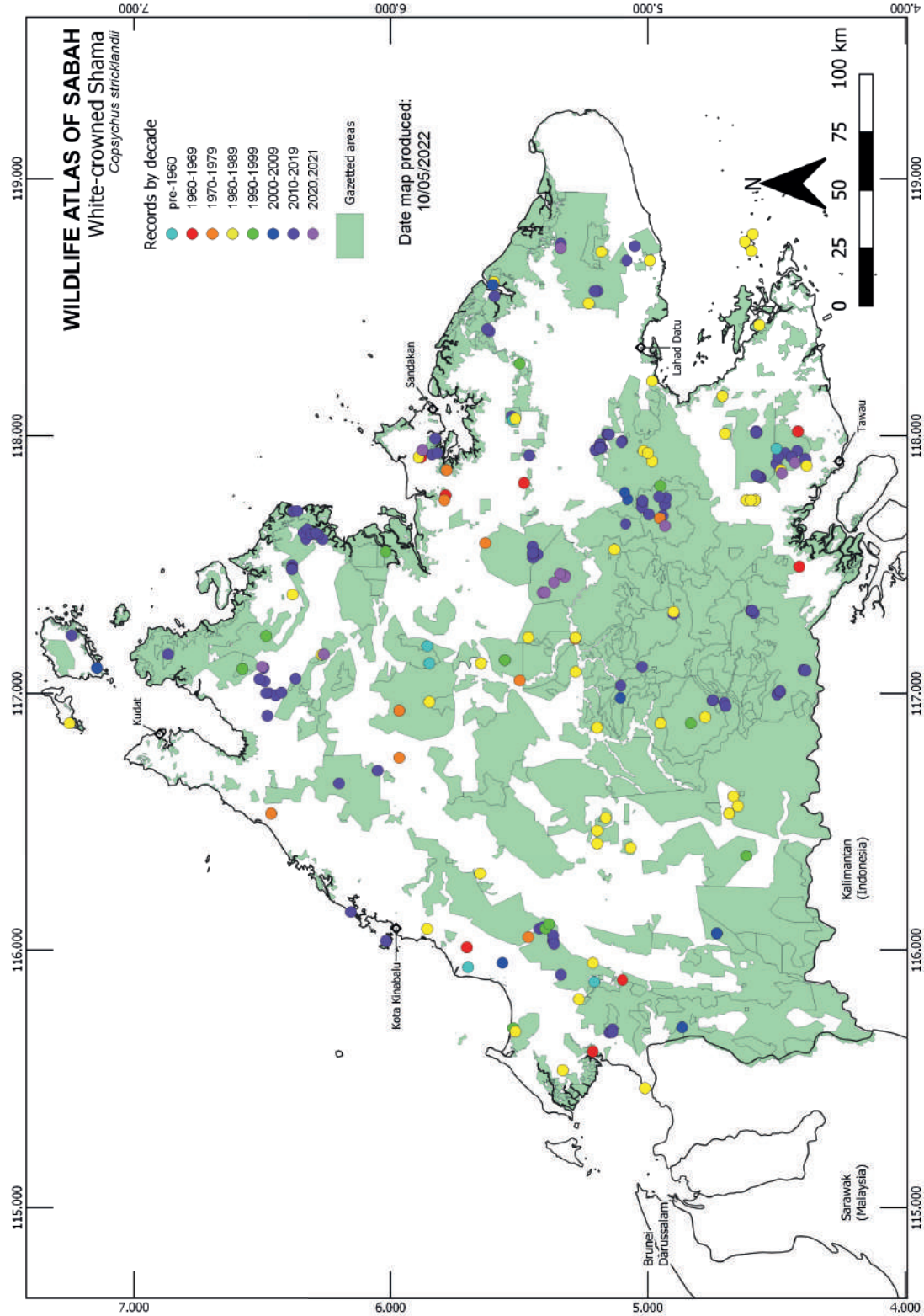


Figure 2. Records of White-crowned Shama in Wildlife Atlas database; other sources include Kimbambangan, Rukuruku and Ulu Tomani, as well as 19th century records from Labuan and Lumbidan (Gawin, 2014; Pegan et al., 2018; Sheldon et al., 2001; 2009).

2010). There are historical records representing essentially all parts of Sabah, from coastal islands inland to about 1,200 m in elevation.

Given their breadth of habitat, White-crowned Shamas are still numerous in Sabah. As long as there is forest with ground cover, the birds do well. However, individuals are easily captured by pet-traders because of their ready response to song playback (Eaton et al., 2015; Harris et al., 2017). As a result, birds tend to be rarer in proximity to villages, roads, and rivers, where access by humans is easy and special protection does not exist. Overall, the number of White-crowned Shamas in Sabah may be somewhat overestimated because, if they occur in an area, their loud and easily recognized song assures their listing by birdwatchers and ornithologists.

Cultural Significance

The beautiful song of White-crowned Shamas has attracted bird-keepers, likely for hundreds of years. Of late, they and White-rumped Shamas have become especially popular as contestants in singing competitions (Chng et al., 2018; Jepson & Ladle, 2009; Leupen et al., 2018).

Dusun names: *wedit talun, manangkala, wodit, wodit sarau*. Murut name: *tampak longon* (Smythies, 1999).

Conservation

Because of their vocal virtuosity, White-crowned and White-rumped shamas are highly prized by cage-bird enthusiasts (Eaton et al., 2015; Lee et al., 2016; Leupen et al., 2018; Nash, 1993; Shepherd et al., 2004). The numbers kept in captivity are quite remarkable. Marshall et al. (2020) surveyed cage-bird ownership on Java and found that more than 3 million shamas are in captivity on that island alone (Figure 3). Because of the pressure exerted on wild populations by this industry, numbers of individuals have plummeted in most of Sundaland. The native population of White-rumped Shamas on Java was extirpated by 1997 (Jepson & Ladle, 2009), causing pet-traders to trap in other areas, especially Sumatra, Borneo, Peninsular Malaysia, and Thailand. Populations in west and south Kalimantan and most of Sumatra appear to be largely depleted (Chng et al., 2018; Eaton et al., 2015; Harris et al., 2017; Leupen et al., 2018; Marshall et al., 2020; Shakya et al., 2018). Populations on small islands in Indonesia are especially vulnerable, and taxa that are now extinct or in immediate danger of extinction include: *C. m. opisthochrus* (Tapah

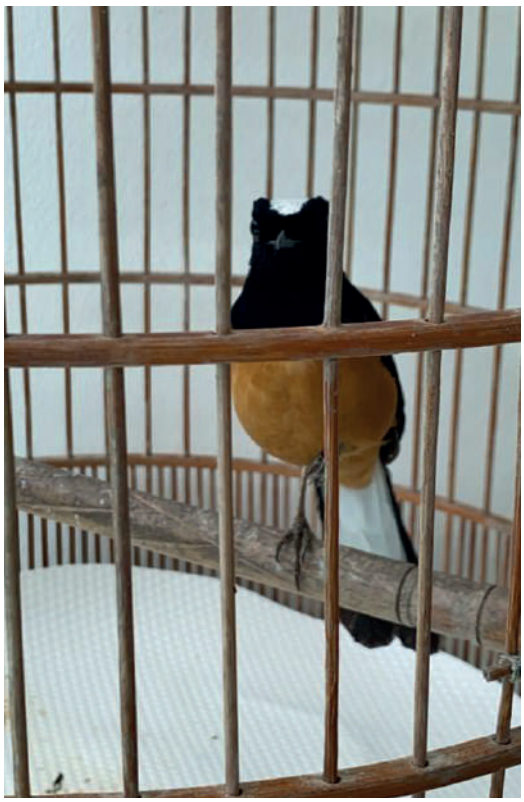


Figure 3. White-crowned Shama in captivity © Frankie Ng

Islands), *C. m. melanurus* (other West Sumatran Islands), *C. m. nigricauda* (Kangean Islands and Matasiri Island), and *C. barbouri* (Maratua Island) (Burner et al., 2018; Eaton et al., 2015; Rheindt et al., 2019).

In Sabah, the population of White-crowned Shamas is still healthy because of the species' occurrence in a wide variety of habitats and the continued existence of large areas of protected habitat (e.g. Crocker Range, Kinabalu and Tawau Hills parks, and Danum Valley, Maliau Basin, and Imbak Valley conservation areas) as well as substantial regenerating forest across the interior of the state. The species is fully protected under Sabah's Wildlife Conservation Enactment 1997 (2016 Amendment). Capture for the pet-trade is permitted, but only through licensing. Severe fines are imposed for poaching: from MYR50,000 (USD12,500) to a maximum of MYR100,000 (USD25,000), a minimum of 6 months to maximum of 5 years imprisonment, or both (Leupen et al., 2018).

Despite severe depredation by the pet-trade, White-crowned Shama (including White-rumped Shama as a subspecies) has remarkably little international protection. It is not listed by CITES and is considered of 'Least Concern' by the IUCN in its Red List (BirdLife International, 2021). This lack of recognition is because White-rumped Shama does not meet critical conservation criteria; it has a large range (from Borneo to India), which encompasses several substantial populations, including Sabah's. However, given the serious state of many isolated populations in Sundaland and Indochina, conservation organisations in Southeast Asia have taken protective action; Traffic.org has listed *Copsychus malabaricus* (including *C. stricklandii*) as a Tier 1 Priority Species meriting special protection (Lee et al., 2016).

Acknowledgements

Ding Li Yong kindly commented on the manuscript before submission. James Eaton provided the photograph.

Data Sources

Individuals / organizations (Number of records): Haysom, Jessica (9); Hearn, Andrew (30); 1StopBorneo Wildlife (1); Forest Solution Malaysia (14); Sabah Museum (41); WWF-Malaysia (97). *Publications (Number of records):* Boonratana & Sharma, 1993 (1); Chung et al., 2019 (2); Davies & Payne, 1982 (29); Gilbert et al., 2018 (1); Kehoe, 2011 (8); KOPEL, 2016 (1); Payne et al., 1989 (1); Rahman & Abdullah, 2002 (1); Rahman et al., 2002 (1); SFD, 2017 (2); Sheldon et al., 2001 (51); Sompud et al., 2013 (1); Wong, 2011 (4); Zahri & Ahmad, 2019 (1).



Emergent forest tree sentinel over oil palm monoculture at Merotai © Glyn Davies

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Future Directions

Glyn Davies

Why is Sabah special?

The geological and climatic history of Sabah has given rise to a surprising array of species and subspecies unique to the State; they are endemic. The persistence of forest habitat in the wetter mountains and coast-adjacent areas over millions of years, combined with repeated isolation and rejoining of forests, has given rise to a unique assemblage of wildlife species despite Sabah only covering a small portion of Borneo.

The mighty rivers of Borneo have contributed to this species richness, by separating populations which were unable to cross the waters (e.g. Brunke et al., 2019). Over time, a single breeding population becomes separated into two, on either river bank, with each evolving different characters to become new subspecies or even species. For example, the Kayan, Barito and Kapuas rivers in Kalimantan separate different subspecies of Red Leaf Monkeys (*Presbytis rubicunda*), and the Kinabatangan River in Sabah does the same, separating the pale *P. rubicunda chrysea* subspecies from the darker *P. r. ignita*, although the pelage of this species is very variable (Chapter 5). A similar pattern applies across Borneo for orangutan (*Pongo pygmaeus*), gibbon (*Hylobates* spp.) and grey leaf monkey (*Presbytis* spp.) species/subspecies, with large rivers separating them although not always the same river for each species (Phillipps & Phillipps, 2018).

Examples of 'Sabah species' include both the Bornean Elephant and Sabah Leaf Monkeys, which are almost entirely restricted to Sabah, while subspecies endemic to the State include (Figure 1): Red Leaf Monkey, Prevost's Squirrel and Horse-tailed Squirrel (*Sundasciurus hippurus pryeri)*. Similarly for birds, the White-crowned Shama and Black-crowned Pitta occur in Sabah, while their closely related counterparts, the White-rumped Shama (*Copsychus malabaricus*) and Garnet Pitta (*Erythropitta granatina*), occur in the rest of Borneo (Sheldon et al., 2015). The South Sabah Zoological Boundary, which separates these species, remarkably follows the international border between Sabah and Kalimantan for many species, although three 'southern species' occur north as far as the Maliau Basin (Phillipps & Phillipps, 2018), Sabah Leaf Monkey, Bornean Elephant and White-crowned Shama extend south into east Kalimantan, to limited and variable extents. It is a strong but not solid boundary.

In the mountains, as the vegetation changes with altitude, another layer of species richness is added. The montane community includes Whitehead's Pygmy Squirrel (*Exilisciurus whiteheadi*), Hose's Civet (*Hemigalus hosei*), and Mountain Treeshrew (*Tupaia montana*), as well as birds like Whitehead's Trogon (*Harpactes whiteheadi*) and Chestnut-hooded Laughing Thrush (*Rhinocichla*



Figure 1. Sabah endemics: species & subspecies with all or most of their populations within the State

a. Prevost's Squirrel (*Callosciurus prevosti pluto*) in Sepilok © Adrian Choo/WWF-Malaysia

b. Bornean Elephant (*Elephas maximus borneensis*) in Sabah Softwoods Berhad, Tawau © Cheryl Cheah/WWF-Malaysia

c. Sabah Leaf Monkey (*Presbytis sabana*) in Tabin Wildlife Reserve © Cede Prudente

d. Red Leaf Monkey (*Presbytis rubicunda chrysea*) in Tawau Hills Park © Aaron Gekoski/WWF-US

e. White-crowned Shama in Trus Madi (*Copsychus stricklandii*) © Nenita Tan

f. Black-crowned Pitta (*Erythropitta ussheri*) in Rainforest Discovery Centre © Liew W. K.

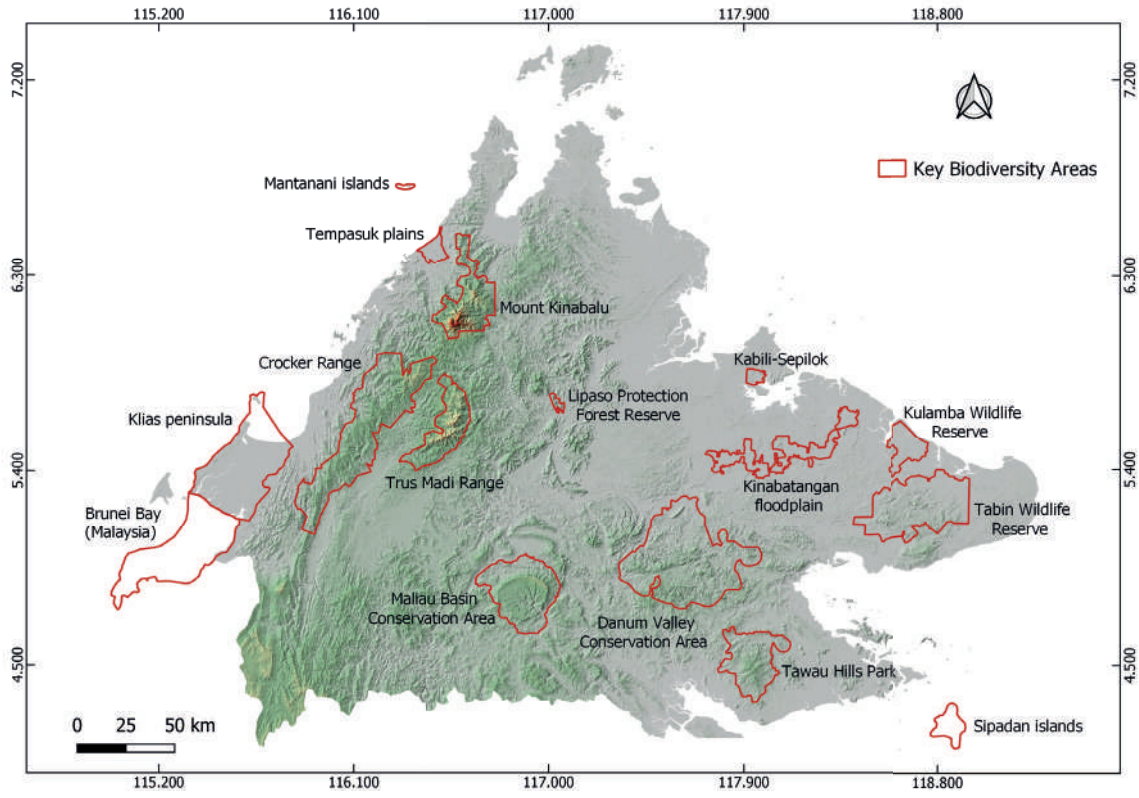


Figure 2. Key Biodiversity Areas (KBAs) of Sabah (https://www.keybiodiversityareas.org/).

treacheri). The montane community occurs at lower elevations on smaller isolated mountains, especially those near the coast, as a result of the *Massenerhebung* effect. These species are relatively abundant on Mt. Kinabalu, Crocker Range and Trus Madi massifs, and although they do occur on mountains beyond Sabah's borders, they still supplement the lowland species array.

In addition to the montane species there is also a distinct **lowland forest community** including Bornean Elephant, Bornean Yellow Muntjac, Red and Sabah Leaf Monkey species, North Bornean Gibbon and Bornean Orangutan (Figure 3). Their populations are most abundant in the lowland forests (below 500 m asl), and they often intermingle with the **riverine community** found along the major rivers merging into the mangrove and nipah forests at the coast. This latter community is characterised by a combination of three primate species: Proboscis Monkey, Silvered Leaf Monkey and Long-tailed Macaque, alongside other animals such as: otters, Storm's Stork and, along smaller streams, the now very rare Straw-headed Bulbul.

From a global perspective, these varied communities mean that Sabah holds a number of Key Biodiversity Areas (KBAs), which are acknowledged by the international conservation community as being "among the most incredible and diverse places on Earth for nature …" (Key Biodiversity Areas, 2022; Figure 2).

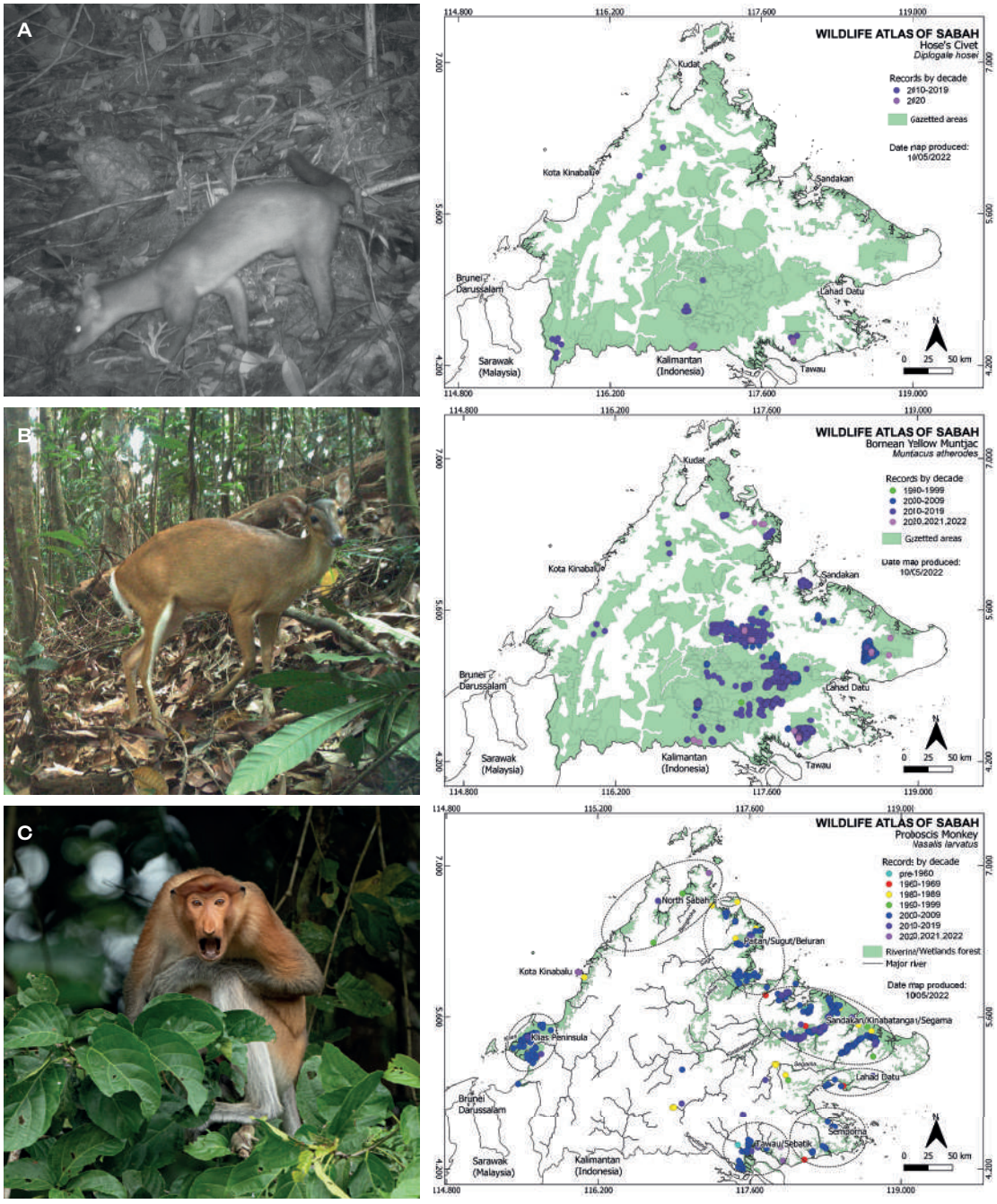


Figure 3. Species from the montane, lowland forest and riverine communities

a. **Montane species:** Hose's Civet captured on camera trap in Tawau Hills Park © WWF-Malaysia

b. **Lowland species:** Bornean Yellow Muntjac captured on camera trap feeding in Tawau Hills Park © WWF-Malaysia

c. **Riverine species:** Proboscis Monkey giving a 'threat gesture' in the Lower Kinabatangan River © Mazidi Abd Ghani/WWF-Malaysia

What has changed in 50 years?

The bulk of records in this Wildlife Atlas of Sabah cover the last 50 years, which provides a window through which to view change. In particular, it is a period during which Sabah saw an enormous timber boom in the 1960s and 1970s, followed by an agriculture boom from the mid-1980s and 1990s, and to a lesser extent the mid-2000s. The impact of these changes has altered Sabah's landscapes more than any other change since the ice ages, and three main conclusions can be drawn from the chapters in this volume.

Species go extinct through hunting to supply markets, especially for traditional medicines and ornaments

The **Sumatran Rhinoceros** went extinct in Malaysia in 2019 when the animal named Iman died in Tabin. She was the last known representative of an ancient and evolutionary distinct species lineage in Sabah, which has already been eliminated from almost all of Borneo by hunting for ornaments and traditional medicines (Payne, 2022). There are reports of a very small remnant population still in East Kalimantan, but Iman's demise clearly shows that a market force, focused on the exploitation of a single species, will drive extinction. The species has been eliminated despite there being areas with suitable habitats.

The **Sunda Pangolin** has also been a long-standing target of traditional medicine traders, and thousands have been killed and illegally exported from Sabah in recent times, such that they are seldom encountered anywhere. And the case of body parts from **Bornean Sun Bears** being sold to tourists in a Kota Kinabalu hotel car park, in August 2016, warns of the illegal wildlife trade also affecting this species, and being linked to international tourism (Daily Express, 2016).

Demand for **red ivory** from Helmeted Hornbills has driven local extinction of the species in some parts of Borneo (TRAFFIC, 2016), but has not reached such dangerous levels in Sabah. Demand for **white ivory** from Bornean Elephants has been reported in Sabah, but fortunately is also not at significant levels at the present time. Trade in both kinds of ivory is illegal, and great vigilance and enforcement is needed to ensure traders and their contracted village hunters do not begin offering any of these animals on the market, either directly or through digital platforms.

The **song bird trade** involves catching live birds and trading them both locally and internationally, especially to Indonesia. The Straw-headed Bulbul has disappeared from most of Borneo, including Sabah, as a result of unsustainable harvesting for this trade. The off-take of White-crowned Shamas in Sabah for the same song bird trade has been less intense to date, with the species still being quite widespread and locally abundant (Leuped et al., 2018).

There is a long tradition in Sabah of **hunting wildlife for food**, for indigenous communities, urban dwellers, and field staff working in timber camps and plantations. This can lead to 'empty forests syndrome' when wildlife has been shot-out of otherwise good quality forest (Bennett et al., 2000; Harrison et al., 2016). Indeed the conclusion of a 1995 hunting study was that commercial wild meat hunting in Sabah was unsustainable (Figure 4), with wildlife populations dropping drastically as hunting intensity increased (Bennett et al., 2000). In neighbouring Sarawak, Brodie et al. (2015b) found that hunting impacts were more negative than logging, which probably has direct implications for wildlife in south-west Sabah but appears less so in eastern Sabah forests where hunting appears lower.

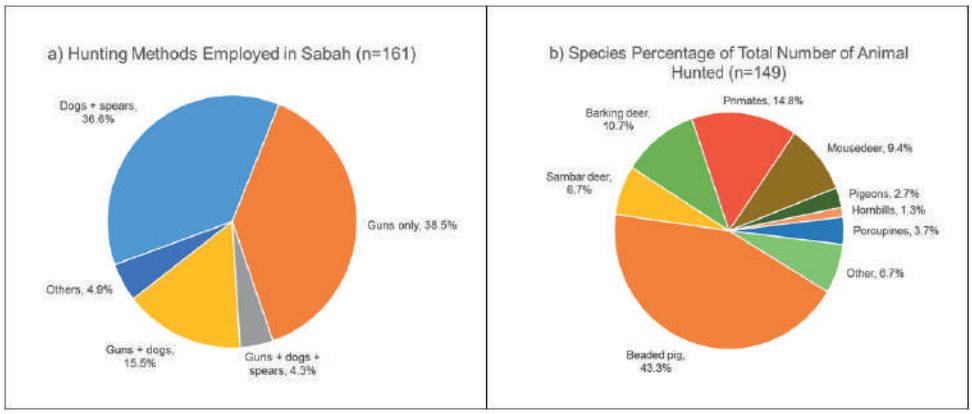


Figure 4. Showing the range of hunting methods employed at six sites in Sabah (including villages, timber camp & plantations), & proportion of different species hunted at 3 village sites in 1993–95 (Bennett et al., 2000)

As a result, wildlife numbers have been maintained across most central and eastern forests. The regeneration of logged forests, increases in certified timber production which limits hunting, and a shift towards commercial hunting within plantations (Figure 5) have all contributed positively. The hunting in west and south-west Sabah, however, remains high and the largest species such as Sambar and Borneo Banteng are always most at risk, especially with many fewer Bearded Pigs available after the African Swine Fever outbreak (Kurz et al., 2021). Reports of recent local extinctions of banteng through 'meat' and 'sport' hunting forewarn that action is needed to prevent them becoming the next mammal species extinction in Sabah (Chapter 13).

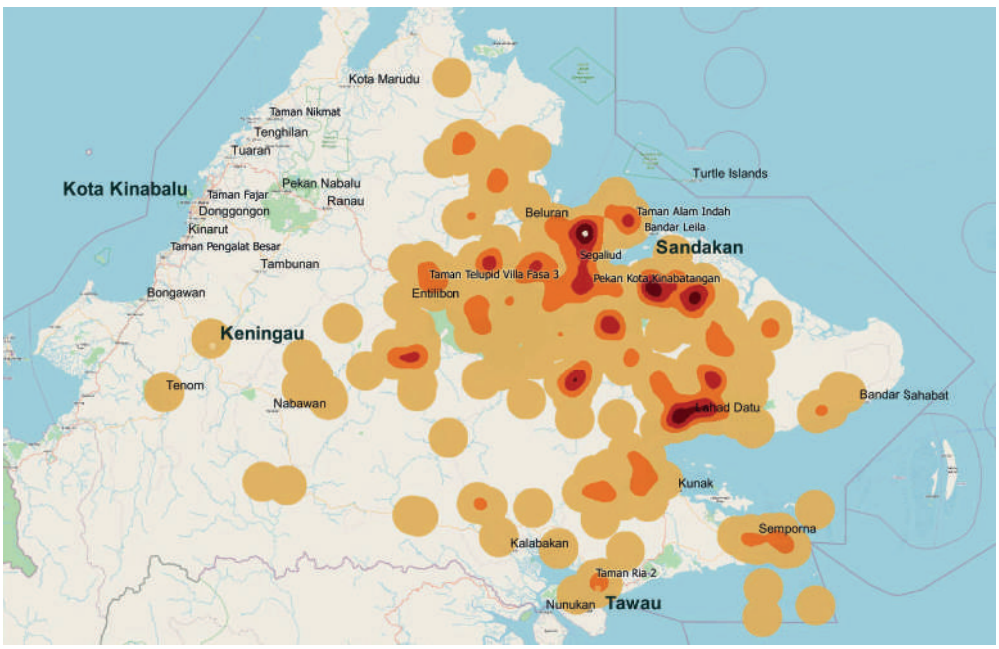


Figure 5. Sabah Wildlife Department records from road check-points in eastern Sabah showing "hotspots". Most of this wildlife was hunted in plantations, with records (N = 264) for Bearded Pigs (77%), Sambar (14%), Muntjac (<2%) and fruit bats (Fiffy Hanisdah et al., 2022). This shows the importance of oil palm plantation areas in supplying wild meat, and hunting as important to reduce crop losses from some commoner species.

Wildlife numbers have declined through forest loss, and in logged forests many species are recovering with forest regeneration

The widespread and unsustainable logging in the 1980s and 1990s left large areas of degraded forests with depleted timber stocks. It is not easy to generalise about the impacts of logging because different rates of timber extraction, ranging from uncontrolled and destructive maximum timber extraction to Reduced Impact Logging (RIL), and varying intensities of hunting by timber camp workers and outside hunters lead to different outcomes. Furthermore, logged forests and their wildlife can recover if they are protected and given time, and the longer the period of regeneration the better the recovery.

For example, orangutan numbers are maintained in sustainably managed forests; RIL in Deramakot Forest Reserve (Ancrenaz et al., 2005), and the majority of Sabah's orangutans now survive in logged forests (Simon et al., 2019). Similarly, Bornean Gibbon numbers have bounced back after 20 years, despite initially very destructive logging in Tabin, while Sabah Leaf Monkeys have been surprisingly slow to recover in the same forests (Davies & Tan, 2019). Both macaque species can adapt fairly well to changes in forest habitats following logging. Among the ungulates, Greater Mousedeer and Bornean Yellow Muntjac adapt least well to timber extraction, but Red Muntjac, Sambar, banteng and elephants benefit from canopy opening and the increased forest floor regrowth at sites where hunting pressure is low (see previous chapters).

The loss of lowland forest to agriculture has caused the greatest declines in Sabah's wildlife. It is estimated that orangutan numbers in Sabah declined from at least 20,000 in 1980 to around 11,000 today, with around 10,000 lost to plantation development (Ancrenaz et al., 2005; Simon et al., 2019). A similar halving of the gibbon population occurred for the same reason over the same period, with about 100,000 deaths estimated through forest loss (Shabrani et al., 2021).

For each taxonomic group, therefore, there is a spectrum of adaptability to habitat change, from forest-specialists which adapt poorly to logging; to forest-generalists which live in forest openings and adapt well to logging, sometimes taking a long time; to non-forest species which cope well with agricultural habitats. Taking a rough estimate for mammals in Sabah (149 species), approximately 20% of species are forest-specialists which are lost or decline steeply when unlogged forests experience intensive logging, compared to over 90% forest species lost when forests are cleared and planted with monoculture agriculture (after Phillipps & Phillipps, 2018).

The current situation for rarest large mammals in Sabah shows Bornean Banteng and Sunda Clouded Leopard to be the very rarest, with Bornean Elephant, probably Bornean Sun Bear, Proboscis Monkey and Bornean Orangutan following closely behind (Table 1).

In addition to population losses, some ecological processes have been lost too. For example, the mass migration of Bearded Pigs across large areas of lowland and hill dipterocarp forest is no longer seen, although animals do still travel substantial distances searching for fallen forest fruit, but no longer in large migrating hoards (Caldecott & Caldecott, 1985). And there are probably other little-known events that have been lost, such as the migration of tens of Smooth-coated Otters down the Labuk River in the 1960s (Davidson, 2007).

A small number of species can adapt to monoculture agriculture

There is a small set of species which can survive the large losses to agriculture and infrastructure, and even thrive in farmlands and oil palm plantations, and their distribution and abundance is greatly under-estimated because few systematic records have been gathered from these habitats.

Table 1. Estimated population of rare larger mammals in Sabah (based on chapters in this volume).

Species	Sabah population estimates 2022	Source
Sumatran Rhinoceros	0[1]	
Bornean Banteng	at least 326	SWD, 2019a. Bornean Banteng Action Plan for Sabah
Sunda Clouded Leopard	750 (300–1,300)	SWD, 2019c. Sunda Clouded Leopard Action Plan for Sabah
Bornean Elephant	1,000–1,500	SWD, 2020a. Bornean Elephant Action Plan for Sabah
Proboscis Monkey	6,000	SWD, 2019b. Proboscis Monkey Action Plan for Sabah
Bornean Orangutan	11,000	SWD, 2020b. Orangutan Action Plan for Sabah

[1] Extinct in 2019

The species, which may enter from adjacent forests or reside within the plantation area itself include: Sunda Leopard Cat, both species of macaques, Bearded Pigs, Malay, Masked and Common Palm Civets, Common Porcupine, Plantain Squirrel, and some hornbills and parrots (Phillipps & Phillipps, 2018; Wearn et al., 2017; Yue et al., 2015). Even rare pangolins, with their diet of ants and termites, can find food within plantation areas, but they are soon hunted out (see above). One non-native species has even benefitted from palm oil. The Jungle Fowl was introduced to the Tabin area in the 1980s by plantation staff and it has now spread to occupy forest-plantation edges over large parts of eastern Sabah.

These species have benefitted from, or at least been able to adapt to agricultural habitats and activities, and some have adapted so well that they have become crop pests – from squirrels and macaques, to Bearded Pigs and elephants. Another recent observation is that forest mammals and birds can travel through monoculture areas, either flying or along the ground, especially if there are forest patches to use as 'stepping stones' through the planted area. This allows widely separated individuals to remain connected and inter-breed and so maintain populations (Oram et al., 2022), albeit at much reduced levels.

Conservation Action

Sabah has lost about half of the forest-dependent wildlife populations – due to hunting, logging, agriculture and infra-structure development (see above). Many wildlife species do recover their populations if given time in logged forest (Wearn et al., 2017), and some can survive oil palm plantations, especially where populations are inter-connected across agricultural landscapes. This gives the opportunity for Sabah to maintain the 'remaining half' of her inspiring natural heritage, or lose it.

The conservation action plans for six rare species (SWD, 2019–2020; Table 1) have identified key areas for intervention, which are used as headings for sections below for consistency, and because they can be used in action plans for many different species.

1. Implement progressive sustainable development policies

To address the underlying drivers of wildlife losses, policy frameworks and legal regulations are required to influence and guide outcomes on the ground. These involve laws and regulations, and taxes and subsidies, especially in forestry, agriculture, transport and tourism sectors, and they build from international and national policy commitments. Two international conventions of immediate relevance are the 1992 Convention on Biological Diversity (CBD), and the 1994 UN Framework Convention on Climate Change (UNFCCC). Malaysia is a signatory to both of these conventions, and has made commitments under the CBD to maintain 50% of the country under forest cover, and Nationally Determined Contributions under the UNFCCC rely on forest areas to mitigate climate change risks by avoiding further deforestation. The Heart of Borneo Declaration supports these objectives, shared between three countries.

At the state level (Table 2), Sabah has reiterated the national commitment to maintaining 50% forest cover, and added further that 30% of the State will be Totally Protected Areas (TPAs) by 2025 (SFD, 2018b). This is an important asset for the Sabah tourism industry, that in 2017 (pre-COVID-19) had revenues amounting to RM7.8 billion. Moreover, in the context of achieving the Sustainable Development Goals (Economic Planning Unit, 2021), there is a State-level policy target to achieve 100% RSPO certified palm oil by 2025, which builds on the important national target of 100% MSPO certified palm oil for all of Malaysia. This addresses the largest driver of deforestation in Sabah – oil palm plantations which cover 20% of the State's land mass, and responds to global market interests in deforestation-free commodities (The Consumer Goods Forum, 2022). It also limits further expansion of this crop in Sabah, and provides a framework for action by the **Sabah Jurisdictional Certification Steering Committee (JCSC)**.

Table 2. Sabah Laws (The State Attorney-General's Chambers, 2022)

Sector	Law/ Legislation
Forestry	Forest Enactment 1968 [with Forestry Policy, 2018]
Wildlife	Wildlife Conservation Enactment 1997
River	Sabah Water Resources Enactment 1998
Environment	Environment Protection Enactment 2002 Compilation of Subsidiaries Laws Environment Protection (Prescribed Activities) Order 2005 Environment Protection (Prescribed Activities) (Environmental Impact Assessment) Order 2005 Environment Protection (Registration of Environmental Consultants) Rules 2005 Environment Protection (Environmental Fees) Rules 2005 Environment Protection (Compounding of Offences) Rules 2005
Biodiversity	Sabah Biodiversity Enactment 2000 (2017)
Sabah Parks	Park Enactment 1984
Fisheries	Sabah Inland Fisheries and Aquaculture Enactment 2003
Economic Development	Sabah Structural Plan 2020 (2001)

In addition to the forestry and palm oil policies, the environment policy is framed in the context of the 12th Malaysia Plan (2021–2025), which impacts Federal government budget allocations for Sabah, as well as "Sabah Maju Jaya" and the Sabah Structural Plan 2020 (enacted in 2001). In the latter case, there are a number of inconsistencies to be resolved, such as proposed linear infrastructure

through Totally Protected Areas (Sloan et al., 2019). The recently established **State Planning Council**, a multi-agency government forum established to oversee integrated development, may be an important forum to resolve these issues, to support sustainable agriculture and sustainable infrastructure development that does not fragment TPAs, and helps reduce human-wildlife conflict. The Council also links with District-level planning bodies, and they all benefit from a clear description of the conservation priority areas in the State (Figure 6) to help guide local and State development decisions.

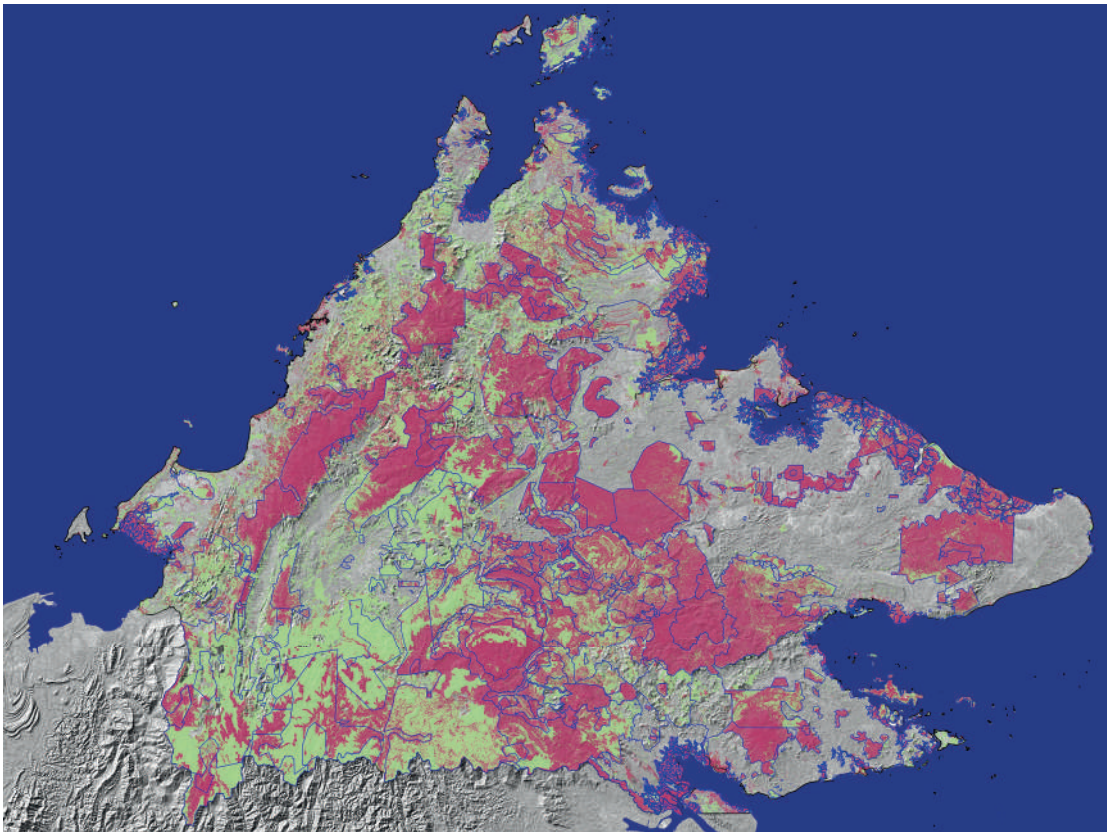


Figure 6. The distribution of Rare, Threatened and Endangered (RTE) species of plants and animals, based on modelling and existing records (SFD Report in preparation for JCSC). Red as higher species richness and green is lower species richness.

2. Maintain good quality forest habitats

Sabah's forests can be divided into two kinds: a) protected areas and b) production areas. Protected areas fall into six categories: National Park (1), State Park (2 inland), Wildlife Sanctuary (2), Wildlife Reserve (1), Bird Sanctuary (1) and Class 1 (Protection) Forest Reserve (1,421,717 ha; Table 3). Combining Forest Reserve Classes I, VI, VII with Sabah Parks, Wildlife Sanctuary and Wildlife Conservation Area gives the Totally Protected Areas (TPAs) cover as 1,942,397 ha (SFD, 2022) in 2021. These areas are the corner-stone of conservation for the State, and include examples of wetland/estuarine, lowland and montane forests types (Table 4), and they support populations of the larger endangered species (and by extension many smaller Rare, Threatened and Endangered species).

Although the establishment of Kinabalu Park dates back to 1964, the recent establishment of a large tranche of Class I (Protection) Forest Reserves has only been in the past decade or so, converting logged-over commercial forests to protection forests following exhaustion of timber resources, and the current policy of 'no net loss' for forested lands bodes well for maintaining 50% forest cover in Sabah (SFD, 2018b). Totally Protected Areas (TPAs) account for 26% of Sabah's landmass (Figure 7), which is well on the way to achieving the 30% State government policy target (Williams et al., 2019), and is aligned to protected area targets being discussed globally under the Convention on Biodiversity (Woodley et al., 2021).

Table 3. Changes in different classes of Forest Reserve (km^2) since 1990

Class — Forest Reserve	1980[1]	1990[2]	2010[3]	2020[4]
Class I — Protection	1,886	1,000	4,668	14,217
Class II — Commercial	33,435	26,746	23,789	16,555
Class III — Domestic	91	74	70	46
Class IV — Amenity	150	2,080	1,640	114
Class V — Mangrove	738	3,164	3,265	2,347
Class VI — Virgin Jungle	362	883	1,030	1,070
Class VII — Wildlife Reserve	-	1,327	1,371	1,395
TOTAL	**36,662**	**35,274**	**35,833**	**35,745**

Sources: [1] Davies & Payne, 1982; [2] Marsh & Greer, 1992; [3] Reynolds et al., 2011; [4] SFD, 2021

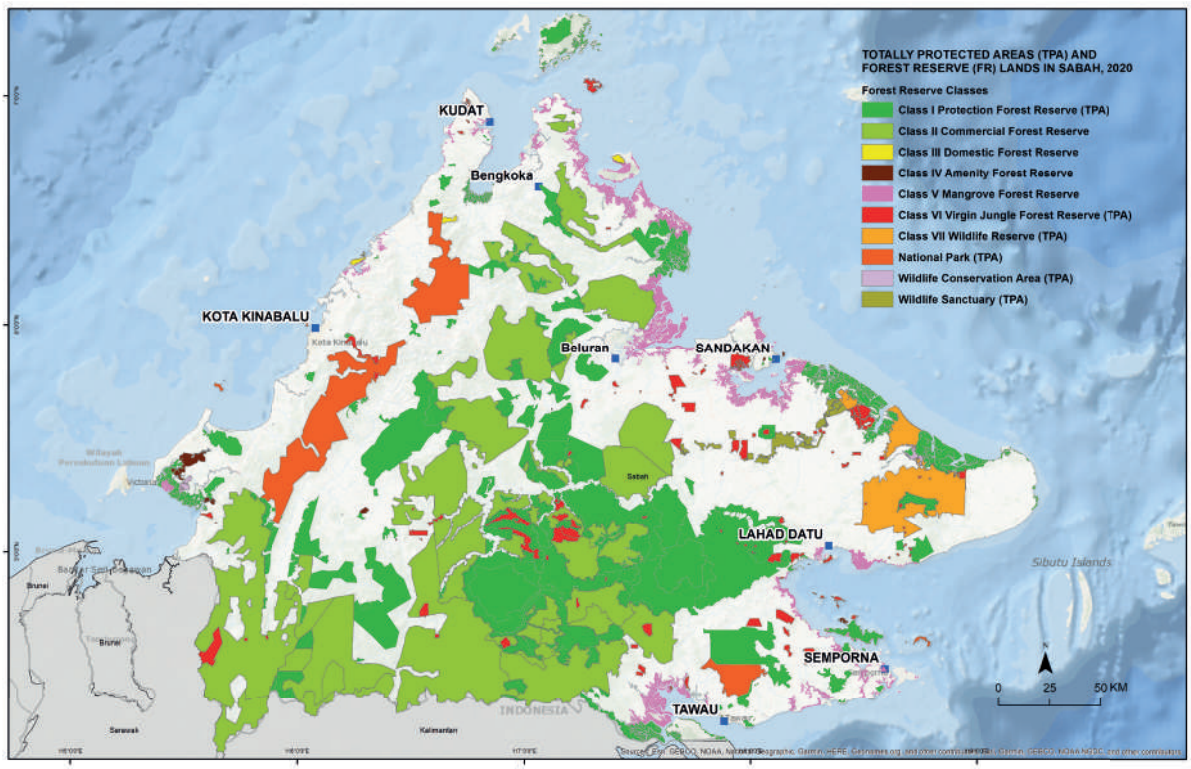


Figure 7. Map of Totally Protected Areas & other Forest Reserve lands (SFD Annual Report, 2021)

Table 4. Summary of the larger Protected Areas in Sabah

	Status and date status given	Area (ha)	Habitats/forest type	Rare, Threatened, Endangered Species[1]
Riverine/coastal/wetlands				
Lower Kinabatangan-Segama Wetlands	RAMSAR site #1849 2008	**78,803**	Mangrove, peat swamp, freshwater swamp, lowland, floodplain lakes, karst/caves	Proboscis (>2,280)
Kinabatangan	Wildlife Sanctuary (part of which is in the Ramsar site) 1997	**26,103**	Mangrove, peat swamp, freshwater swamp, lowland, floodplain lakes, karst/caves	Proboscis (see above) Orangutan (800) Elephant (300–350) Clouded Leopard (min. 5) Banteng (0)
Kulamba	Wildlife Reserve (part of Ramsar site) 1984	**20,682**	Mangrove, freshwater swamp	Proboscis (see above) Orangutan (245) Banteng (+) Elephant (0)
Klias Peninsula	Klias & Binsuluk Class 1 (Protection) FR 1984 & 1992	**15,736**	Mangrove, peat swamp, freshwater swamp, heath	Proboscis (818) Elephant (0) Orangutan (0) Banteng (0)
Lowland/Upland				
Tabin	Wildlife Sanctuary & Class 1 FR 1984	**111,971**	Logged lowland & upland forest	Orangutan (1,100) Elephant (250–300) Banteng (52) Clouded Leopard (30)
Ulu Kalumpang	Class 1 FR (adjoining Tawau Hills Park) 1992	**50,964**	Logged lowland and upland	Orangutan (>50) Elephant (60+ incl. Sabah Softwoods Bhd) Banteng (+) Clouded Leopard (+)
Danum Valley*	Class 1 FR & Yayasan Sabah Conservation Area 1980	**43,800**	Unlogged lowland Dipterocarp = 26,770; unlogged upland Dipterocarp = 14,404; ultramafic = 1,947	Orangutan (600) Elephant (20-25, part of larger central forests population) Banteng (+) Clouded Leopard (min. 8)
Mountain				
Mt. Kinabalu	National Park & UNESCO World Heritage Site 1964 & 2000	**75,381**	Unlogged hill, sub-montane & montane	Orangutan (+) Clouded Leopard (+) Elephant (0)
Crocker Range	State Park 1984	**139,919**	Logged hill, sub-montane, montane	Orangutan (+) Elephant (0) Banteng (0) Clouded Leopard (min. 20)
Nuluhon-TrusMadi	Class 1 FR (FMU 10) 2013	**184,527**	Logged hill, sub-montane & montane	Orangutan (280) Clouded Leopard (+) Elephant (0) Banteng (0)
Tawau Hills Park	State Park (adjoining Ulu Kalumpang FR) 1979	**27,972**/	Unlogged and logged lowland, hill, sub-montane	Orangutan (>30) Elephant (+) Clouded Leopard (min. 10)
Maliau Basin*	Class 1 FR & Yayasan Sabah Conservation Area 1981	**58,840**	Unlogged lowland/upland Dipterocarp = 864; unlogged Dipterocarp/[2]Kerangas = 24,458; Kerangas = 32,997	Orangutan (138) Elephant (25-30 incl. Sapulut Reserve) Banteng (31) Clouded Leopard (min. 11)
Imbak Canyon*	Class 1 FR & Yayasan Sabah Conservation Area 2003	**30,000**	Unlogged lowland/upland Dipterocarp = 2,941; unlogged Dipterocarp/Kerangas = 20,731; Kerangas = 3,820	Orangutan (24) Banteng (+)

[1] Population estimates based on indirect surveys and population density estimates; [2] Kerangas is also known as Heath forest;

*See Yayasan Sabah Conservation Area management section below; (+) Denotes presence

Mangrove reserves cover an additional 364,168 ha, of which about 234,680 ha are within Class V (Mangrove) Forest Reserves (SFD, 2022; Wong et al., 2020), and many other mangroves in Class I (Protection) Forest Reserves. These, along with swamp forest, lake, riparian and coastal vegetation have not been subject to any State-wide review or conservation plan since the post-2004 national wetlands report (Shukor, n.d.). This urgently needs attention, given the importance of these habitats for biodiversity, ecosystem services and carbon sequestration.

A second important point is that an area of about 1 million hectares is co-managed as the Yayasan Sabah (Sabah Foundation) concession (Yayasan Sabah, 2011), within the permanent forest estate of the Sabah Forestry Department. From the wildlife conservation perspective, three Conservation Areas have been designated surrounding the unlogged reserves noted in Table 5: Danum Valley, Maliau Basin, Imbak Canyon. Combined these Conservation Areas cover over 600,000 ha, including the majority of the remaining unlogged forests in Sabah, and importantly they are designed to maintain connectivity with each other, and thereby reduce the risk of population fragmentation and isolation.

Table 5. Designated conservation areas

Conservation Area (CA)	Forest Reserves under CA Management Committee(s)	Area (ha)
Danum Valley	Danum Valley & extension, Sg. Taliwas, Bukit Piton, Mt. Louisa & extension, Malua, Ulu Segama, Sapagaya & extension, Tg. Tumunong Hallu, N. Gunung Rara	298,942
Maliau Basin	Maliau Basin, Maliau buffer zone & extensions, Gunung Rara Wildlife Corridor, Tambulanan, Sg. Anjeranjermut, Sg. Sumagas, Sg. Tiagau & extension	173,015
Imbak Canyon	Imbak Canyon, Sg. Imbak buffer zone and extensions, Sg. Lulunguyon, Mt. Magdalena & extension, Sg. Imbaj VJR, Batu Timbang VJR,	130,934

Within the TPAs there is a need to optimise benefits of biodiversity conservation and ecosystem service provision, such as watershed management and forest carbon storage and sequestration, and prevent illegal activities leading to wildlife losses. To be effective, management plans, staffing capacity and resources are all required, along with management tools, such as the protected areas Management Effectiveness Tracking Tool (METT) and IUCN Green Listing approaches (Woodley et al., 2021). These are important to avoid protected areas becoming 'paper parks' that fail to achieve their conservation and sustainable development objectives, and to ensure government agencies can fulfil their statutory functions.

By contrast, in the 2000s oil palms were planted in both the Kalabakan and Bongaya Forest Reserves, within the Yayasan Sabah concession, converting over 100,000 ha of forest to agricultural crops. Further expansion of oil palm into forest reserves will preclude Sabah from developing a certified sustainable palm crop for the future, and it will also fail to achieve its CBD target of 50% forest cover, both of which are contrary to the Sustainable Development Goals.

3. Restore forest habitats

The Class II (Commercial) Forest Reserves, which account for 1,655,483 ha, are an essential buffer and supplement to the TPAs which alone cannot maintain viable populations of the rarest and/or

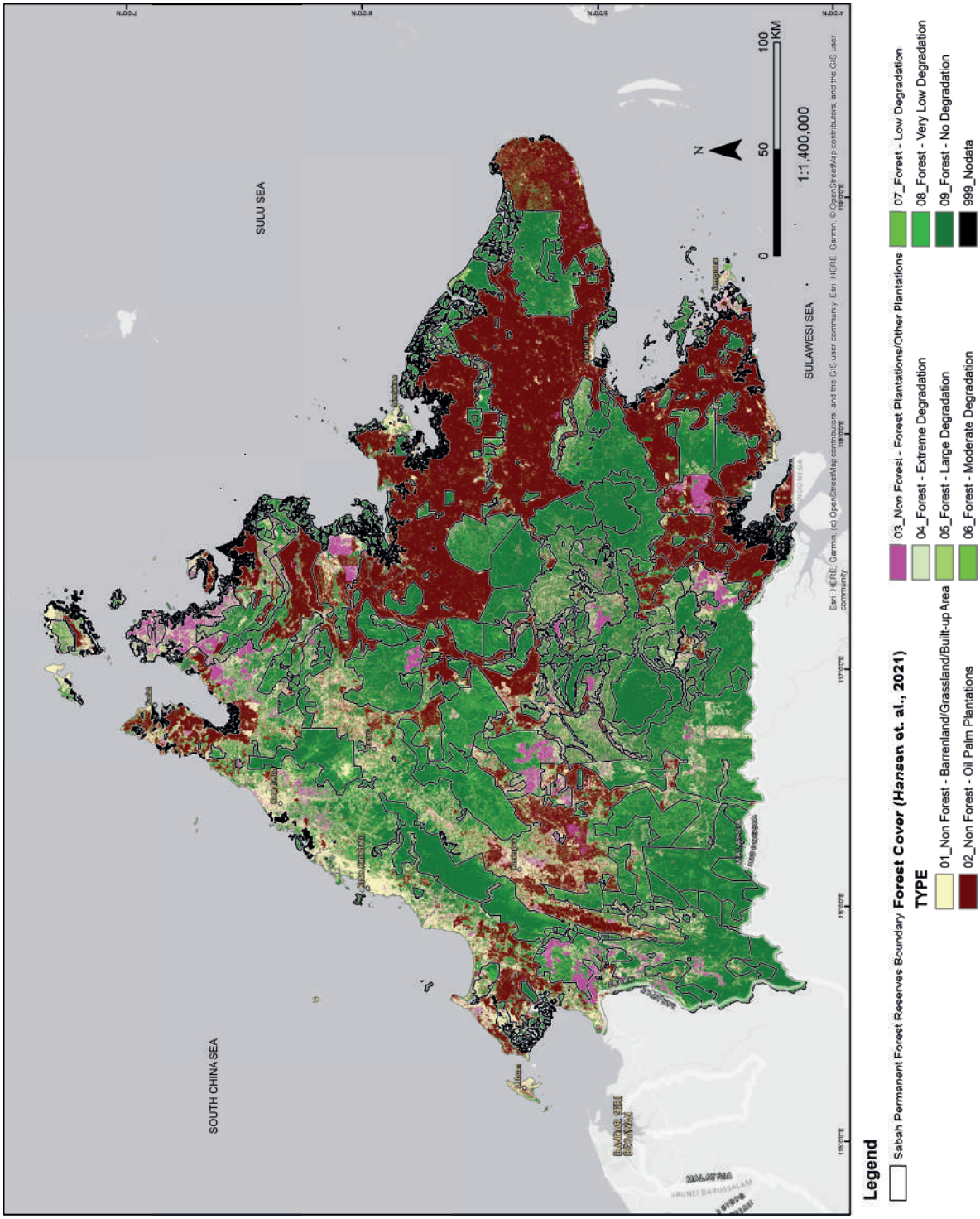


Figure 8. Sabah Forest Tree Cover, 2021

wide-ranging species. The disturbance to the forest during the process of timber extraction can be reduced through Reduced Impact Logging methods, including as FSC certified requirements. This includes leaving High Conservation Value (HCV) areas undisturbed, which can then act as refuges during logging operations and become sources for recovery thereafter.

In the many badly degraded areas, natural regeneration needs to be enhanced by enrichment planting with native trees, especially species which are wildlife food plants, and to provide structure for arboreal species, and shelter for others. Some areas have been subject to silviculture treatment, such as climber cutting, to release trees that are being held back by climbing plants. However, a number of climbing plants, especially from the legume family (beans/peas) are important food plants for primates and other animals, and care should be taken to leave these intact (e.g. Shabrani et al., 2021).

Another important element of restoration is to maintain ecological connectivity (Brodie et al., 2016; Gilbert-Norton et al., 2010), especially where forest habitats have become fragmented by agricultural and linear infra-structure development (see also climate adaptation below). This may require negotiations for allocation of private land for wildlife corridors (e.g. Cheah et al., 2021).

There is also an important benefit in maintaining or restoring forest buffers along rivers, to reduce sedimentation and chemical run-off from plantations into rivers, and support wildlife populations (Deere et al., 2022). This is a requirement under Department of Irrigation and Drainage, as well as under RSPO certification standards, to maintain riparian reserves and significantly more support and enforcement is needed before this benefit for people and nature can be realised.

4. Mitigate climate change — avoided deforestation

As the scale and impact of both climate change and nature losses becomes more fully understood, so actions for wildlife conservation and climate change mitigation become more closely tied. In Sabah, airborne surveys in the 2010s have confirmed that the forests hold millions of tons of carbon (Asner et al., 2018), as well as substantial 'blue carbon' in the mangroves (Wong et al., 2020), and so 'avoided deforestation' of these wildlife habitats presents a key nature-climate win for climate mitigation. This conforms with the national policy on climate change (2009).

The challenge now is to be able to realise the value of the carbon stocks in the standing forest, which could pay for sustainable forest management costs. However, the current market price of forest carbon is too low to defray the costs of forest management (Phillipson et al., 2020), and many voluntary carbon offset schemes are poorly designed and do not bring lasting climate, nature or people benefits (Sarawak Report, 2022).

To bring together the climate and nature components of sustainable development, **nature-based solutions** (UNEP & IUCN, 2021) have been advocated, which address three intertwined issues: climate change, biodiversity loss and inequitable development (Hacking et al., 2021). These solutions need to be implemented at significant scale, as part of landscape or jurisdictional programmes, and one example in Sabah is the living landscapes approach of WWF-Malaysia being trialled in three of Sabah's eastern landscapes as a contribution to Sabah's Jurisdictional Certification programme.

A video on WWF-Malaysia's Living Landscapes Approach: Protect, Produce, Restore.

5. Adapt for climate change — ensure ecological connectivity

While efforts to limit climate change are urgently needed, climate change impacts are already being felt in Sabah. There is evidence that moths (Chen et al., 2009) and birds (Harris et al., 2012) on Mt. Kinabalu have changed their distribution, and are now found at higher, cooler elevations, and example given of the grave risk of animals getting separated from the main breeding populations (Bernard et al., 2014a; Struebig et al., 2015). In the medium to long term, sea level rise, variable rainfall, increased likelihood of extreme weather events, and rising temperatures are all likely to affect wildlife either directly (Brodie et al., 2017), or indirectly through changes in plant growth and fruit production, or emergence of new pathogens and parasites.

Each species will respond differently, and climate vulnerability assessments need to be made to assess the many options for different species or species groups. From a global review of climate adaptation actions (LeDee et al., 2021), maintaining healthy populations in protected areas is the most common, which gives the best chance for species to adapt to climate impacts. This must be supported by maintaining ecological corridors, to ensure populations could migrate over time to suitable habitats, and not become fragmented and isolated in unsuitable areas.

The policy to establish 30% Totally Protected Areas gives space for healthy wildlife populations to be maintained, and the TPA network needs to minimise fragmentation risks (Williams et al., 2019). The Imbak Canyon 'corridor' is important in this respect, linking the Maliau Basin forests with Danum Valley forests (Figure 9). The most cost-effective way to maintain these ecological corridors is to retain forest cover, even as logged forest, and where this does not happen, then costly forest restoration is needed.

6. Protect species

Hunting

Even if healthy forest ecosystems are retained, hunting and trapping can still eliminate species. For the wildlife trade, each target species requires careful trade assessment, with intelligence gathering on internet sales and supply chains, from consumers to traders to hunters. On the ground, surveillance and patrols are needed to identify wildlife markets and poaching hotspots, with enforcement agencies resourced to uphold the law, and court sentences at appropriate levels to deter this lucrative illegal trade (Baga, 2022).

The management of hunting for local food consumption, whether for villages, plantations or urban centres, needs a different approach to take account of basic needs and long-standing traditional rights. Detailed engagement is needed with communities, Indigenous Peoples, and companies/workers to determine the rights and regulations in a given area. Thereafter Free, Prior and Informed Consent (FPIC) methods should be used to build consensus amongst stakeholders to co-create hunting management plans, as required under the Sabah Biodiversity Enactment.

The challenge is to safeguard protected species while having sustainable levels of off-take for commoner species, under hunting licences. Indeed Bennett et al. (2000) concluded that **local hunting** in Sabah in the mid-1990s was unsustainable. This challenge is particularly acute at the present time because of the decline in Bearded Pigs following the African Swine Fever outbreak, with greater hunting pressure falling on the remaining deer and primate species. This, in turn, draws attention to the need for a review of Schedule II species in

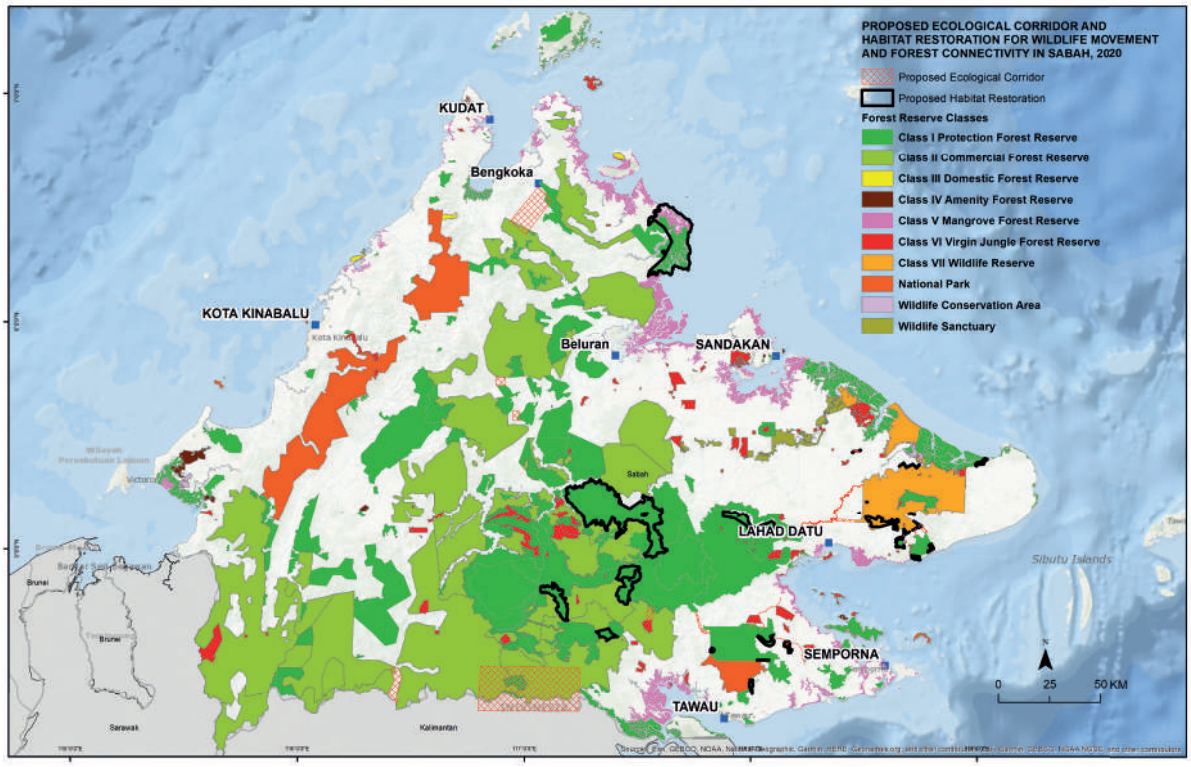


Figure 9. Proposed Ecological Corridor & Habitat Restoration for Wildlife & Forest Connectivity (WWF-Malaysia, 2021)

Sabah's Wildlife Conservation Enactment, for which hunting licences should no longer be issued for rarer species (e.g. leaf monkeys and gibbons).

Agriculture

Another complex issue is the need to reduce oil palm crop damage by elephants. In some cases fencing is necessary, and many large plantations have established effective electric fences to control elephant movements. This approach runs into difficulties, however, where fences block traditional elephant migration routes, or poor fence alignment between neighbouring plantations leaves gaps through which the elephants can pass. More elaborate systems are needed to mitigate Human-Elephant Conflict (HEC), including landscape planning to align fences between neighbours, establishing elephant patrol groups in villages, and promoting co-existence between humans and wildlife. In addition, government and large companies will need to allocate some lands for elephant/ecological corridors.

Large plantation companies can further support wildlife conservation by providing a **'forest shield'** around protected areas that neighbour their plantations (Davies & Tan, 2019). If workers are prohibited from illegal hunting in adjacent protected forests, and the plantation security gates are closed to prevent entry by hunters into the forest, then the forest block is shielded and protected from the main direct threats to its wildlife.

A different issue of human-wildlife co-existence is when villagers or plantations request

larger animals, such as elephants, sun bears and orangutans, to be removed because people are frightened. In cases where neither people nor animals are at risk, there is a need to keep animals in forest patches inter-connected across the agricultural landscape, so that populations can survive in the long term (Oram et al., 2022). If animals are to be moved, however, this raises the issue of where to relocate them, and the need to follow strict translocation guidelines for the safety of wildlife and people (IUCN/SSC, 2013).

Captive breeding and wildlife health

While these conservation actions focus on maintaining habitats and protecting wildlife, some species already have alarming low populations and captive breeding must be considered. Initially this is to prevent the extinction of the species in Sabah, and eventually to allow re-introduction into the wild (see translocation guidelines above). Not all species are equally suited to captive breeding, but for Sabah the Bornean Banteng is a prime candidate for immediate attention, as might be the Straw-headed Bulbul.

Finally, the recent emergence of African Swine Fever in 2020/21, killing hundreds of thousands of domestic swine and wild Bearded Pigs, alerts to the threat of emerging pathogens and parasites. While viral diseases such as COVID-19, with its links to unknown wildlife vectors, are currently receiving much international attention, the risk of disease transmission through movement of domestic and wild animals within Sabah requires high standards of biosecurity. Monitoring wildlife health for these diseases is important to guide policy and action by veterinary services and others, and so too is assessing the impact of agricultural chemicals on wildlife and human health.

7. Develop 'conservation centres' for public engagement

Sepilok Orangutan Rehabilitation Centre was set up by the State government in 1964 to take care of orangutan pets which were confiscated after being kept in appalling conditions in houses and timber camps, often young animals taken from their mothers (MacKinnon, 1971). It was the first 'conservation education centre' in the State where people could see and better understand orangutans, and from this it developed into a major education and tourism centre, with the nearby Bornean Sun Bear Conservation Centre, Rainforest Discovery Centre and a number of 'eco-hotels'. All of these are important in raising awareness about conservation issues and building public and political support for conservation.

The 'conservation centre' model is also found at: Kinabalu Park HQ; Tabin Rainforest Lodge and the BORA centre; Kinabatangan Wildlife Sanctuary with numerous lodges and two research/conservation headquarters (Danau Girang Field Centre and HUTAN); the science/tourism centres in Danum Valley, Maliau Basin and Imbak Canyon Conservation Areas; as well as numerous smaller sites (Sabah Biodiversity Strategy, 2011). Indeed, Sabah's international reputation for ecological science and ecotourism all encourage national pride and political interest in Sabah's natural heritage.

8. Monitor populations

It is remarkable to note how reports from timber and plantation companies, citizen scientists, as well as government, research and conservation groups have informed this Atlas, and it is appropriate to reflect on the knowledge we now have about Sabah's wildlife. Many chapter authors have noted that it is difficult to study wild animals, especially those with cryptic and often nocturnal habits. We need more information to better understand species' ecology and society, and to be able to assess whether populations are increasing, stable or decreasing in the face of threats, or in response to conservation interventions.

Indirect survey methods, such as helicopter surveys for orangutan nests, or transects to count elephant dung, or camera-trap surveys of carnivores and ungulates have all been used to assess wildlife populations. They are relatively cheap, can be used to cover large areas, and clearly indicate the species' presence. They also give rough population estimates that indicate trends over time. As these techniques are used, and new ones such as eDNA screening and acoustic surveys (Ladin et al., 2021; Sethi et al., 2018) are developed, the limits of remote and indirect survey methods caution against making simplistic statements. They need to be verified by more detailed direct studies, such as full-day follows of primate groups, or radio/satellite-collaring of animals to track their daily movements and behaviour, without which the many population figures in this Atlas can only be taken as indicative.

Monitoring the condition of the forest trees (e.g. Hansen et al., 2013), and their forest carbon content (e.g. Asner et al., 2018), and patterns of leaf, flower and fruit production are all additionally important topics to inform our understanding of Sabah's wildlife (e.g. Granados et al., 2019), and to assess whether the conservation actions summarised here are having the desired impact on the ground.

Acknowledgements

Many thanks to Angela Lim for editorial advice, and Diana Anthony, Suzika Juiling and Jane Wong for maps and WAS database records. Henry Chan, Sheelasheena Damian, Benoit Goossens and Glen Reynolds kindly provided peer review comments, and Waidi Sinun and Robert Ong gave summary statistics on Yayasan Sabah's Conservation Areas. For all of which, many thanks.

Data Sources

Hose's Civet

Individuals/organizations (Number of records): Brodie, Jedediah (15); Sabah Forestry Department (4); WWF-Malaysia (4). *Open source database (Number of records):* eMammal (20). *Publications (Number of records):* Nagano et al., 2019 (1); York et al., 2013 (1).



Bornean Elephant © John Japil/WWF-Malaysia

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