THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

Factors shaping the conservation of the critically endangered

Javan Rhinoceros *Rhinoceros sondaicus*

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Master of Environmental Management

A thesis submitted for the degree of Doctor of Philosophy at
The University of Queensland in 2021
School of Biological Sciences

Dedication

This thesis is dedicated to my late brother Stewart 30/04/1965 - 14/10/2019. For ongoing love and support through my thesis journey, you always believed in me, awesome thanks for all the good times and many laughs. I miss you man.

Thesis Abstract

The overall objective of this PhD is to conduct innovative research that contributes to improving the long-term survival of the rare and critically endangered Javan rhino, *Rhinoceros sondaicus*. A single small population of 74 Javan rhinos (October 2020) currently remain globally, all individuals located in a single region on the western tip of Java, Indonesia, in Ujung Kulon National Park. This thesis comprises seven chapters: **Chapter 1** introduces the background and applied context for the thesis within the broader literature on the factors shaping the conservation of the Javan rhino. Understanding local community awareness and the implications for the species' management is critical for the development of future conservation actions for a single population species such as the Javan rhino, as examined in **Chapter 2**. The Ujung Kulon National Park's eastern boundary adjoins agricultural lands and resides in Banten Province, one of Indonesia's most heavily populated regions, which results in continuous human pressure on remaining habitat, wildlife, and protected areas. The eastern edge of the national park is surrounded by 19 villages, each has a traditional dependency on national park resources. During the years 2015 and 2016, I interviewed 76 local villagers, including each of the 19 village leaders and three local community members from each village. Based on identified gaps including community members' limited knowledge of National Park regulations, boundaries and conservation initiatives, key recommendations have been instigated, including establishment of community reference groups in each village to drive consultation with authorities and to influence communities through improved education and awareness of conservation management objectives.

In **Chapter 3,** I aim to examine Javan rhino frontline management to determine the approaches used and attitudes of frontline staff to rhino management and implications for future management. Substantial resources are being invested in Javan rhino management, yet it is very challenging to study and monitor the species in the field, and it is therefore difficult to assess whether past and current management actions are successful. In order to understand frontline management, I interviewed 36 Javan rhino conservation staff, including almost all the rhino protection unit staff and frontline national park staff. Overall, staff perceptions of the current management actions were positive, yet staff raised multiple challenges that remain inherent to the survival of the small persisting rhino population. These included ongoing anthropogenic threats ranging from habitat encroachment from human population growth to transfer of disease from domesticated stock (mainly water buffalo *Bubalus bubalis*).

In **Chapter 4,** I aimed to research the impact of the arenga palm *Arenga obtusifolia* on Javan rhino habitat and foraging. National park and conservation authorities suggest that available Javan rhino habitat is compromised by two major factors, human encroachment, and the dominance of the native arenga palm. Arenga palm now dominates the rainforest canopy in many areas of the park and reduces available rhino foraging by limiting the growth of rhino food plants. To examine the impact of arenga palms on rhino habitat and foraging, arenga palms were manually cleared across 15 x one ha experimental sites by local community members and I monitored these sites over two years (2016 - 2018) for the impact of palm control, plant response and post clearing visitation frequency of rhino. Palm control resulted in increased diversity and abundance of rhino food plants, and rapid visitation to cleared sites by rhinos replacing areas initially covered by monoculture palm. The findings suggest for the first time that rhino habitat manipulation and clearing of arenga palm in selected forest patches is a viable management technique to increase foraging for rhinos.

In **Chapter 5,** I examine the role wallows play in Javan rhino behaviour and ecology. All members of the family Rhinocerotidae have a requirement to wallow in mud or water to protect their skin from sun damage, remove ectoparasites and for thermoregulation. Javan rhino need to wallow regularly throughout the year. Access to wallows is therefore a critical element of Javan rhino habitat. I found, spatially recorded, and analysed the characteristics of 35 wallows in the eastern Gunung Honje section of the park. I analysed 137 remote camera trap videos (recorded between 2011 and 2015) and 255 videos (recorded in 2016) and discovered that wallows are important communication hubs for Javan rhinos. I identified and categorised eight behavioural patterns recorded at and near wallows from 68 videos taken between (2011-2015) in the 30,000ha peninsula area of Ujung Kulon. This increased our knowledge of Javan rhino vocalisation via 55 recordings comprising 157 individual vocalisations taken at and near wallows, identifying seven vocalisation descriptors with accompanying sonograms. The results tested and supported the hypothesis that Javan rhino utilise wallows not only for thermoregulatory function, but also as sites of interaction and communication among rhinos. This understanding of the role of wallows in rhino communication is important towards future reintroduction efforts of rhinos. In **Chapter 6,** I examine the social behaviour and communication of Javan rhino using camera trap videos. Direct observation of Javan rhino is extremely difficult due to its rarity and remote rainforest habitat, consequently our knowledge of its social behaviour and communication remains limited. To increase our understanding, I analysed 392 remote camera trap videos (2011-2016) in this study.

In the final **Chapter 7,** I summarise the findings by chapter of the thesis and discuss them with reference to the literature and the contributions to knowledge. Collectively this work improves the current understanding of the factors shaping the conservation of Javan rhino by increasing awareness of frontline management, knowledge of Javan rhino ecology, social and communication behaviour, and the management of key threats such as the management of the invasive arenga palm.

Declaration by author

This thesis is composed of my original work and contains no material previously published or written by another person except where due reference has been made in the text. I have clearly stated the contribution by others to multi-authored papers that I have included in my thesis. I have clearly stated the contribution of others to my thesis, including statistical assistance, survey design, data analysis, significant technical procedures, professional editorial advice, and any other original research work used or reported in my thesis. The content of my thesis is the result of work I have carried out since the commencement of my research higher degree candidature and does not include a substantial part of work that has been submitted to qualify for the award of any other degree or diploma in any university or other tertiary institution. I have clearly stated which parts of my thesis, if any, have been submitted to qualify for another award.

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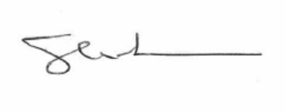

Steven Graham Wilson

Publications during candidature

Peer reviewed papers

Wilson, S.G., Biggs, D. & Kark, S. (2021). Protecting an icon: Javan rhino frontline management and conservation. *Oryx*, August/September 2021.

Wilson, S.G., Hockings, G., Deretic, J.M. & Kark, S. (2020). More than just mud: The importance of wallows to Javan rhino ecology and behaviour. *Pachyderm* Vol. 61, August/September 2020.

Conference abstracts

Wilson, SG, Hockings, G, Wood, JM, & Kark, S. (2018). Understanding an icon: learning the language of Javan rhinoceros. Oral presentation (presented by SW) at the International Eco Acoustics Congress in Brisbane 24th - 28th June 2018.

Publications included in this thesis

1. Wilson, S.G., Biggs, D. & Kark, S. (2021). Protecting an icon: Javan rhino frontline management and conservation. *Oryx*, August/September. Incorporated as **Chapter 3**.

Contributor	Statement of contribution
Author - Steve Wilson (Candidate)	Wrote paper (75%), collected and analysed data (10%)
Author - Duan Biggs	Edited paper (5%) development of survey design (5%)
Author - Salit Kark	Edited and co-designed paper (5%)

2. Wilson, S.G., Hockings, G., Deretic, J.M. & Kark, S. (2020). More than just mud: The importance of wallows to Javan rhino ecology and behaviour. *Pachyderm* Vol. 61, August/September 2020. Incorporated as **Chapter 5**.

Contributor	Statement of contribution
Author - Steve Wilson (Candidate)	Wrote paper (75%), collected and analysed data (10%)
Author - Georgina Hockings	Development of behavioural templates and paper design (5%)
Author - Salit Kark	Edited and co-designed paper (5%)
Author - Joanne Deretic	Sonogram analysis and design (5%)

Contributions by others to the thesis

No contributions by others

Statement of parts of the thesis submitted to qualify for the award of another degree

None

Research involving Human or Animal Subjects

Yes

Human Ethics approval

This research was approved by the University of Queensland Behavioural & Social Sciences Ethical Review Committee (Approval No. 2015000371).

Animal Ethics approval

The University of Queensland Animal Ethics Committee approved this study (AEC No.

ANRFA/SBS/018/15/UKNP/YABI)

Informed consent

The *in-situ* field work, and involvement of participants was approved by the Ujung Kulon National Park Authority and Ministry of Research, Technology and Higher Education, Republic of Indonesia, as part of Steve Wilson's foreign research permit conditions. All participants signed consent forms before contributing.

Acknowledgements

To National Geographic for initial inspiration on the plight of Javan rhino. Hermawam, Head of Section Handeuleum Section 2 (rhino habitat) for *in situ* help and access to his staff when needed, many thanks. Mohamad (Aphuy) Syamsudin UKNP ranger for field staff coordination and spatial mapping expertise, a great friend with good English! Haerudin for bike transport (despite challenges with punctures) in poor road conditions during our community survey work. Usep Suhendar and Hasan Hambali for going all out with survey assistance and taking their bikes on some seriously bad roads to remote villages. Deddy Wardhana (YABI) great assistance in working me through the complexities of Indonesian visas, research permits and KITAS, very much appreciated. Lukman Hakim for picking me up at airports and getting me where I needed to go, many thanks. Dewo, hire car man extraordinaire, big thanks for getting me back and forth to Ujung Kulon, on good and bad roads, amazing driver with uncanny knowledge of Java's road network. Asep Yayus Firdaus and Irma UKNP wildlife monitoring staff for providing usable rhino clips and mapping of wallow sites on the peninsula.

Daryan, field coordinator UKNP rhino monitoring unit, for sharing his passion and knowledge of rhino behaviour, video clips and maps. Patat, UKNP ranger for survey help, many thanks. Samaya and Acep RPU team for survey help. Ujang Sufri, UKNP ranger, great help coordinating surveys and *in situ* assistance. RPU staffers Sartol and Sarkhim, for help in the rain and wet conditions over the journey. UKNP ranger Apud Syaifudim, for assisting with visits to arenga plots and meeting with local wood carver. Agat, Head of Ujung Jaya Legon Pakis (traditional area) for *in situ* assistance, Entus Sutisna and Ugang Sukri, UKNP rangers, for getting me out in canoe on the Cigenter River. Special thanks and acknowledgment to the late Dr Widodo Ramono, Director Indonesian Rhino Foundation (YABI), for letters of support, organisational support, and access to camera trap data, and critical support re gaining approval for research visas and KITAS, and great conversations on the conservation of rhino. Former UKNP Directors Dr Mohi Haryono, Dr Ujang Mamat Rahmat and current Director Anggodo for letters of support, organisational support, and access to camera trap data, very much appreciated. Minggu, Manager Villa Prima Homestay and his family in Taman Jaya, always supportive, for comfy accommodation and tucker over the PhD journey. Mohammad Hanif, Research and Education Officer/IRF Liaison YABI, great friend and help in coordinating on my PhD journey, special thanks. Ja Jaj Sudrajat RPU, for survey assistance. Yoga Herdiana, Database Officer YABI for mapping assistance.

Waladi Isnan, Manager RPU and JRSCA, many thanks for field support and organising, and for good operational conversations and insight. Ayani, Coordinator Habitat JRSCA, great *in-situ* support. Indra Iriana, GIS/Mapping guru, for always being eager to help, many thanks. Thanks to Mangaa (Ma' a'), driver at YABI, coffee and smokes in between the madness of Javan traffic and for getting me where I needed to go. Amila Anggraini and Amila Muraenid, for UKNP permit and research support. Doyok, local guide, great jungle cook for help getting around in the rain! Former Goulburn Broken CMA CEO Chris Norman and Angus Emmott for my initial PhD application support and enthusiasm for my project. Dr Damian Michael ANU for letter of support and encouragement. Professor Hugh Possingham for letters of support and encouragement. Clare Campbell, Director Wildlife Asia, for providing initial contacts in the rhino game which got me started. Dr Marta Pascual, CEED and Ikerbasque Foundation, for social research support and providing relevant papers. Melisa Lewins for assistance re UQ animal ethics approvals. Peter Geddes for all things IT over a long period, thanks Pete. UQ's Gail Walter for consummate admin support over the PhD journey. Vanessa Campbell, special thanks for spatial mapping assistance and interest in my work. Karen Brisbane, for support and always being interested. Simon Casanelia, for spatial mapping expertise and always being interested.

Darelle Backway and Andrea Muskee, computer trouble shooting wiz's, and for always being interested. Kaela McDuffie, big thanks re UQ Animal Ethics assistance. Georgina Hockings UQ Honours student, great conversations, and work on deciphering Javan rhino behaviour from videos. Rubén Venegas, Hernán Cáceres and Eduardo Gallo Cajiao PhD compatriots for UQ IT support and enthusiasm. Dr Simone Blomberg for statistical analysis advice over the PhD journey. Michael Tse, UQ Human Ethics Committee Coordinator, for practical advice and assistance. Kees Rookmaaker, Rhino Resource Centre for assistance and guidance in sourcing information, particularly in the historical space, many thanks. Warmest thanks to the late Professor Colin Groves for his assistance in understanding museum specimens and cataloguing, and for good wishes. Tim Barlow and Rhiannon Sandford, editing prowess and honest feedback, you always made my papers read better, many thanks. Jo Deretic, acoustic expertise and help in developing frequency sonograms of rhino vocalisations, and genuine enthusiasm for my work, special thanks Jo. My UQ Readers Associate Professor Diana Fisher and Professor Kerrie Wilson, many thanks for constructive feedback and support. Heather Christensen, for UQ assistance with travel issues and protocols and having great patience! Big thanks to GB CMA's Vicki Mackenzie for editorial and proofing assistance with my confirmation document.

David Williams, Eco Dev at Tatura, very grateful for discussions and guidance around data analysis and variables. To my great friend Inov Sectionov, Research and Education Officer/IRF Liaison YABI, very important cog in my PhD wheel, eternally grateful for all your help and support, I just couldn't have got there without your help! To my co-supervisors Associate Professor Anne Goldizen and Dr Duan Biggs many thanks for sharing your expertise and expanding my knowledge on all things academic. To Professor Salit Kark, my Principal Supervisor, wonderful support, and guidance over my PhD journey, very fortunate to have you in my corner, much heartfelt thanks. To my wonderful godmother Jenny Burrowes for always trusting I would get there, and for showing interest in whatever I was doing at the time, special thank you. To my family, parents Bill and Jude Pinder and favourite uncle Rob Whitehill for always being interested and supportive. My late brother Stewart, sisters Peta, Jenny, and Cathy for always showing support. To my amazing kids, Coen for joining me on two trips to Java and Sumatra, and Daly and Allira for supporting my PhD efforts and taking the journey with me, I couldn't have got there without you, extreme thanks, you guys were amazing. Special thanks and tribute to my late father Leslie, for imparting the DNA and tools to find a way to expand on my love of nature, heartfelt thanks always. Most importantly, to Tracey, my partner for over 30 years, heartfelt thanks and love for always being there, I couldn't have got there without you, you deserve the most credit and thanks.

Financial support

Self-funded.

Key words

Javan rhino, *Rhinoceros sondaicus*, Ujung Kulon National Park, conservation, local community, frontline management, arenga palm, *Arenga obtusifolia*, wallows.

Australian and New Zealand Standard Research Classifications (ANZSRC)

http://www.abs.gov.au/Ausstats/abs@.nsf/Latestproducts/6BB427AB9696C225CA2574180004463E?opendocument

ANZSRC code: 050202, Conservation and Biodiversity, 80%

ANZSRC code: 050211, Wildlife and Habitat Management, 20%

Fields of Research (FoR) Classification

http://www.abs.gov.au/Ausstats/abs@.nsf/Latestproducts/6BB427AB9696C225CA2574180004463E?opendocument

FoR code: 0502, Conservation and Biodiversity, 80%

FoR code: 0602, Behavioural Ecology, 20%

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List of Acronyms and Abbreviations used in the thesis

AREAS WWF's Asian Rhino and Elephant Action Strategy

ARP Asian Rhino Project

AsRSG Asian Rhinos Specialist Group (under IUNC-SSC)

AfRSG African Rhinos Specialist Group (under IUNC-SSC)

AUD Australian dollar

BBSNP Bukit Barisan Selatan National Park

CBD Convention on Biological Diversity

CBNRM Community-based natural resource management

CEPF Critical Ecosystem Partnership Fund

CITES Convention on Trade in Endangered Species of Fauna and Flora

CTNP Cat Tien National Park

DNPWLM Department of National Parks and Wildlife Management

EU European Union

FFI Fauna and Flora International

GLNP Gunung Leuser National Park

JRSCA Javan Rhino Study and Conservation Area

LIF Leuser International Foundation

MPB Global Management and Propagation Board (Sumatran rhinos)

IDR Indonesian Rupiah

IPB Institut Pertanian Bogor

IPZs Intensive Protection Zones

IRIS Indonesian Rhino Information System

IRF International Rhino Foundation

IRV Indian Rhino Vision

IUCN-SSC International Union for Conservation of Nature (The World Conservation Union)-Species Survival Commission

JRSCA Javan Rhino Conservation Study Area

KSNP Kerinci Seblat National Park

KTP Kgalagadi Transfrontier Park

LIPI Lembaga Ilmu Pengetahuan Indonesia

NGO Non-Governmental Organization

NP National Park (e.g. Bukit Barisan Selatan)

NTFP Non-Timber Forest Products

MoF Indonesian Ministry of Forestry

MoU Memorandum of Understanding

MPU Marine Protection Unit

PHKA Perlindungan Hutan dan Konservasi Alam (Directorate General of Forest Protection and Nature Conservation of the Ministry of Forestry)

PKBI Program Konservasi Badak Indonesia (Indonesian Rhino Conservation Program)

KZN KwaZulu-Natal

PKBA Perlindungan Hutan dan Konservasi Alam (Directorate General of Forest Protection and Nature Conservation of the Ministry of Forestry)

PKBI Program Konservasi Badak Indonesia (Indonesia Rhino Conservation program)

RCO Rhino Conservation Officer

RPU Rhino Protection Unit

RTF Rhino Task Force

SADC Southern African Development Community

SDIs Spatial Development Initiatives

STCP Sumatran Tiger Conservation Program

SPU Sea Protection Unit

SVC Savé Valley Conservancy

TBNRM Transboundary natural resource management

TFCA's Transfrontier Conservation Areas

UKNP Ujung Kulon National Park

UNEP United Nations Environmental Program

UNESCO United Nations Educational Scientific Cultural Organisation

UNICEF United Nations International Children's Emergency Fund

USD United States Dollar

USFWS-RTCF US Fish and Wildlife Service's Rhino and Tiger Conservation Fund

WCS Wildlife Conservation Society

WI Wetland International

WKNP Way Kambas National Park

WTTC World Travel and Tourism Council

WWF Worldwide Fund for Nature

YABI Rhino Foundation of Indonesia

YMR Yayasan Mitra Rhino (Indonesian Rhino Foundation)

Chapter 1 Introduction

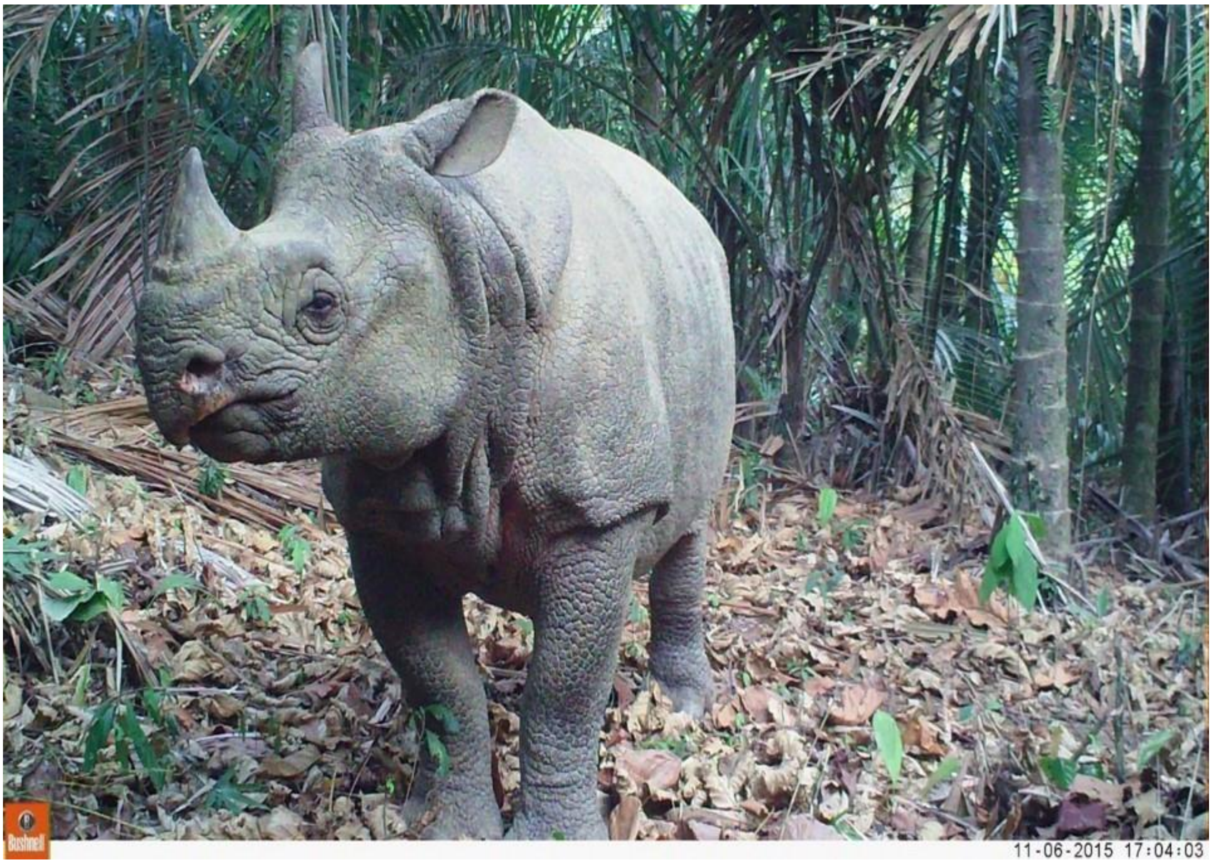

Figure 1.1: Male Javan rhino *Rhinoceros sondaicus* captured moving on camera trap in 2015, in Ujung Kulon National Park, West Java, Indonesia (Image: Courtesy Ujung Kulon National Park Authority).

1.1 Background to the research problem

There is evidence suggesting that the sixth mass extinction in the history of Earth is currently occurring (Myers 1990; Leakey & Lewin 1992; May et al. 1995; Wake & Vredenburg 2008; Barnosky et al. 2011; Ceballos et al. 2017). Unlike the distant past mass extinction events near the end of the Ordovician, Devonian, Permian, Triassic, and Cretaceous Periods (Raup & Sepkoski 1982; Jablonski 1994), this current event is different in its causes, character, and rates of extinction, largely resulting from anthropogenic drivers (Verdaasdonk 2018; Pálinkás 2018). Globally, species are now going extinct ~100 times faster than background extinctions before humanity due to combined pressures and threats such as global climate changes, human population pressures, urbanisation, hunting and poaching, fragmentation of habitats, the introduction and spread of exotic species and pathogens and other factors (Estes et al. 2011; Barnosky et al. 2011; Ceballos et al. 2015; Pálinkás 2018).

Despite 15% of the Earth's terrestrial areas and 7% of the ocean's surface in total being declared as protected areas (UNEP-WCMC & IUCN 2016) significant gaps remain in the effective protection of biodiversity around the world (Rodrigues et al. 2004; Johnson et al. 2017; Pálinkás 2018), with existing protected areas varying in their resilience and ability to protect biodiversity and prevent extinction events (Le Saout et al. 2013; Knapp et al. 2017). The global trade and illegal trade of wildlife and wildlife products business alone is currently worth $10-20 billion USD (UNODC 2014; WWF 2016). The global demand for productive land continues to be at odds with environmental protection requirements (Sayer et al. 2013) often causing conservation disputes (Redpath et al. 2012).

The United Nations Food and Agricultural Organisation estimates that it will require at least a 70% increase in food production to feed a projected human population of 9.1 billion people in 2050 (United Nations Food and Agriculture Organisation 2009). Globally, despite ongoing attempts to meet the needs of both human population and nature conservation objectives many challenges remain (Godfray 2010; Barrett 2010; Balmford et al. 2012; Pálinkás 2018). For example, the overall conservation status of the world's mammal species continues to deteriorate, due to threats such as habitat decline and loss and continued overexploitation (Hoffmann et al. 2011; Ripple et al. 2016). In addition to reducing population numbers and abundances of various species, threats such as poaching and habitat loss compounded by diverse and unique ecological traits of some species have reduced the current ranges of many species from their historical extents (Ceballos & Ehrlich, 2002, 2009; Morrison et al. 2007; Fisher 2011).

According to the International Union of Conservation of Nature (IUCN), 44 of the 74 largest terrestrial herbivores (>100 kg) are threatened with extinction (including 12 critically endangered or extinct in the wild), and 43 have declining populations (IUCN 2016). The majority of the large threatened terrestrial herbivores are found in developing countries, the exception being European bison or Wisent *Bison bonasus* (Sandom et al. 2015). The loss of large herbivores creates a trophic cascade, causing negative impacts across a broad spectrum of species, including apex carnivores, scavengers, small herbivores, and small mammals, with consequent impacts on ecological system processes such as aspects of vegetation, hydrology, nutrient cycling, and fire regimes (Ripple et al. 2015, 2016).

1.2 Drivers of terrestrial mammal declines

A review of the Class Mammalia by Hoffman et al (2011) recognised 5,487 extant species. Despite this diversity, the overall conservation status of the world's mammal species continues to decline with an estimated one-fifth of mammals threated with extinction (Ripple et al. 2015, 2016). Over 60% of the world's largest carnivores and largest mega-herbivores area threatened with extinction (Ripple et al. 2015, 2016). Globally, it is estimated that at least 60% of primate species are threatened with extinction and 75% have deceasing populations (Estrada et al. 2017). Mega-herbivore species, such as the Javan rhino *Rhinoceros sondaicus* (Figure. 1.1) and the Sumatran rhino *Dicerorhinus sumatrensis*, now both number under 100 animals each (Emslie et al. 2019).

1.2.1 Hunting and poaching

Across Southeast Asia, humans have been hunting wildlife for at least 40,000 years (Zuraina 1982; Milner-Gulland et al. 2003). In modern times, hunting intensity has increased with rising human population densities and declining forested landscapes across the Asian region (Sodhi et al. 2004; Velho et al. 2012). For example, the first 90 years of British colonial rule in India instigated a system of rewards and bounties, driving a strong desire to hunt wildlife (Velho et al. 2012). Over 80,000 tigers *Panthera tigris* were hunted and killed during the period 1875 to 1925, averaging over 15/week for 50 years (Rangarjan 2001). In recent times, the hunting of low-density populations of large mammalian fauna is likely to have a negative impact on population dynamics and long-term viability (Bodmer et al. 1997; Velho et al. 2012). Excessive overhunting for wild bush meat across the developing world is becoming a critical factor in the decline of the largest terrestrial herbivores (Milner-Gulland & Bennett 2003; Craigie et al. 2010; Lindsey et al. 2013; Brasheres et al. 2014).

The global trend of increased wealth, especially in the Middle East, Russia, and China (Dubois & Laurent 1998; Guriev & Rachinsky 2009; Duffy 2016), is expected to drive interest in many forms of hunting and increase demand for animal products such as rhino horn or tiger body parts. However, hunting, when managed properly, can generate substantial income that, at least in part, is directed towards conservation of target species and their habitats (Lewis & Alpert 1997; Leader-Williams 2009). For example, in Southern Africa, the development and shift of agricultural land to natural habitat for private game ranches has positively impacted the recovery of white *Ceratotherium simum* and black rhino *Diceros bicornis* numbers (Leader-Williams et al. 2005; Cousins et al. 2008; Lindsey et al. 2009). In the modern era, ongoing human population growth, consequent demand and rising GDP are related with significant growth in commercialised bushmeat hunting relative to subsistence hunting across many parts of the world (Estrada et al. 2017).

1.2.2 Human population growth and land-use change

Rapid human population growth poses an ongoing threat to remaining wildlife populations (Dinerstein 2011). For example, in Asia, the preferred habitat of Javan rhino *Rhinoceros sondaicus* and Sumatran rhino *Dicerorhinus sumatrensis* is lowland rainforest, critical rhino habitat now being converted to oil palm and rubber plantations (Dinerstein 2011). Greater one-horned rhino *Rhinoceros unicornis* thrive in fertile floodplains, which are also prime human development sites for agriculture, logging, and intensive cultivation (Dinerstein 2003, 2011). This rapid development has been supported by the expansion of agricultural land, corresponding rises in livestock numbers, causing increased isolation of protected and conservation areas and consequent decreasing wildlife populations (Hackel 1998; Ripple et al. 2016; Pálinkás 2018). This situation is further exacerbated by threats such as logging, through creation of access roads, improved hunting equipment and ineffective or inadequate wildlife protection (Ling et al. 2002; Smith et al. 2003; Pálinkás 2018). Global market demand increases for nonarboreal (e.g., rice, sugar cane, and soybeans) and arboreal crops (e.g., natural rubber and oil-palm), livestock (e.g., cattle), and tropical hardwood timber has driven broad-scale industry-supported deforestation across mainland Africa, Central and South America, Madagascar, and Asia (Laurance et al. 2014). The globalization of financial markets and worldwide commodity boom has driven the ongoing demand for tropical timber and expansion of industrial logging, driving deforestation and the economic imperative to expand road building in forested areas (Malhi et al. 2014). Habitat fragmentation exacerbates the effects of hunting by allowing hunters access to former remote areas and reduces the options for population growth of hunted species should hunting ever be brought under control

(Brook et al. 2014). Across Asia, large terrestrial mammal populations such as elephant and rhino are often exposed, because these habitats are under major pressure from conversion to agricultural activities and oil-palm plantations (Wikramanayake et al. 2002; Ripple et al. 2015, 2016; Meijaard et al. 2018).

1.2.3 Mammal species decline and Allee effects

Allee effects have impact on many flora and fauna species (Nardelli 2014). For example, individual reproduction and survival can be compromised in small populations through issues such as access to or mate shortage (reproductive isolation), or lack of conspecific cooperation (Nardelli 2014; Payne & Yoganand 2017). Often, the value humans attribute to the rarity of a species that can drive higher demand, can, for example increase poaching pressure and rapidly drive a species towards extinction, can be termed an anthropogenic allee effect (Courchamp et al. 2006; Harris et al. 2013). The anthropogenic allee effect often causes negative growth rates at low densities, driving populations to even lower densities, leading to an extinction spiral (Nardelli 2014). In small, scattered, and isolated populations, it is only a matter of time before the average mortality rate exceeds the annual birth rate, and before the population goes extinct (Ahmad et al. 2014). The Sumatran rhino is a prime example of a species impacted by small populations and anthropogenic Allee effect. Unusually, and unlike other rhino species, female Sumatran rhino ovulate only if induced by males (Roth et al. 1998; Roth 1999). In fragmented or heavily hunted habitat, reproduction events fail to occur when the population becomes so low and isolated (reproductive isolation) that both sexes are unable to meet, contributing to impaired reproductive pathology such as tumours of the uterus and low or reduced sperm activity (Hermes et al. 2006; Agil et al. 2008; Payne & Yoganand 2017).

1.3 Rhino taxonomy and distribution

All rhinos belong to the mammalian order Perissodactyla (derived from the Greek words *perissos*, of numbers odd and *daktulos*, a finger or toe) (Dinerstein 2003). The family Rhinocerotidae is included in the order Perissodactyla, together with the Tapiridae (tapirs) and Equidae (horses and asses) (Tougard et al. 2001). The Tapiridae are represented in one genus (*Tapirus*) with four species found in Central and South America and one in southeast Asia, whereas Equidae is represented in one genus (*Equus*) with six species distributed throughout the world (Wilson and Reeder 1993, 2005). In 2013, an additional new species was added to the 17-living species of Perissodactyls, with the discovery and description of a new species of tapir, from southern Columbia and Brazil, the Kabomani tapir *Tapirus kabomani*, and one of the largest terrestrial mammals to be newly described, and the only new Perissodactyla in over 100 years (Cozzuol et al. 2013). Local indigenous people undoubtedly maintained knowledge of the newly described species, suggesting a role for Traditional Ecological Knowledge (TEK) in understanding the broader biodiversity of the region (Cozzuol et al. 2013). Modern perissodactyls are medium to mega-sized herbivores, ranging in size from the smallest equids (weighing 200kg) to the largest rhinos (3,500kg) (Nowak 1991).

Perissodactyls are united as a mammalian order by their limb and skeletal structure, and their body weight is borne by the large central digit (Nowak 1991). The Equidae (horses and asses) have a single functional toe on each foot (the third digit), while the Rhinocerotidae have three distinctive toes per foot. The Tapiridae, considered the closest to the ancestral perissodactyl form possess four toes on the forefeet (Nowak & Paradiso 1983). Perissodactyls move about on their hooves or digits, never on the sole with the heel touching the ground; the ulna and radius are reduced, which has simplified the wrist and ankle joints (Nowak & Paradiso 1983). The rhino families' characteristic and distinctive horns are present on the frontal bones of all living species of the Rhinocerotidae, are dermal in origin and retain no bony core as in the artiodactyls (e.g., antelopes, deer and bovids) (Norman & Ashley 2000). The five living rhino species belong to the order Perissodactyla, suborder Ceratomorpha, family Rhinocerotidae and the two sub-families Rhinocerotinae, for *Dicerorhinus* and *Rhinoceros*; and Dicerotinae, for *Diceros*, and *Ceratotherium* (Nowak & Paradiso 1983). Living rhino species have 82 chromosomes, the exception being black rhino with 84, which are amongst the highest for mammals (Dinerstein 2011).

1.3.1 The Family Rhinocerotidae

The family Rhinocerotidae is a small group of mega-herbivorous mammals that has suffered significant reductions in distribution, range, and numbers (Dinerstein 2011). The family Rhinocerotidae have three-toed hooves, a key characteristic of the odd-toed ungulate mammalian order Perissodactyla. Living rhino consist of four genera *Dicerorhinus*, *Rhinoceros*, *Ceratotherium* and *Diceros*, of which only the latter two occur in Africa (Owen-Smith 1992). The five extant species include the Black rhino *Diceros bicornis* (Figure 1.2), White rhino *Ceratotherium simum* (Figure 1.3), Greater one-horned rhino *Rhinoceros unicornis* (Figure 1.4), Sumatran rhino *Dicerorhinus sumatrensis* (Figure 1.5) and Javan or lesser one-horned rhino *Rhinoceros sondaicus* (Figure 1.6) (Nowak & Paradiso 1983; Wilson & Reeder 2005; Grubb 2005) (Table 1). All species are listed on the Convention on Trade of Endangered Species (CITES) Appendix 1, with three listed as critically endangered (*D. bicornis*, *D. sumatrensis*, *R. sondaicus*) one as vulnerable (*R. unicornis*) and one as near threatened (*C. simum*) on the *IUCN Red list* (IUCN 2016) (Table 1). A revision on the taxonomy of all groups of ungulates was recently published by Colin Groves and Peter Grubb (Rookmaaker 2011). There are currently two views regarding the number of black rhino subspecies. Groves & Grubb (2011) recognise eight subspecies; and Emslie and Brooks (1999) recognise four subspecies. For the purposes of this thesis, Emslie & Brooks (1999) descriptions have been used. Of the four black rhino subspecies, three extant subspecies remain, *D. b. bicornis, D. b. longipes* now extinct, *D. b. michaeli*, and *D. b. minor* (Goddard 1967, 1968; Foose et al. 1993; Groves 1967; Emslie & Brooks 1999) (Table 1). White rhino includes two subspecies, southern white rhino *C. s. simum* and northern white rhino *C. s. cottoni* (Nowak & Paradiso 1983). The northern white rhino (recently proposed as a separate species *C. cottoni*; Groves et al. 2010) became extinct in the wild in 2008 (Emslie 2020); in 2009 four aged captive animals were transported to a Kenyan conservancy (Leader-Williams 2013), the last hope for its survival. As of April 2018 only two animals, both non-reproductive females remain, the last male died on March 19, 2018 (Anonymous 2018). With their large body mass and ability to thrive on a low-quality vegetation diet, rhinos have persisted over extended evolutionary periods, making them amongst the most biologically successful of the mammals (Dinerstein 2011).

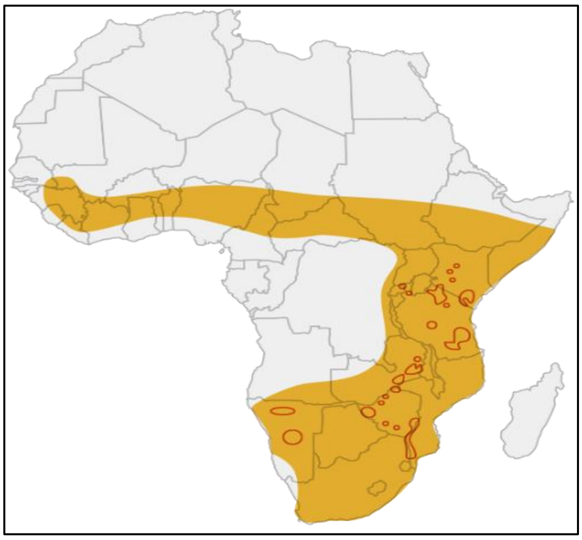

Figure 1.2: Map of black rhino's *Diceros bicornis* historic distribution range (shaded) historic and current distribution (red). Source: IUCN 2016.

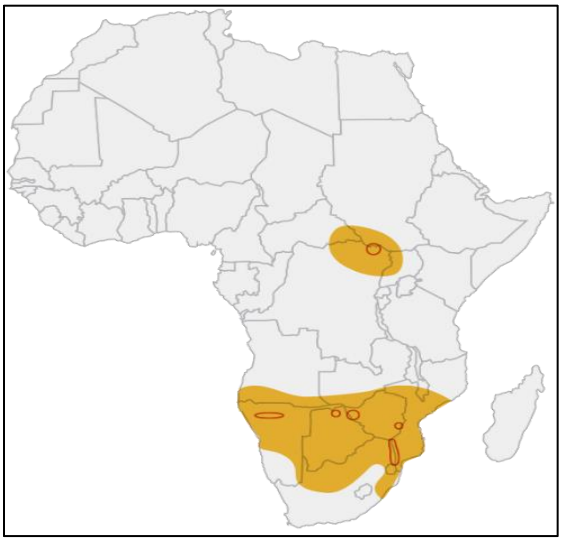

Figure 1.3: Map of southern and northern white rhino's *Ceratotherium simum* (shaded) and current distribution range (red). Source: IUCN 2016.

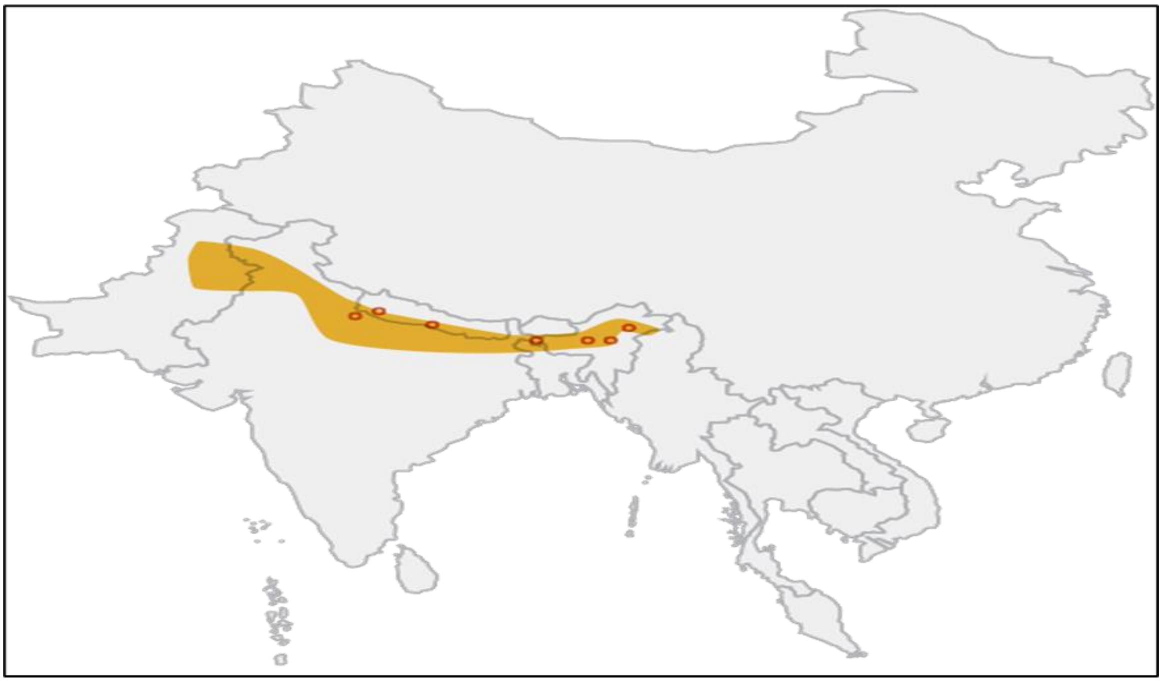

Figure 1.4: Map of greater one-horned rhino *Rhinoceros unicornis* historic (shaded) and current distribution range (red). Source: IUCN 2016.

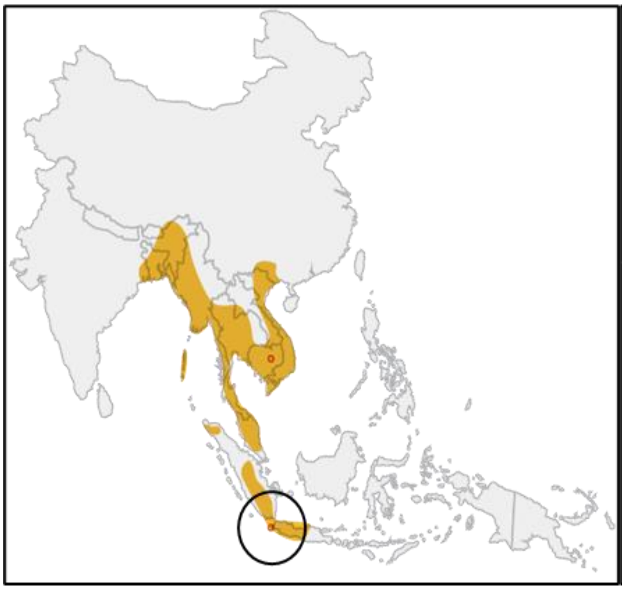

Figure 1.5: Map of the Javan rhino *Rhinoceros sondaicus* historic (shaded) and current distribution range (red dot). Source: IUCN 2016.

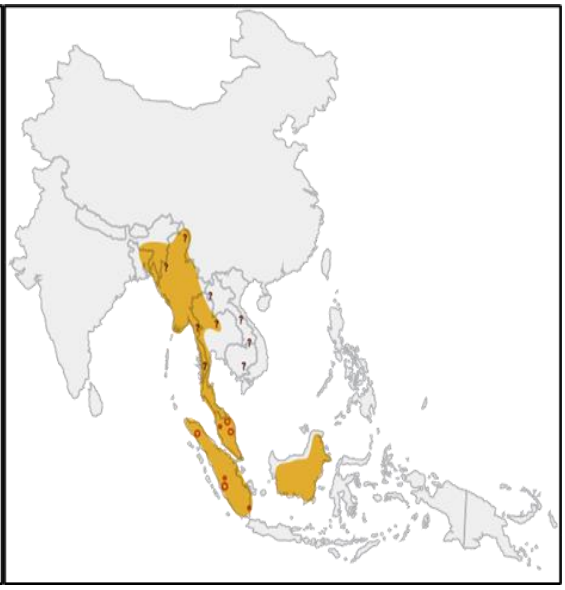

Figure 1.6: Map of the Sumatran rhino *Dicerorhinus sumatrensis* historic (shaded) and current distribution range (red). Source: IUCN 2016.

Table 1 Current distribution range, broad description, and present status of the five extant rhino species († denotes extinct).

Species	White rhino *Ceratotherium simum*	Black rhino *Diceros bicornis*	Greater one-horned rhino *Rhinoceros unicornis*	Sumatran rhino *Dicerorhinus sumatrensis*	Javan rhino *Rhinoceros sondaicus*
Sub-species	*Ceratotherium s. cottoni* (northern white)	*Diceros b. bicornis* (south western), *D. bicornis michaeli* (eastern), *Diceros b. minor* (southern-central), *Diceros b. longipes*†	Monotypic	*Dicerorhinus s. sumatrensis* *Dicerorhinus s. harrissoni* *Dicerorhinus s. lasiotis*†	*Rhinoceros s. annamiticus* † *Rhinoceros s. sondaicus* *Rhinoceros s. inermis* †
Population size	17,212-18,915	5,366-5,627	3,588	40-78	74
Current distribution	South Africa, Namibia, Botswana, Kenya, Mozambique, Zimbabwe, Swaziland, Uganda, Zambia	South Africa Namibia Botswana Kenya Tanzania Mozambique Zimbabwe Malawi Angola, Zambia, Swaziland	Nepal India	Indonesia. Sumatra (3 x protected areas only), Kalimantan (few animals)	West Java, Indonesia, only in Ujung Kulon National Park,
Body height (m)	1.5-1.8	1.4-1.7	1.7-2	1-1.5	1.5-1.7
Weight (kg)	1800-2700	800-1300	1800-2300	600-700	900-2000
IUCN Red List Status (2016)	Near Threatened	Critically Endangered	Vulnerable	Critically Endangered	Critically Endangered

Sources used: Dinerstein 2011; Brook et al. 2014; Haryono et al. 2015, 2016; IUCN 2016; AfRSG & AsRSG 2016; International Rhino Foundation 2016; Emslie et al. 2019; Gokkon 2020.

1.4 Factors shaping Asian and African rhino declines

1.4.1 Poaching for Rhino horn trade

The trade in rhino horns has been traced back as far as 2600BC (Nowell et al. 1992; Rabinowitz 1995). Across tropical Asia, rhinos have been hunted for thousands of years (Brook et al. 2014). Over 1,000 years ago, the trade was well established and during the mid to late 1800's, traditional medical demand for rhino horn escalated across China, resulting in increased hunting pressure on wild populations effectively reducing all three Asian species from most of their former ranges (Loch 1937; Hubback 1939; Harper 1945; Groves & Leslie Jr 2011; Payne & Yoganand 2017).

Globally, the trade in rhino horn has traditionally focused on two main market areas; the first is carved rhino horn handles for *jambiya* (traditional daggers) carried by Yemeni men as a sign of social stating (Ayling 2012). In 1982, the importation of rhino horn was banned in Yemen, which unusually has seen a steady reduction in demand due to the use of culturally acceptable substitutes, meaning Yemen is no longer a major consumer country for illegal rhino horn trade (Cota-Larson 2010; TRAFFIC 2011). However, Vigne & Martin (2008) report a small but persistent demand remains for rhino horn *jambiyas* (traditional daggers) among northern tribesman and more affluent young Yemeni men.

The second and largest rhino horn market globally is in SE Asia. Traditionally, in Chinese medicine, rhino horn is ground into powder and consumed orally (Ayling 2012). Users argue its use as having curative properties with abilities ranging from fever reduction, hangover relief, rheumatism, gout, and stroke (Milliken & Shaw 2012). In modern times a growing misconception that rhino horn can cure cancer has increased demand in Vietnam (Ayling 2012). Since 2003, Vietnam has become the world's leading importer of legal trophies and illegal rhino horns from South Africa (Milliken & Shaw 2012). Increasing economic prosperity has allowed Vietnamese people to afford high-value wildlife products (Nowell 2012a) and rhino horn's rarity builds a powerful status value and prestige within traditional Asian gifting culture (Milliken & Shaw 2012). Driven by growing affluence during the 1970's across many parts of Asia and the Middle East increased the demand for rhino horn (Rabinowitz 1995; Duffy 2016). Rising rhino horn prices encouraged a surge in rhino hunting, and consequently during the period 1970-1987; an estimated 85% of the world's remaining rhino population was lost (Fitzgerald 1989). The CITES ban on the trade of rhino horn has been in place since 1977, where demand can only be met through the illegal market, which is supported and driven by the poaching of rhinos for their horns (Leader-Williams 1992). Despite the trade ban, poaching continues to rise. High poaching levels are driven by the significant growth in the retail price of horn, from an estimated USD $4,700 per kg in 1993 (Loh & Loh 1994) to a high of around USD $65,000 per kg in 2012 (Marshall 2012). On today's black-market rhino horn is selling for an estimated USD $25,000 per kg (Stoner et al. 2017). Both white and black rhino have two horns (Aucoin & Deetlefs 2018). White rhinos have between 3-6kg of rhino horn, black rhino between 1.5-3kg (Moneron et al. 2017). Ongoing illegal demand for rhino horn has driven increased pressure from conservation agencies, especially in South Africa, which has seen an upward trend in poaching, for consideration of a well-managed regulated legal trade based on using appropriate renewable harvesting methods of horn from live white rhinos (Biggs et al. 2013). In contrast to Yemen, driven by rising wealth and increasing affluence in Asia, particularly China and Vietnam, demand for rhino horn has spiked (Cota-Larson 2010; Milliken & Shaw 2012; Carmignani 2015; Duffy 2016).

Supporting this rhino horn demand, poachers, often in mobile, highly organised, well-armed and resourced gangs have targeted rhinos across Africa (Milliken & Shaw 2012; Ayling 2012). For example, between 2006 and 2017, at least 8,355 black and white rhinos were poached in Africa, with the majority in South Africa (Carmignani 2015; Dean 2018; Knight 2018). This continuing illegal trade has driven different applications of rhino conservation and protective approaches which authorities and partner organisations must resource, implement, and enforce. Historic rhino population estimates are at best educated speculations. For example, in Africa accurate rhino population recording didn't commence until 1980 (Emslie & Brooks 1999). It is quite feasible that both Asian and African rhino taxa could have once numbered in the hundreds of thousands, possibly millions. In 1970, an estimated 65,000 black rhino remained across Africa (Leader-Williams 2013). During the period 1970 to 1992, excessive poaching saw black rhino numbers drop to 2,300 animals (IRF 2015; IUCN 2016). Today, Africa's black and white rhinos continue to be protected mainly by four range States, South Africa, Namibia, Kenya, and Zimbabwe with 2017 totals of white rhino (17,212-18,915) and black rhino (5,366-5,627) (Emslie et al. 2019). Current estimates for the Asian species are Sumatran (40-78), Javan (74), and greater one-horned (3,588) (Emslie et al. 2019; Gokkon 2020) (Table 1).

1.4.2 Rhino reproduction and recruitment challenges

Compared to the recovery of other rhino species, the trajectory for Sumatran and Javan rhino has been their persistent low populations which by the 1930's were in rapid decline across all range countries and spiralling down the extinction path (Payne & Yoganand 2017).
Many female Sumatran rhino suffer from compromised reproductive pathology (Payne & Yoganand 2017), most likely exacerbated by reproductive isolation from lack of access to potential mates and pregnancy. Nearly half of female Sumatran rhinos captured between 1984 and 1995 suffered the condition (Schaffer et al. 2001). The phenomenon is associated and afflicts many mammalian families, where either a lack of breeding or ability to complete pregnancies to full term causes the condition, which significantly affects rhinos (Hermes et al. 2006). The lack of breeding success across the few remaining Sumatran populations is clearly at crisis point and the consolidation of all small, isolated populations into one management unit, supported by intensive captive breeding and rapid introduction of advanced reproductive technology appears the only way forward (IRF 2015; IUCN 2016; Payne & Yoganand 2017).

The single remaining Javan rhino population is stable (74 animals) (Gokkon 2020) and breeding but remains at risk of from several threats ranging from outbreaks of poaching, disease risk from domestic stock to a major tsunami (Haryono et al. 2015; Setiawan et al. 2017). The establishment of a second population would free up habitat, food resources and promote breeding in the current population (Emslie et al. 2019). With ongoing political will, protection and resourcing greater one-horned rhino numbers continue to trend upwards across India (2,939+) and Nepal (649+) (Emslie et al. 2019). For both African species, ongoing biological management of remaining populations is essential for the maintenance of and to increase rhino reproductive capability in the face of continued high poaching rates (Emslie et al. 2019).

1.4.3 Rhino protection and conservation initiatives

Over the past 150 years, the establishment of protected areas has been the main approach to support wild populations in habitat. In recent times the focus on many Asian rhino populations has been to reduce the threat of poaching through the instigation and use of rhino patrol or rhino protection units (RPUs), and, since the late 1990's has been effective in reducing and detecting poaching threats (Payne & Yoganand 2017). Across Africa, in addition to protected areas the large-scale conversion of domestic livestock ranches to focused wildlife and game ranches (due to legislative change and availability of excess animals from protected areas to private owners) has benefitted many species (Cousins et al.

2008). Rhino conservancies are another conservation approach used across Africa. Conservancies are typically fenced off areas of land (up to 1000 km^2) but can be larger and encompass a collective of private properties with security provided by the landowners (Hall-Martin & Knight 1994). In recent years, the rise of militarized conservation has expanded across Africa and to other parts of the world (Duffy 2014). Conservation agencies and private landowners acknowledged the rising threat to wildlife, including rhino from well organised and highly equipped poaching gangs, which warranted a coordinated response (Duffy et al. 2013).

1.5 Background to the conservation of Javan rhino

1.5.1 Conservation status of the Javan rhino

The critically endangered Javan or lesser one-horned rhino is one of the world's rarest endangered species (IUCN 2016). The Javan rhino formerly occurred from north-eastern India, Bangladesh, Myanmar, Thailand, Lao PDR, Cambodia, Vietnam, through Peninsula Malaysia to Sumatra and Java and probably southern China (Rookmaaker 1980; Grubb 2005). An accurate picture of Javan rhino historical range remains unclear, as early historic records often failed to distinguish rhino to species level, and the Javan rhino exhibited to partial sympatry with the other Asian species, the greater one-horned and Sumatran rhino (Rookmaaker 1980). A Javan rhino of the subspecies *annamiticus* formerly occurred in Vietnam, Lao PDR, and Cambodia (Nowak & Paradiso 1983).

A small, isolated population was discovered in 1990 in South Vietnam (Schaller et al. 1990). These remaining animals were restricted to the area in and around the Cat Loc (Dong Nai province) region near Cat Tien National Park in Vietnam (Schenkel & Schenkel-Hulliger 1969a, 1969b). In spite of protective measures, the Javan rhino subspecies *annamiticus* was declared extinct in Vietnam in 2010 (IRF 2011; WWF 2012), leaving the Ujung Kulon National Park population of Javan rhino subspecies *sondaicus* in West Java, Indonesia as the only remaining population of the species (Haryono et al. 2015). The Ujung Kulon population has been subject to many population trends since the early 1900's (Figure 1.7). Investigations into locating other potential habitat sites for Javan rhino have been ongoing (Ramono et al. 2009; Nardelli 2016), with an aim of increasing numbers and securing a buffer around existing habitat and rhino populations. The Indonesian Rhino Conservation Action Plan (Indonesian Ministry of Forestry 2007) has set a goal of "creating conditions conducive to, and then actually developing, and increasing viable populations of Javan rhinos in the wild."

The aim of the action plan is to increase the current wild population by 20% and relocate small groups to other suitable areas (Ellis 2010).

1.5.2 Javan rhino ecology and behaviour

Due to its isolation, rarity and protected status, our knowledge of Javan rhino ecology, biology and behaviour has remained limited (Rookmaaker 1980). The Javan rhino is a solitary, mobile generalist browser that uses its bulk and reach to move foliage into its reach (Schenkel and Schenkel-Hulliger 1969a; Hoogerwerf 1970; Ammann 1985; Santiapillai et al. 1993a, 1993b; Ramono et al. 2009). Its preferred habitat is open or tree-fall areas containing primary lowland and secondary evergreen rainforest (Ammann 1985). Javan rhinos prefer to eat the leaves, shoots, and twigs of woody species, with little to no known consumption of grass or herbaceous species (Sody 1959; Schenkel & Schenkel-Hulliger 1969a; Hoogerwerf 1970; Ammann 1985; Santiapillai et al. 1993a, 1993b). Early studies by Hoogerwerf (1970) suggested Javan rhino are highly dependent on the shrub and sapling layers found in secondary vegetation.

The highest densities of Javan rhino are found in coastal areas (Setiawan et al. 2017), where it is presumed most of its mineral requirements are provided through the consumption of salt-sprayed vegetation, halophytic plants (e.g., mangroves) or by drinking sea or brackish water which has been observed (Ammann 1985). Male rhinos are generally solitary and separate themselves spatially and temporally through olfactory communication using dung and urine to convey scent signals (Schenkel & Schenkel-Hulliger 1969a, 1969b). Several habitat assessment and utilisation studies have been undertaken since the late 1960’s (Schenkel & Schenkel-Hulliger 1969a, 1969b; Hoogerwerf 1970; Schenkel et al. 1978; Sadjudin 1984; Ammann 1985; Hommel 1987; Haryono 1996; Muntasib 2002; Rahmat 2007; Ramono et al. 2009; Chandradewi 2011).

1.5.3 Importance of wallows to Javan rhino behaviour and communication

Wallowing, the immersion of the body in water or in mud, is a widespread behaviour among large mammalian herbivores (Owen-Smith 1988). The core function of wallowing is for heat regulation (Dinerstein 2003, 2011). Other reasons for wallowing include reduction of sun damage (Sody 1959; Varada & Alessa 2014), removal of ectoparasites (Hoogerwerf 1970; Owen-Smith 1973, 1975), skin conditioning (Ammann 1985), and olfactory advertisement by impregnating the skin with the urine-rich mud or water of the wallow (Schenkel & Schenkel-Hulliger 1969a, 1969b). Javan rhino in Ujung Kulon National Park regularly use wallows that are often well concealed by rainforest vegetation (Ammann 1985).

In dry periods, to reduce heat stress Javan rhino will use tidal waterways, muddy wallows, and riverbanks (Ramono et al. 2009).

1.5.4 Sympatry with other species and predation

The interspecific interactions of Javan rhino with other species are not well understood (Groves & Leslie, Jr. 2011). Javan rhino in Ujung Kulon are sympatric with other large herbivores such as Javan banteng *Bos j. javanicus*, barking deer or muntjac *Muntiacus m. muntjak*, Javan deer *Rusa timorensis russa* and Javan wild pig *Sus scrofa vittatus*. These are potential competitors for forage and space (Haryono et al. 2015). Both the Bali tiger *Panthera tigris balica* and Javan tiger *P. t. sondaica* were declared extinct within the last 50 and 20 years, respectively (Seidensticker 1987; Nowell & Jackson 1996; Sunquist & Sunquist 2009). The extinction of an apex predator from an ecosystem is significant (Brook et al. 2008), the consequent changes to trophic levels may cause unknown effects that have implications for many of the endangered species in Ujung Kulon National Park including Javan rhino.

The predator-prey relationships of Javan leopard *Panthera pardus melas* and Javan dhole *Cuon alpinus sumatrensis* in Ujung Kulon may have altered and their relationship to Javan rhino and other large herbivores is not understood and worthy of study. Although no records of tiger, leopard, or dhole predation on Javan rhino calves are cited, the predation of greater one-horned rhino calves by tiger is a common occurrence in Rajiv Gandhi Orang National Park, Assam, India (Hazarika & Saikia 2010). This predation effect on greater one-horned rhino calves by tiger was also reported by Talukdar (2002) in Kaziranga National Park, Assam, India. Aside from humans, an adult Javan rhino, as with other rhinos, has no regular predators (Laurie et al. 1983; Hillman-Smith & Groves 1994; Dinerstein 2011).

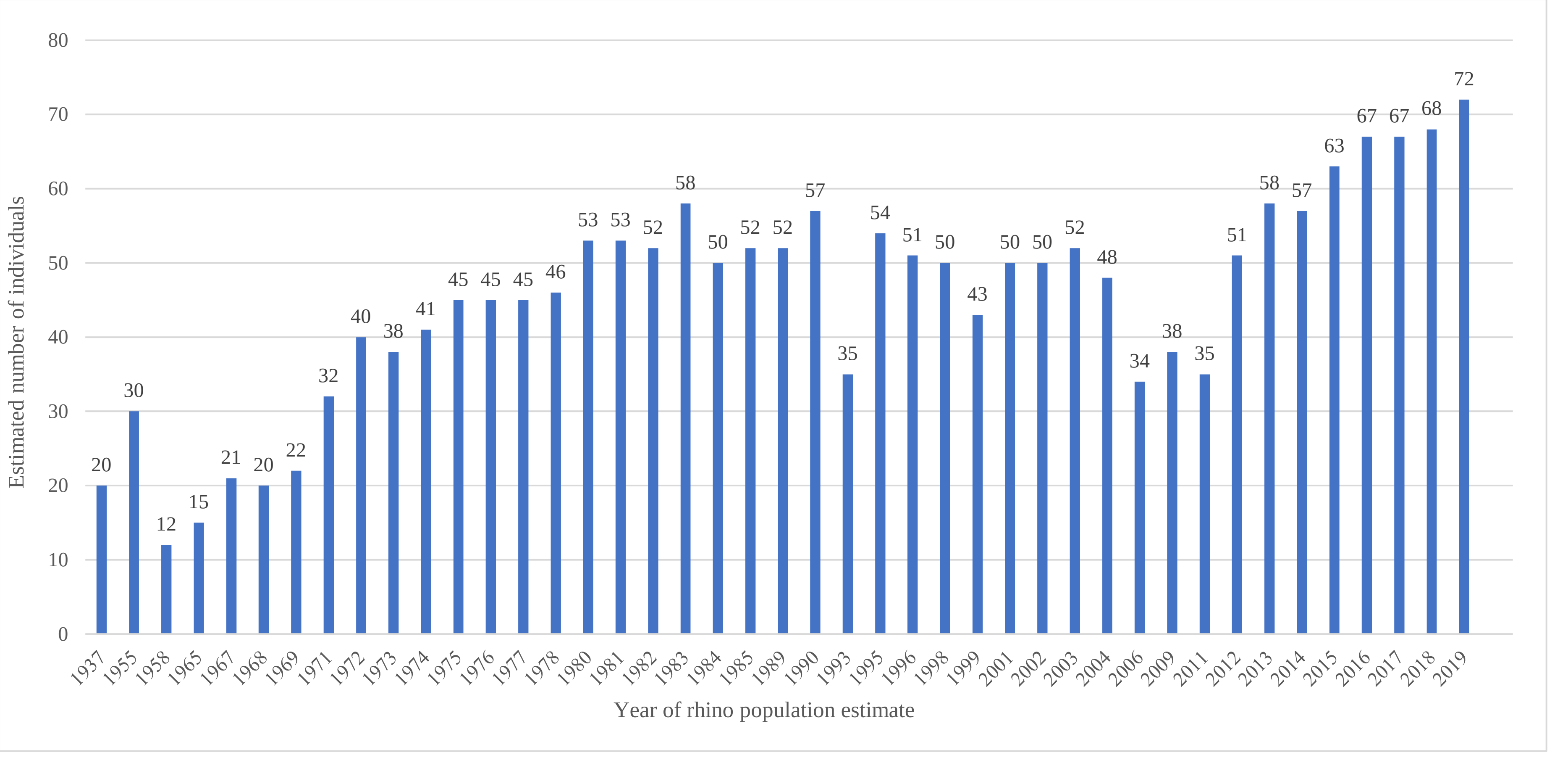

Figure 1.7: Estimated Javan rhino population trends in Ujung Kulon NPP (1937-2019). Source: Ammann 1980, 1985; AsRSG 1995, 2012; Foose & Van Strien,1997, 1998; Griffith 1993; Haryono et al. 2015; Hoogerwerf 1938, 1970; IUCN 2016; Khan 1989; MOF 2007; Sadjudin 1987; Sadjudin et al. 1981; Santiapillai et al. 1989, 1990; Schenkel & Schenkel-Hulliger 1969a, 1969b; Sody 1941; Sriyanto et al. 1995; Talbot 1960; TNUK 1996; Van Strien & Rookmaaker 2010; Emslie et al. 2019; Talukdar 2018; Gokkon 2019.

1.5.5 Javan rhino current distribution and study area

Located in Western Java, Indonesia, Ujung Kulon National Park (UKNP) is a peninsula protruding from the southwest extremity of mainland Java, to which it is joined by a low isthmus some 1-2 km wide (Ramono et al. 2009). Ujung Kulon (*coordinates* 6°44’48” S 105°20’1” E), was established in 1992 and listed as a UNESCO World Heritage Site in 1991 (Forestry Statistics of Indonesia 2007). The total park area is: 122,551 ha, divided into 78,214 ha of land (terrestrial), and 44,337 ha of surrounding reef and sea (marine protected area) (Forestry Statistics of Indonesia 2007) (Figures 1.8, 1.9). The topography of Ujung Kulon is flat to mountainous, with the highest peaks Gunung Honje (620 m) in the east and Gunung Payung (480 m) in the western peninsula (Haryono et al. 2015). The peninsula area of Ujung Kulon is interspersed with several rivers including Citadahan, Cicakanggalih, Cibunar, Cikesek, Cibandawoh, Cigenter, Cikarang and Cijungkulon (Figure 1.8) (Haryono et al. 2015).

These Ujung Kulon waterways are important water sources for both rhino and other wildlife, especially during dry periods (Ramono et al. 2009; Haryono et al. 2015). Ujung Kulon is managed by the central government through the technical implementation unit of the Directorate General of Forest Protection and Nature Conservation of the Ministry of Forestry (Forestry Statistics of Indonesia 2007). The climate of Ujung Kulon is tropical with a seasonal mean average rainfall of 3250 mm, mean temperature range of 25°C - 30° C and relative humidity of 65% - 100% (Ramono et al. 2009) (see Table C.1 Average annual climate data (temp/rainfall) for Ujung Kulon NP, Appendix C).

The Indonesian archipelago, and the Ujung Kulon region, occurs in one of the most seismic and volcanically active areas of the world (Van Strien & Rookmaaker 2010). On the 27th of August 1883, the nearby volcanic island of Krakatau erupted sending destructive tsunami waves across the Sunda Straits towards Java (Van Strien & Rookmaaker 2010). Actual insight into the impact of the tsunamis was recorded by a British ship 222 km south of Ujung Kulon on the day: “*Encountered carcasses of animals including even those of tigers and about 150 human corpses…besides enormous trunks of trees borne along by the current”* (Ministry of Forestry 1995). The volcanic explosion of Krakatau in the 19th century produced several tsunamis that destroyed the villages and agricultural crops of the coastal areas on the western peninsula and covered the entire Ujung Kulon area in a layer of ash (Van Strien & Rookmaaker 2010).

Figure 1.8: Trail map of Ujung Kulon National Park (UKNP), West Java, Indonesia showing key Javan rhino study areas (dark circles). Map: Courtesy Ujung Kulon National Park Authority).

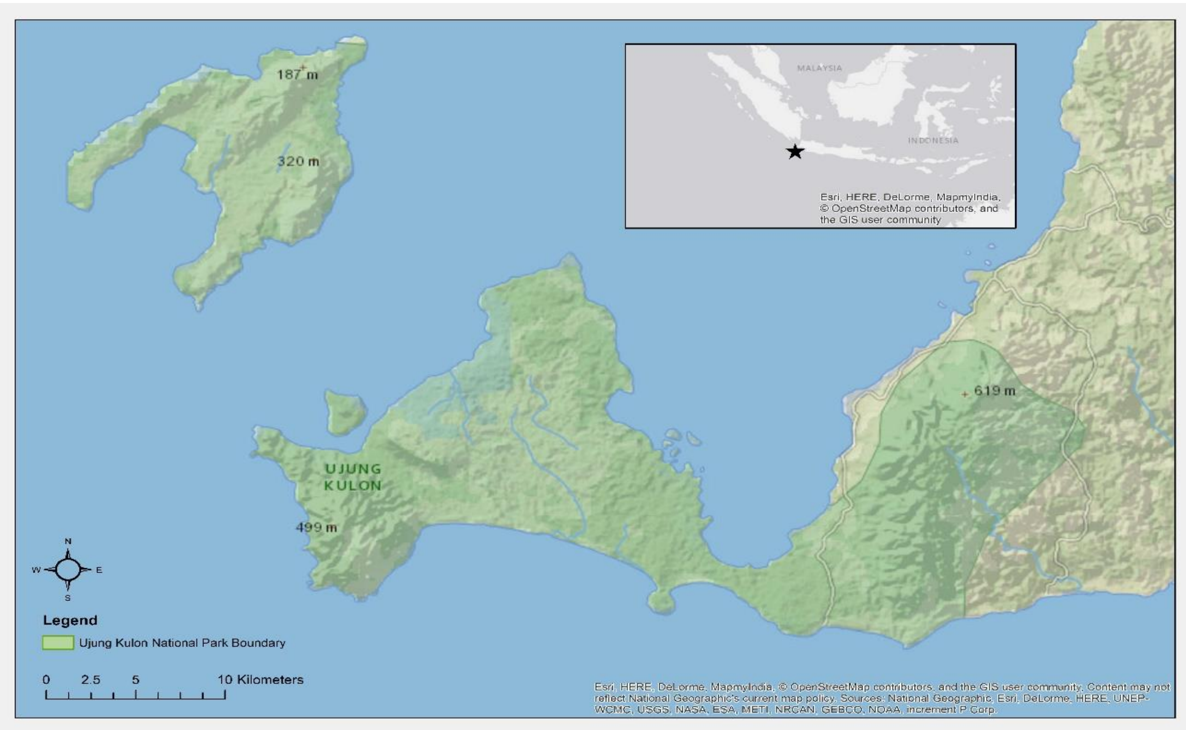

Figure 1.9: Regional context map of Ujung Kulon National Park, West Java, Indonesia. Map ESRI, HERE, De Lorme, Map India © OpenStreetMap contributors, and GIS user community.

This event saw the total evacuation of the peninsula by humans, thereby creating the opportunity to become a nature refuge for much of Java's flora and fauna, and the most intact remaining lowland forest habitat on the island of Java (Forestry Statistics of Indonesia 2007). The Ujung Kulon region was never heavily populated before or after the 1883 eruption, it eventually recovered from the impacts of the eruption, and some villagers returned (Van Strien & Rookmaaker 2010). Eventually, in the early 1900's the Ujung Kulon peninsula was abandoned by those returning villagers due to government concerns over outbreaks of malaria and dysentery, and presence of tigers in the area (Hoogerwerf 1970). It remains unclear just how the 1883 Krakatau event impacted on Javan rhino inhabiting the affected Ujung Kulon peninsula area. It has been suggested the current population most likely came from re-colonisation post the Krakatau eruption and is at risk from founder effects (Fernando et al. 2006).

Today's population of 74 animals (Gokkon 2020) has been isolated since the 1930's recovering from a 1967 estimated low of 25 individuals, genetic drift, impacted by a small population size, founder effects and bottlenecks, it remains remarkable that the population still retains two haplotypes (Fernando et al. 2006). Given the region's seismic and volcanically active status (Van Strien & Rookmaaker 2010), the risk of an earthquake causing a tsunami remains high. Earthquakes causing tsunamis in the Ujung Kulon region predict the risk of tsunami heights of (>3m) is relatively low (up to 10% of area), however over longer periods (>100 years), tsunamis of 30 metres are likely (Horspool et al. 2014; Løvholt et al. 2014). Modelling identified a tsunami of 30 metres would inundate most if not all habitat areas where Javan rhino concentrate (Setiawan et al. 2017). Krakatau, which lies off the west coast of mainland Java, was declared a Nature Reserve in 1921, followed by the islands Pulau Panaitan and Pulau Peucang Nature Reserve in 1958, the Gunung Honje Nature Reserve in 1967, and most recently Ujung Kulon NP in 1992 (Ministry of Forestry 1995). In 2005, Ujung Kulon NP was designated an ASEAN Heritage Park (Forestry Statistics of Indonesia 2007). Despite a low number of human residents, the Ujung Kulon peninsula was regularly poached, many ignored the 1909 protection decree preventing the killing of rhinos on Java (*Staatsblad van Nederlandsch Indië*, no. 497, 23 October 1909) (Sody 1941, 1959). Rhinos were actively poached up until the early 1990s (Lessee 1994; Van Strien & Sadjudin 1995; Nardelli 2016) when active *in-situ* rhino protection became part of park management (Ramono et al. 2009) (Figure 1.10). Today, Ujung Kulon authorities' conservation focus is *in-situ* protection of Javan rhino supported by a policy of non-disturbance.

The rhino population is actively monitored by national park and rhino protection staff using camera traps, dung collection (for DNA analyses) and footprint plaster casting, supported by active patrolling of Ujung Kulon peninsula to search for illegal activities (Ramono et al. 2009). The 5,100-ha research site in the eastern Gunung Honje section of the park (Figure 1.8) is only now being actively monitored and will be a focus of my research in Chapters 4, 5 and 6.

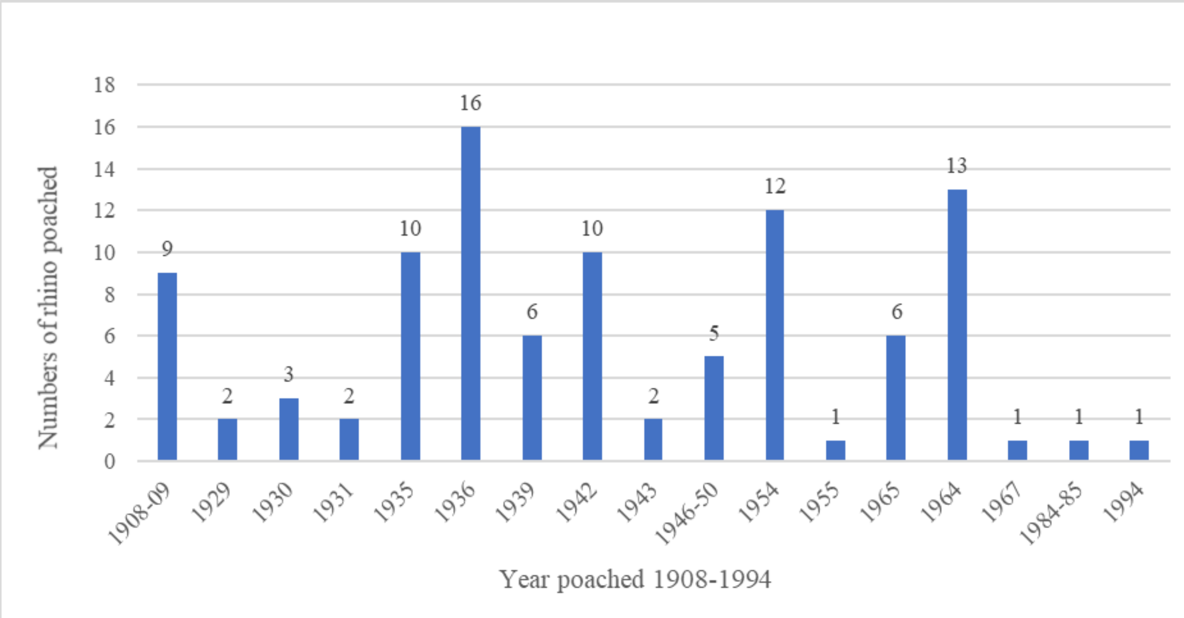

Figure 1.10: Records of Javan rhino poached in Ujung Kulon during 1908 to 1994. Data sourced from historic and modern records including Loch 1937; Voogd & Siccama 1939; Sody 1941; Talbot 1960; Talbot & Talbot 1964; Groves 1967; Schenkel & Schenkel-Hulliger 1969a, 1969b; Hoogerwerf, 1970; PHPA 1982; Sadjudin & Djaja 1984; Nardelli 1987, 2016; Sadjudin 1991; Ramono et al. 1993, 2009; Van Strien & Sadjudin 1993, Lessee 1994; AsRSG 1995; Van Strien & Rookmaaker 2010.

1.5.6 Conservation actions and organisations involved in Javan rhino conservation

The Javan rhino is currently protected by numerous national and international regulations and for many years significant popular and scientific publications have attempted to highlight the species' critically endangered status in Southeast Asia. Despite its iconic name and periodic publicity, scientific studies directed at the many unknown aspects of its biology and ecology, which are fundamental for its survival and recovery, have been slow in coming (Groves & Leslie, Jr. 2011).

Studies undertaken to date on Javan rhino can be categorised into three areas of focus: population, distribution and conservation (Setiwan & Yahya 2002; Indonesian Ministry of Forestry 2007; Fernando et al. 2006); importance of local communities in the management of protected areas and threatened species (van Merm 2008), and habitat assessment and utilisation (Schenkel & Schenkel-Hulliger 1969a, 1969b; Hoogerwerf 1970; Schenkel et al. 1978; Sadjudin 1984; Ammann 1985; Hommel 1987; Haryono 1996; Muntasib 2002; Rahmat 2007; Ramono et al. 2009; Chandradewi 2011). Over the past decade many key conservation organisations have become active participants in Javan rhino management and conservation (Table 2). Collaborative efforts between the authorities and non-government organisations (NGO’s) in the national park are focused towards preserving the Javan rhino, protecting its habitat from destruction and fragmentation, improving, and supporting anti-poaching activities (active *in-situ* patrolling by rhino protection and national park staff), and reducing in-park illegal resource extraction (Ramono et al. 2009).

Table 2 Summary table of conservation authorities and non-government organisations (NGO's) involved in Javan rhino conservation.

Organisation	Role and contribution
International Rhino Foundation (IRF)	Global strategic support and funding resources
Rhino Foundation of Indonesia (YABI)	Administer Rhino Protection Units (RPUs), support rhino monitoring activities (i.e. camera trap recording)
Asian Rhino Project (ARP)	Funding resources for local conservation activities
Ujung Kulon National Park Authority (UKNP), Indonesia	National Park management via Ministry of Forestry
World Wildlife Fund (WWF) Indonesia	Local strategic support and funding resources
IUCN/SSC Asian Rhino Specialist Group	Global strategic scientific support and guidance

1.6 PhD Framework and Aims

This PhD thesis comprises seven chapters, organised as an introduction (**Chapter 1**), followed by five standalone research chapters (**Chapters 2 - 6**) and a conclusions chapter (**Chapter 7**). This thesis is structured around five research chapters as follows:

Chapter 2 Implications of local community awareness to the conservation of the Javan rhino, one of Earth's rarest mammals
The aim of this chapter was to examine the community awareness of local people living near Ujung Kulon National Park to Javan rhino conservation and determine the implications for future conservation of the rhinos, by addressing the following questions:

2a Level of community awareness of Javan rhino conservation and management?

2b Level of support for Javan rhino conservation activities?

2c Does involvement in Javan rhino conservation activities affect the levels of awareness and support?

I hypothesise that community attitude to rhino conservation improves with awareness and involvement in conservation activities

Chapter 3 Protecting an icon: Javan rhino frontline management and conservation

The aim of this chapter was to determine the approaches used and attitudes of rhino protection staff and national park staff to rhino management, and implications for future management, by asking the following questions:

3a Rhino protection and national park staff view of the main threats to Javan rhino?

3b Are current conservation approaches in Ujung Kulon sufficient to meet the perceived requirements for the ongoing protection of Javan rhino?

3c Benefits of employing rhino protection and national park staff that come from local villages, and does coming from a local village assist them in their work?

I hypothesise that national park rangers with more years of experience than rhino protection unit staff will have different perspectives on the conservation of Javan rhino.

Chapter 4 Understanding the implications of Arenga palm *Arenga obtusifolia* dominance for the conservation and management of Javan rhino

The aim of this chapter was to determine the implications for conservation and management of arenga palm on rhino, habitat, and food plants, by asking the following questions:

4a Conservation implications of arenga palm dominated habitat for Javan rhino habitat use and distribution?

4b Does removal of arenga palm increase the availability of rhino food plants?

4c Time period over which rhino food plants grow, and rhino visitation occurs?

I hypothesise that habitat manipulation of arenga palm in selected forest patches is a viable management technique to increase foraging for rhinos.

Chapter 5 More than just mud: Importance of wallows to Javan rhino ecology and behaviour

The aim of this chapter was to determine wallow characteristics, spatial analysis of wallows in the study area, and their importance to Javan rhino ecology, social interaction and communication behaviour, and implications for conservation planning, by asking the following questions:

5a Wallow characteristics and their importance to Javan rhino ecology and conservation?

5b Does interaction and vocalisation increase at wallowing sites?

I hypothesise that Javan rhinos utilise wallows not only for thermoregulatory function, but also as sites of interaction and communication.

Chapter 6 Understanding an icon: Social behaviour and communication in the Javan rhino

The aim of this chapter was to examine the rarely studied and data deficient area of Javan rhino social interaction and communication behaviour, by asking the following questions:

6a What is the social structure of the Javan rhino?

6b What are the intraspecific interactions that occur among Javan rhinos?

6c How do Javan rhinos communicate?

6d What is the vocal repertoire of the Javan rhino?

Chapter 7: Thesis Discussion and Conclusion

The final chapter summarises the findings of the thesis and discusses them with reference to the literature and the contributions to knowledge. Collectively, this work will improve current understanding of the factors shaping the conservation of Javan rhino by i) increasing awareness of effectiveness, data gaps and future risks to current conservation initiatives, ii) increase knowledge of Javan rhino ecology, social and communication behaviour, iii) and optimise the management of key threats, for example, the management of the invasive arenga palm.

Chapter 2 Implications of local community awareness to the conservation of the Javan rhino, one of Earth's rarest mammals

Figure 2.1 Image taken by author of local community member from the West Javan village of Taman Jaya, Indonesia, undertaking a survey questionnaire with rhino protection staff and Indonesian language interpreter. Image: Steve Wilson.

2.1 Abstract

Attitudinal studies are important tools for evaluating community awareness, understanding and acceptance of conservation activities, and for assessing their impacts and efficiency. For an exceptionally rare species such as the Javan rhino, with only 74 individuals persisting in one population, understanding local community awareness is critical for the development of future conservation actions. The single remaining population of the critically endangered Javan rhino survives in Ujung Kulon National Park (UKNP), West Java, Indonesia. Java is also one of the world's most populated islands, with over 152.8 million residents, which results in continuous pressure on remaining habitat, wildlife, and protected areas. The eastern edge of the park is surrounded by 19 villages, all which have some reliance on national park resources. This study was aimed at assisting National Park managers and conservation planners. I interviewed local villagers, including all 19 village leaders and local community members from each village. I found that local communities were supportive but held limited knowledge of National Park regulations and park boundaries. I also found community knowledge of the conservation and management of Javan rhino was low, valuable information to the authorities who in response have established a community engagement team who now keep community informed and updated on the conservation effort.

2.2 Introduction

The growth of human populations, particularly across Asia, leads to rapid habitat loss and ongoing interactions with remaining wildlife populations (Dinerstein 2011; AsRSG 2012). All five surviving rhino species remain threatened. The remaining Javan and Sumatran rhino *Dicerorhinus sumatrensis* in Asia are two of Earth's rarest mammals, persisting in lowland rainforest, which is rapidly being converted to oil palm and rubber plantations (Dinerstein 2011). Populations of greater one-horned rhinoceros *R. unicornis* thrive on fertile floodplain ecosystems, which are also optimum development sites for agriculture and intensive cultivation (Dinerstein 2003, 2011). Rhino populations are further impacted by factors such as logging, increased access via creation of roads, improved hunting equipment and ineffective wildlife protection (Ling et al. 2002; Smith et al. 2003; Karanth & DeFries 2010). Across Africa and Asia rhinos are protected through a range of management approaches, often based on the level of threat and protection required (AfRSG 2012; AsRSG 2012). The Asian approach to rhino conservation involves protection of animals *in situ* through anti-poaching efforts using rhino protection units (RPUs) (AsRSG 2012).

These rhino protection units undertake maintenance and protection of core habitats, and where suitable translocation of isolated individuals or animals from overpopulated habitats to viable habitat or *in-situ* intensive management situations (AsRSG 2012). Increasingly, communities living in locations adjacent to rhino protection areas or buffer areas are being encouraged and supported to engage in rhino conservation (Dinerstein 2011; AsRSG 2012; Thapa et al. 2013). Listed on the IUCN Red List as Critically Endangered (IUCN 2016), the Javan rhino formerly occurred from north-east India, Bangladesh, Myanmar, Thailand, Lao PDR, Cambodia, Vietnam, and probably southern China through Peninsula Malaysia to Sumatra and Java (Rookmaaker, 1980; Grubb, 2005). Today, the taxon's only surviving Javan rhino population resides at one location, in Indonesia's Ujung Kulon National Park (UKNP), West Java, Indonesia (Khan 1989; Hariyadi et al. 2011, 2012, 2016), where the conservation of its habitat is a crucial management priority (Hariyadi et al. 2016). The current population of Javan rhino in Ujung Kulon is 74 animals (Gokkon 2020). Available Javan rhino habitat is compromised by two major factors, human encroachment, and dominance of arenga palm *Arenga obtusifolia* (Haryono et al. 2016). Arenga palms now dominate the rainforest canopy in many areas of the park, and reduces available rhino foraging, by limiting the growth of rhino food plants.

Today, Ujung Kulon National Park Authorities' main focus is *in situ* protection of Javan rhino supported by a policy of non-disturbance. The rhino population is actively monitored using camera traps, dung collection (for DNA analysis) and footprint plaster casting, supported by active patrolling of the Ujung Kulon peninsula and park environs by non-government resourced rhino protection units and national park staff to search for illegal activities (Haryono et al. 2015). Commencing in 1998, the Indonesian and International Rhino Foundations began supporting rhino protection units in Ujung Kulon. Today, it employs 25 rhino protection staff, rotating four-person field teams (three rhino protection/one national park ranger) (Ellis 2010). Protected area and conservation management authorities are increasingly utilising attitudinal studies as tools for evaluating community awareness of the impact of conservation activity (Kideghesho et al. 2007; Karanth & Nepal 2012). Without the cooperation and involvement of communities (Figure 2.1) who live close to wildlife and protected areas, conservation actions are less likely to succeed (Ripple et al. 2015). Community involvement in the management of protected areas correlates positively with protected area policy compliance (Anthony 2007; Andrade & Rhodes 2012; Allendorf & Gurung 2016).

Active engagement and participation of local villagers in the management of a protected area can often result in more effective protection (Dinerstein 2003, 2011; Steinmetz et al. 2006; Knapp et al. 2017). Well-resourced and coordinated community-driven activities assist local people becoming key stakeholders in the conservation effort (Aucoin & Deetlefs 2018). For example, to protect wildlife in Nepal, the Nepalese government successfully introduced a policy of sharing tourism revenues from protected areas with local communities living adjacent to its reserves (Budhathoki 2004; Sharma 2017). A similar positive result has occurred in West Bengal, India, where improved relations between wildlife management personnel and local villagers had positive impact on protection and reduced poaching of greater one-horned rhino (Martin & Vigne 2012). Through this approach, authorities, and the local community work together, supported by rhino awareness programmes, eco-projects and eco-tourism businesses that benefit local villagers enabling them to reduce their reliance for forest resources (Martin & Vigne 2012). The eastern edge of Ujung Kulon, adjacent to the Gunung Honje Range (Figure 2.2) is surrounded by 19 villages (Figure 2.3), live the Sundanese (Javan) people that have traditionally used park resources for their livelihood, and in some cases continue to do so (YMR et al. 2002; Van Merm 2008; Haryono et al. 2016).

Sundanese society is based on large extended families who provide support and assistance to each other within the broader family unit (Ministry of Forestry 2010). The local village is the lowest level of government administration in Indonesia and is the most influential on village life and handles matters of the village through the elected village leader (Statistics Indonesia Banten Province 2018). The inhabitants of these villages are mostly subsistence farmers and fishermen, however not all of their needs can be met by their farming and fishing activities. Local communities are still reliant on national park resources, including firewood, timber and bamboo as building materials, and vegetable proteins (YMR et al. 2002; Van Merm 2008; Haryono et al. 2016). Other national park resources provide villagers with a source of income, such as collection of '*jernang*' (a red palm resin used for making dye), wild honey and edible-nest swiftlet *Aerodramus fuciphagus* nest collecting (Van Merm 2008). Often local people lack viable alternative livelihoods, they continue to rely heavily on park resources (Haryono et al. 2016). Given the Ujung Kulon peninsula has no people living in it, the main area of village and local community activity is centred on the Gunung Honje Mountain region (eastern section of the national park) (see Figure 2.2). Ujung Kulon also experiences periodic illegal logging and the tending of domestic livestock, mainly buffalo and goats on the national park fringes and within the park area (Van Merm 2008; Haryono et al. 2016).

A significant and ongoing risk and consequence of the tending of livestock in or near the National Park is increased risk of disease being transferred from livestock to wildlife, especially large herbivores such as Javan banteng *Bos j. javanicus*, rusa deer *Rusa timorensis*, Javan wild pig *Sus scrofa vittatus* and Javan rhino. There is some suspicion that anthrax or another infectious agent was implicated in five rhino deaths in 1982 (WWF - IUCN 1982), at least two animals in 2002-2003, five in 2010-2013 (Hariyadi et al. 2012; UKNP 2012) and two in 2014 (UKNP 2014). This theory is supported by Santiapillai & Suprahman (1986), citing an outbreak of *Septicaemia epizootica*, which killed 50 buffaloes and 350 goats in the neighbourhood of Ujung Kulon in November 1981.

To help mitigate this risk, in 2010, authorities launched the 5,100 ha Javan Rhino Study and Conservation Area (JRSCA) including installing an 8 kilometre-long rhino proof fence at the base of the eastern Gunung Honje range (Figure 2.2) to protect the habitat area, exclude domestic stock and keep rhino protected (Ellis 2010). Between 1979-1980 and again in 2010-2011 (Widodo Ramono, personal communication, 31st May 2017) the Indonesian Government removed over 300 illegal settlers living within Ujung Kulon's eastern Gunung Honje area. This removal has reduced, but not eliminated, ongoing threats due to illegal activities engaged in by local communities mostly for subsistence reasons (Haryono et al. 2016). Ujung Kulon authorities and non-government organisations (NGOs) have utilised local community labour and skills in arenga palm control since 2010, clearing 106.5 ha to date which has enhanced the relationship between village communities and National Park authorities (Sectionov, personal communication, 3rd November 2018).

The objectives of this chapter were to a) understand local people's opinion of Javan rhino; b) determine local knowledge of the Javan rhino and Ujung Kulon National Park conservation effort; c) understand the importance of Javan rhino and national park to local identity and lives; d) understand local views of perceived risks to Javan rhino and national park; e) understand the social context of having the Javan rhino and national park nearby, and f) determine the level of trust and relationship between community and national park authorities. The aim is to use this information to assist future management actions that can benefit conservation outcomes for the conservation and management of Javan rhino (Triguero-Mas et al. 2010; Moreto et al. 2017). To address these aims, I interviewed 76 local villagers (Figure 2.1), including each of the 19 village leaders and three local community members from each village asking a series of themed focus questions that allow us to better understand local community attitudes to ongoing Javan rhino conservation and management.

2.3 Methods

2.3.1 Study area

Ujung Kulon National Park (6°44’48” S 105°20’1” E), was gazetted in 1980, and in 1992, the park, along with the volcanic Krakatau archipelago, and larger islands including Panaitan, as well as smaller islands such as Handeuleum and Peucang in the Sunda Strait, was declared Indonesia’s first UNESCO World Heritage Site (Haryono et al. 2016) (Figure 2.2). Ujung Kulon with a total area of 120,551 ha encompasses 76,214 ha of terrestrial and 44,337 ha of marine ecosystems (Indonesian Ministry of Forestry, 2010). Ujung Kulon represents the largest remaining tract of lowland tropical rainforest on the island of Java (Haryono et al. 2016). An area of 30,000 ha in the Ujung Kulon peninsula is the core area for Javan rhinos (Nardelli 2016; Hariyadi et al. 2016). The community living near and adjacent to Ujung Kulon, West Java (Figure 2.3), resides in the Banten Province, one of 34 provinces across Indonesia. Banten is the westernmost province on the island of Java, Indonesia. In 2019, the human population of Banten was officially estimated at 14,269,391, noting a population census is carried out every five years (Statistics Indonesia Banten Province 2019).

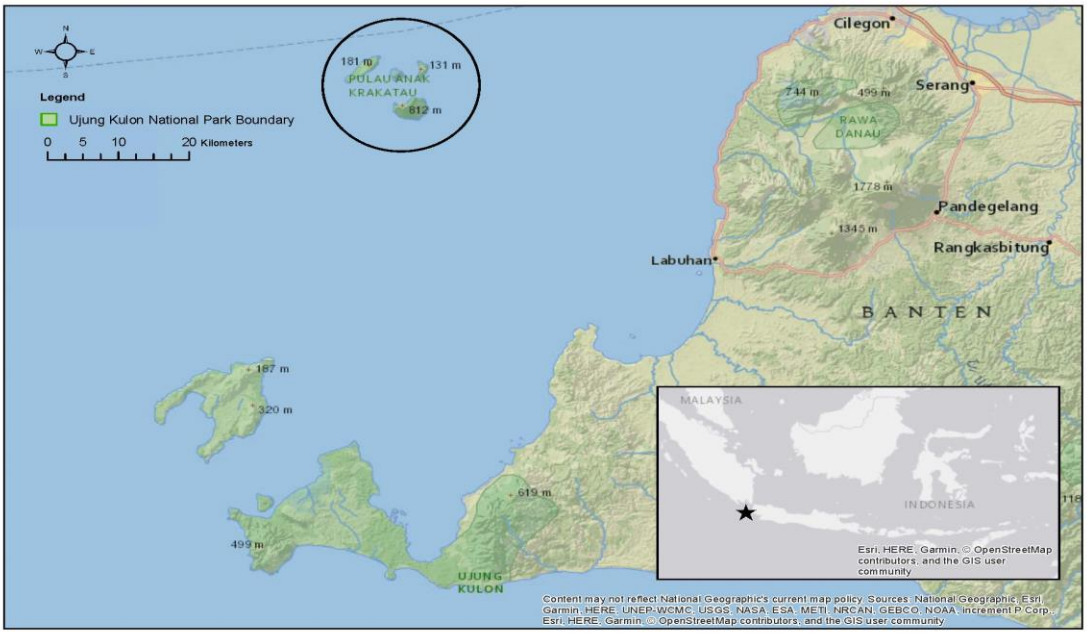

Figure 2.2: Map of Ujung Kulon National Park (UKNP), West Java, Indonesia (light green shaded area) (6°44’48” S 105º20’1” E). Note dark circle around Anak Krakatau. Map: Courtesy ESRI, HERE, DeLorme, MapIndia © OpenStreetMap contributors, and GIS user community.

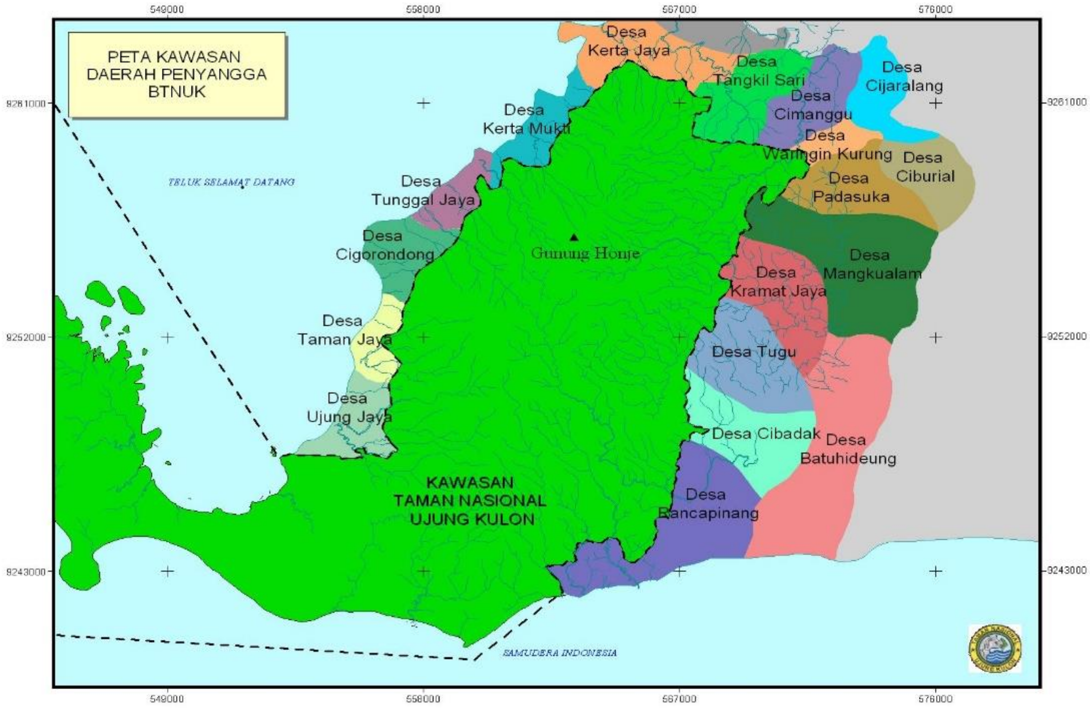

Figure 2.3: Map of 19 village precincts surrounding eastern section of Ujung Kulon National Park. Map: Courtesy Ujung Kulon National Park Authority (6º44’48” S 105º20’1” E).

Beginning 19/05/2015 - 25/05/2015, interviews with each of the 19 local village community leaders were undertaken. This required Indonesian conservation authority support and an Indonesian interpreter. Cultural protocol dictates consultation through the village leader or ‘*kepala desa’* who speaks for the community. In the event of the village leaders’ absence, the village secretary can speak on their behalf. Three separate survey sessions followed, each speaking to 19 local community members, one from each village, during 08/09/2015 - 20/09/2015 and 19/03/2016 - 26/03/2016. During each village visit, the interpreter would randomly (note: families habitually sit outside the front of their homes) ask local people whether they would like to participate in a survey on Javan rhino, in most cases they were pleased and interested in assisting. Only three people (2.28%) of all villagers approached refused to participate, however, in each case they deferred to older members of the family, which is culturally appropriate (Walpole & Goodwin 2001). Pre-survey consultation with Ujung Kulon and Indonesian Rhino Foundation (YABI) staff acknowledged the low literacy and limited educational backgrounds of local villagers. It was recommended by a national park staff member the survey questions be kept clear and as basic as possible, and that adult participants be targeted, as they could provide the most informed responses, and culturally, young people if asked would defer to their elders (Walpole & Goodwin 2001).

The survey questionnaire was first developed in English, and then translated into Bahasa. Questionnaires were piloted on three people, including a rhino protection staff member who came from a local village, as well as the interpreter and a local villager (see Figure A.1 Local Community Questionnaire, Appendix A). As a result of the pre-testing and discussions, some questions were deleted, and others modified to improve clarity (Bernard 2002; Czaja & Blair 2005). During the pilot process we trialled the questions and the responses together with the interpreter. Additionally, during the pilot, we found that after initial introductions it was easier for the interpreter to ask participants the questions and record the responses, as this made the process flow more easily. Before administering the questionnaire, cultural norms were followed, i.e. introduction of the researcher, interpreter, the form and rationale of the questionnaire and an explanation of its intended purpose. All participants signed a research consent form before commencing and additionally signed their questionaries upon completion. Village leaders would stamp and sign their completed questionnaires with their respective village seals. Participants varied in their times to complete the questionnaire, with an average duration between one to two hours to complete. Under normal travel and weather conditions, in most cases I completed three, sometimes four survey questionnaires each day.

The survey adapted and used Stankey & Schindler's (2005) themes for studying community attitudes and their relationship to the management of rare species, which includes five factors that influence peoples' attitudes. These themes include knowledge, ethics, perceived risks, spatial, temporal, and social context, and trust. In this study, I used the model described by Stankey & Schindler (2005) to develop a four-point Likert scale (2-5) for each of the attitude-determining factors, to be able to quantify them. Responses would be ranked from 1 = 0 (don't know), 2 = (no risk) to 5 = (very high risk). Additionally, the survey asked a series of 12 questions about local peoples' opinions on rhino conservation, including five questions requiring a response on a four-point Likert scale. Village leaders were also asked several additional questions relating to their tenure as leader and village population data, which is a leader's responsibility to record and manage (Table 1). Completed questionnaire qualitative data was converted back into English by the interpreter, and both quantitative and qualitative data was entered into Microsoft Excel spreadsheets. Quantitative answers were translated into points on a four-point Likert scale, with the aim of assessing how favourable each answer would be for rhino conservation. For example, under the theme 'Perceived risks', local community respondents' were asked to rank on a Likert scale if the growing human population around Gunung Honje and West Java is a threat to Ujung Kulon and Javan rhino.

The results were analysed in order to identify which factors are important in defining local community attitudes to Javan rhino conservation and to test the hypothesis that community attitude to rhino conservation improves with awareness and involvement in conservation activities. The Likert scale has been used successfully in other social research projects pertaining to rare species. For example, Van Merm (2008) used Stankey & Schindler's (2005) approach and the Likert favourability scale to translate local community answers during his master's dissertation work in several west Javan villages.

Similarly, a Likert scale was used by Reading & Kellert (1993) on their study of community attitudes toward a proposed reintroduction of the critically endangered Black-footed ferret *Mustela nigripes* in North America. The survey questionnaire used 42 questions (village leader), and 39 questions for local villagers. Twenty questions are based on a Likert scale (2-5) ranking response, the remaining involved qualitative responses. Differences amongst the 76 local community responses to 20 Likert scale and general questions (Refer Tables A.3 - A.8 in Appendices A) were calculated using chi-square (χ^2) tests of independence examining the difference between observed (O) and expected (E) values. Predictor variables used in the analysis included local community knowledge of Javan rhino conservation status, National Park boundaries, regulations, awareness of conservation initiatives, cultural importance, and views of risk factors.

Questions were tabled into themes, adapted from Stankey & Schindler's (2005) study. These included responses and results, Table A.3 (People's opinion on rhino conservation), Table A.4 (knowledge), Table A.5 (ethics), Table A.6 (risk), Table A.7 (spatial, temporal, and social context), and Table A.8 (trust). Maps were created using ArcMap 10.5 software (ESRI). Spatial layer used was World Imagery. Source: ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Data analyses were performed using Microsoft Excel. I considered test statistics as significant with P values < 0.05.

2.4 Results

Overall, 76 local community members, including 19 village leaders and 57 local villagers completed survey questionnaires. The sample comprised 53 males (69.7%) and 23 females (30.3%), age range (18 - 66). Village leaders lived in their villages on average for 33.53 years, SD ± 19.04, range (0.7 - 57) (Table 1). The average tenure as village leader was 4.78 years, SD ± 6.020, range (0.7 - 15).

Local villagers lived in their villages on average for 34.19 years, SD ± 12.724, and range (4 - 66 years) (Table 1). The population of the 19 villages living around the eastern boundary of Ujung Kulon (Figure 2.2) has grown by 21.55% since 2010. Increasing from 52,599 to 63,936 as of May 2015, a population increase of 11,337 (Table 2). In 2010 the average village size was 2,821, by May 2015 it had grown to 3,365.

2.4.1 Community opinion of Javan rhino conservation theme responses

Overall only three questions (Table A.3) produced positive results, including 1) has your community or any local people been involved in Javan rhino activities to date produced positive results (χ^2 tests > 11.84, P = 0.000, df = 1), 2) how interested are young people in Javan rhino conservation (mean 2.77; SD ± 2.11; χ^2 tests > 8.89, P = 0.002, df = 1) and 3) how interested are your older people in Javan rhino conservation are (mean 2.92; SD ± 2.17; χ^2 tests > 7.578, P = 0.005, df = 1). Community acknowledged the importance of protecting Javan rhino (mean 4.17; SD ± 1.50, important, Table 2) and National Park (mean 4.38; SD ± 0.92, important, Table A.3).

2.4.2 Community knowledge theme responses

Overall only two questions (Table A.4) produced positive results, including, 1) do your community and local people know how many Javan rhino there are (χ^2 tests > 10.31, P = 0.01), and 2) do you have a suggestion on how authorities could best inform community of Javan rhino and Ujung Kulon National Park activities (χ^2 tests > 4.26, P = 0.038, df = 1). On this question many communities, 47 (62%) were unsure of the best approach to inform. The remaining 29 (38%) of community suggested community outreach or the ranger informs. The level of community awareness of Javan rhino conservation and management was effectively low. This was reflected in consistently low Likert scale scores. For example, questions asking knowledge of National Park regulations averaged (mean 1.59; SD ± 1.78, no knowledge, Table A.4), and knowledge of National Park boundaries averaged (mean 1.53; SD ± 1.82, no knowledge, Table A.4). Awareness of the new conservation area and rhino fence was low averaging (mean 1; SD ± 1.7, no knowledge, Table A.4). Villages situated adjacent to the national park had higher awareness of the boundaries and regulations than those villages further away and without staff living in those villages.

2.4.3 Community ethical theme responses

There were no significant results for this theme (Table A.5). Culturally, Javan rhino and the National Park are viewed as important aspects of local people's identity and lives.

The ethics questions were defined as the existence value that local community gave to the Javan rhino as well as the cultural and traditional associations they have with the species. Ethical questions about the rhinos' value and importance of the national park to local people consistently scored high averaging (mean 4.43; SD ± 1.07, important, Table A.5). Community support for Javan rhino conservation was strong and is linked to the community's cultural connection to the Javan rhino and Ujung Kulon. For example, the question asking the importance of having rhino around for their grandchildren, elicited the highest response, averaging (mean 4.63; SD ± 0.72, important/very important, Table A.5).

2.4.4 Risk related theme responses

Responses to risk questions elicited low Likert responses with no significant results. For example, questions on the growing human population and its risk to the National Park and its wildlife averaged (mean 2.69; SD ± 1.74, no risk, Table A.6), (χ^2 tests > 19, P = 1.30, df = 1, Table A.6). The question if roads, infrastructure, and transport options were improved do you see this as a risk to the NP and its wildlife was low also (mean 2.46; SD ± 1.72, no risk, Table A6), (χ^2 tests > 17.05, P = 3.63, df = 1, Table A.6).

2.4.5 Spatial, temporal, and social context theme responses

Community responded favourably to questions relating to the benefits of having Javan rhino and the National Park nearby, averaging (mean 3.55; SD ± 1.60, some benefit, Table A.7). When asked what benefit, 86% responded with positive comments, for example "the rhino helps local people". This suggested community understood the conservation effort to build a healthy rhino population and a well-managed National Park were linked to potential commercial opportunities from having the rhino and National Park nearby. This was reflected in responses (mean 3.55; SD ± 1.60, some benefit, Table A.7), and 83%, repeatedly stating tourism (e.g., tour guide) and flow on job opportunities would help local village economies.

2.4.6 Trust theme responses

Community response to the question of how important the relationship between the local community and the Ujung Kulon NP Authority was high (mean 4.23; SD ± 1.01), (χ^2 tests > 68.21, P = 1.46, df = 1, Table A.8). The level of trust between community and the authorities was viewed as good and positive (mean 3.68; SD ± 1.43, some importance, Table A.8), (χ^2 tests > 50.57, P = 1.14, df = 1, Table A.8). The strongest indicator of community support was the question asking if community had not been involved in conservation activities, would they like to be, elicited a 100% yes response.

2.5 Discussion

The survey results highlighted the local community was generally positive about the presence and value of Javan rhino and having the national park nearby. However, overall community knowledge and awareness of Javan rhino conservation activities and national park regulations and boundaries was low. The most informed communities came from the villages of Ujung Jaya, Taman Jaya and Cigorondong. This may be due to community being more likely to interact with National Park and rhino protection unit staff based at the Ujung Kulon National Park Authority operations headquarters in Taman Jaya and the rhino protection staff bases situated in Cigorondong and Ujung Jaya.

Ujung Kulon NP activities including routine patrolling and conservation management activities such as arenga palm control and plant propagation and tree planting are coordinated out of these bases. National Park and rhino protection staff live in these local villages, increasing communication channels of sharing conservation and park activity information with locals. This was reflected in community knowledge of arenga palm, a major threat to the habitat and food resources of rhino, and with an active conservation management program. The 88% do not know response highlighted this. However, the 12% of community that had some knowledge of the palm came from the villages Ujung Jaya, Taman Jaya and Cigorondong, possibly indicating community gets more exposure to communication from authorities due to the presence of staff bases compared to villages that do not have staff bases nearby. As a patriarchal society, the Sundanese (Javan) women, children and young people would naturally defer to the older men in their families. Their village leaders are always men.

As a traditional and structured society, we assumed questionnaire responses were based on their real experience or exposure to a question. For example, when asked, how interested are your young people in Javan rhino conservation, if they had no obvious knowledge of a young peoples' interest, they were reluctant to speak on young peoples' behalf. This appeared to be the case for the significant results to the questions regarding People's opinion of both old and young people to Javan rhino conservation and knowledge of community involvement in conservation activities. The one-on-one methodology used to survey these communities was accepted by those involved as has been shown in other contexts, when working with people of low literacy and limited educational backgrounds (Groenendijk 2003; Van Merm 2008; Haryono et al. 2016). It could be argued that some of the results could be biased by participants telling us what we wanted to hear (Sheil & Wunder 2002).

The diversity of the themes and questions asked should have avoided this bias. People were grateful and pleased to be asked to contribute and it appeared the experience was positive for them. Post survey feedback from local community to National Park and rhino protection staff on the questionnaire and research has been positive (Syamsudin, personal communication, 28th September 2016). The living conditions in all the villages visited was similar, and all communities faced the same challenges related to their location. Similar observations were made by Van Merm (2008) during his community research in the area. Therefore, the sample size (n=76) may be considered large enough to represent all 19 villages. The similarity of the participants' answers supports this notion. The growing human population around Ujung Kulon is a significant risk given there is no additional land available to support this growth.

Competition between the national park, rhinos and human settlements will continue, unless viable alternative livelihoods can be seen, which could include increased in-park conservation work. It remains unclear as to how much impact human population growth has occurred as not all areas of the park see regular patrol activity. National park border areas where they interface with village cultivation and agricultural land is worth examining, noting some form of incremental edge effect into national park land would be occurring and exacerbating habitat decline (Indonesian Ministry of Forestry 2007; Gunawan et al. 2012). Protected area authorities appear to have limited influence on decisions made outside a protected area's administrative boundaries. The authorities' knowledge base is often lacking to understand the effect of anthropogenic activities on protected areas and the species residing within them (DeFries et al. 2010).

2.5.1 Level of community awareness to Javan rhino conservation and management?

The survey participants acknowledged the rarity and uniqueness of the rhino and its protected habitat. However, despite strong intent and claims of wanting to be involved and informed, they essentially remain uninformed of the conservation challenges, their impacts and the management requirements of rhino and the park. When asked about the National Park and rhino risk factors the community response was narrow in context. For example, increased population and better roads and infrastructure 'might' increase the risk of illegal activity. No feedback was given regarding the risks of human population increases and corresponding growth in domestic livestock numbers, which could significantly raise the risk of disease transfer, given less land is available and park resource use intensifies. This highlights the broad lack of community awareness of the conservation threats.

Opportunities do exist to improve communication channels between authorities and local community. For example, World Rhino Day is actively supported by both authorities and community, and an event is held in Taman Jaya during September each year. These types of large-scale events can be used to promote and inform local community of current and intended activity. The significant χ^2 results highlighted community was unclear how best to be informed of Javan rhino and National Park activities. National Park and rhino protection staff have more detailed knowledge and practical exposure to the risks and the management and conservation activities need, so are well placed to influence community within the confines of their staff bases at Taman Jaya, Ujung Jaya and Cigorondong and more widely.

Regular visits by authority staff to other villages to share information would be welcomed by local communities. Additionally, authorities could meet with village leaders and local clerics to share concerns and information would be a positive and practical way forward. By utilising respected people of influence, who, once appropriately informed and with a solid understanding of the authorities' conservation and management objectives, would be in an ideal position to influence the broader local community. The support of local people is a critical element for maintaining an ecologically viable and functional protected area (Sodhi et al. 2010). When community was asked the importance of the national park to community question it elicited a strong response, with repeated reference of its importance to village life, notably provision of water and resources. However, the beneficial elements coming from ecosystem services in forested areas would in most cases be poorly understood by local people. There are some evidence local people with longer residency valued ecosystem services more (Sodhi et al. 2010). Of the participants interviewed the average residency was 34.19 years.

A community education program that highlighted the benefits forested areas provide beyond biodiversity and habitat preservation outcomes through to benefits such as, crop pollination, carbon sequestration, and flood mitigation may be a means of raising awareness and ideally reduce impacts on the resource. Protected areas are often surrounded by dense human populations and are correspondingly increasing the amount of ecosystem stress (DeFries et al. 2007). There has been debate amongst elements of the conservation community that forests should be protected and preserved not only for biodiversity conservation but for ecosystem services as well (Daily 1997; Kareiva & Marvier 2007). Local communities face many challenges through the remoteness of their location, a mostly subsistence existence (farming/fishing) and poor services.

For example, power outages are a common occurrence, with ongoing transport and access issues. The main access road and smaller feeder roads that edge around the national parks' boundary quickly deteriorate from the township of Sumur (Figure 2.2), on the parks' north-eastern corner through to the main national park service entries at Taman Jaya and Ujung Jaya. In extended wet periods the road network becomes virtually impassable, slowing motorbike, foot, and vehicular traffic to slow walking pace. Hence road conditions dominate and influence village life. The targeting of villages which are close to the National Park but don't reside on the National Park's borders would be a valuable exercise. These villages include Sumber Jaya, Ciburial, Cijaralang and Batuhideung (Figure 2.3). These four villages scored consistently lower, having no knowledge of National Park regulations, boundaries, or awareness of conservation activities.

2.5.2 Does involvement in Javan rhino conservation activities affect the levels of awareness and support?

Most (70%) of the surveyed villagers who had been involved in conservation activities in some way was positive. However, outside of direct involvement, their overall lack of knowledge of national park and conservation management is cause for concern, particularly reflective in the poor community understanding of park regulations and knowledge of park boundaries responses. The open question asking community if it would like to contribute or be involved in conservation management planning of Javan rhino and the national park elicited a 100% yes response. This feedback being valuable to authorities wanting to improve community awareness and understanding of their activities and management intent (Haryono et al. 2015). A study of local community attitudes to the Gunung Halimun National Park in West Java, Indonesia, determined that lack of understanding of protected area concepts between local people and authorities creates ongoing challenges in achieving conservation objectives (Harada 2003). Local participation and regular communication with local people are key issues for ensuring more effective park management (Harada 2003; Triguro-Mas et al. 2010; Karanth & Nepal 2012; Aryal et al. 2017).

2.5.3 Level of support for Javan rhino conservation activities?

The responses emphasised despite involvement in conservation activity is viewed favourably and community wants to contribute, this does not necessarily correspond with increased awareness. Therefore, the hypothesis that community attitude to rhino conservation improves with awareness and involvement in conservation activities is not supported. Despite this, support was generally strong regarding community interest.

All communities were completely united in wanting more regular communication from the authorities. This study has provided valuable insight into the attitudes and approaches of local communities and the following recommendations are listed for consideration. Establish a community reference group in each village. A potential model could include four to six representatives, including the elected village leader as chairperson. The group would meet four times annually and would discuss and take community concerns and issues back to the authorities. Authorities would regularly communicate with these groups.

Recommendations that have been identified from this study include the instigation of a social skills training program, incorporating conflict resolution and diplomacy. Village leaders, clerics, and rhino protection staff and National Park rangers could be targeted for such training. Undertake National Park boundary and village precinct development assessments. This would include assessment of viable areas for the creation of alternative livelihoods for local people. For example, community forestry, carbon sequestration plantings, rhino food plant plantations, bee keeping (for pollination enhancement and for (profit/commodity), and options that allow rhino entry, including creating wetlands (possible tourism opportunity). Through an established community reference group, opportunities to develop projects, source funding and expertise to create alternative livelihoods for local people could be directed to appropriate organisations such as the World Bank. Establish an intelligence network across the local villages to gather information on illegal encroachment, logging, and wildlife poaching activity. This network would also examine current impacts of such activity in the National Park, to determine just how large the impacts are and where to direct effort. This network could feed into or be a component of the proposed community reference group model.

This study is the first to examine community attitudes and approaches to rhino management across all 19 villages and communities surrounding Ujung Kulon in a conservation research context (Widodo Ramono, personal communication, 24th March 2016). The data captured from this study will help inform national park managers and conservation planners of local community attitudes and understanding of current conservation activity and assist in identifying future risks e.g. human population growth and include community considerations regarding possible reintroductions of rhinos into former historic ranges. Studies such as this can also reveal what attitudes exist towards conservation activity, protected areas, or threatened species management, which may explain community behaviour (Lepp & Holland 2006).

Finally, attitudinal studies can inform management authorities and even government policy makers which factors influence attitude, which would greatly benefit prioritising areas of conservation action, such as community involvement in threatened species and protected area management.

Table 1 Village leader tenure and village leader/villager years of living in village.

Variable	Mean	Median	Mode	Std Dev
Village leader tenure (n=19)	4.789	1.7	0.7	6.020
Village leader years living in village (n=19)	33.531	39	0.7	19.046
Villager years living in village (n=57)	34.192	34	33,30,40	12.724
Combined village leaders/villagers' years living in village (n=76)	34.531	34.5	30,40	14.423

Table 2 Village leader information and 19 local village population data(n = 19) for the villages surrounding the eastern boundary of Ujung Kulon National Park (UKNP).

Village	2010 (pop)	2015 (pop)	Yrs in village	Yrs village leader	Village livelihood	Proximity to Ujung Kulon NP
Ujung Jaya	3581	3974	51	15	farming, fishing	borders UKNP
Taman Jaya	2500	2700	33	2	farming, fishing	borders UKNP
Cigorondong	2220	2488	48	4	farming, fishing	borders UKNP
Tunggal Jaya	3050	3167	41	4	farming, fishing	borders UKNP
Kerta Mukti	3737	3742	12	7 mths	farming, fishing	borders UKNP
Kerta Jaya	2284	3051	53	7 mths	farming, fishing	borders UKNP
Tangkil Sari	3452	3347	45	5	farming, fishing	borders UKNP
Sumber Jaya	3750	4161	57	13	farming, fishing	5 km from NP border
Cimanggu	2263	2831	7	7 mths	farming	borders UKNP
Cijaralang	1850	3098	19	17 mths	farming	5 km from NP border
Waringin Kurung	2811	2883	39	11	farming	borders UKNP
Ciburial	4853	5239	34	8	farming	5 km from NP border
Padasuka	4547	4876	40	7 mths	farming	borders UKNP
Kramat Jaya	1200	3027	27	21	farming, fishing	borders UKNP
Mangkualam	2115	2360	51	7 mths	farming, fishing	borders UKNP
Tugu	1342	1546	57	7 mths	farming, fishing	borders UKNP
Cibadak	2018	3020	7	7 mths	farming, fishing	borders UKNP
Batuhideung	2935	3427	11	7 mths	farming, fishing	5 km from NP border
Rancapinang	3091	5003	30	7 mths	farming, fishing	borders UKNP
Total = 19	52,599	63,936	av. 33.5	av. 4.78		

Chapter 3 Protecting an icon: Javan rhino frontline management and conservation

Figure 3.1 Image of two rhino protection staff installing a camera trap in Ujung Kulon National Park, West Java, Indonesia. Image: Steve Wilson.

Note: The peer reviewed, and accepted paper has been incorporated into **Chapter 3.**

Wilson, S.G., Biggs, D. & Kark, S. (2021). Protecting an icon: Javan rhino frontline management and conservation. *Oryx*, August/September 2021.

3.1 Abstract

Managers of threatened species in remote protected areas play a pivotal role in shaping the outcomes of management and conservation programs. The Indonesian island of Java supports the last remaining population of the Javan rhino *Rhinoceros sondaicus*, one of the world's most critically endangered mega-herbivores, with 74 individuals persisting in the wild in one location, Ujung Kulon National Park. Substantial resources are being invested in this single species management, as it is very difficult to monitor the Javan rhino in the rainforest and to assess whether past and current management actions have been successful. Understanding frontline staff insights into the outcomes of past conservation actions and required future actions are key in enhancing the outcomes of threatened species conservation actions. To study frontline staff perceptions to Javan rhino conservation, management actions and their outcomes, and operating environment, we surveyed 22 of 25 rhino protection staff and 14 of 16 National Park rangers. While staff perceptions of conservation outcomes were overall positive, there are key anthropogenic threats and challenges that rhino protection staff raised, which are inherent to the survival of the last persisting population. These range from habitat encroachment due to human population growth, and efficiency of fencing to transfer of disease from domesticated stock, mainly buffalo and goats to rhinos. Work that systematically addresses insights and concerns of on-ground staff in such remote areas can help identify important areas for future conservation actions and threat mitigations to save Javan rhino and other iconic and highly threatened species.

3.2 Introduction

The Javan rhino *Rhinoceros sondaicus* is listed on the IUCN's Red List as Critically Endangered (IUCN 2016). The species' wide-ranging historical range extended from north-eastern India, Bangladesh, Myanmar, Thailand, Lao PDR, Cambodia, Vietnam, and likely also southern China through to Peninsular Malaysia, Sumatra, and Java (Rookmaaker 1980; Grubb 2005). Whilst the Javan rhino's historical population numbers are unknown, in Java, there is historical evidence suggesting they were once common in parts of their range, such as that from Dutch tea planters in Indonesia, who viewed Javan rhinos as a pest and hunted them during colonial times (Dinerstein 2003). For example, in Java, between 1746-1747, a reported 60 Javan rhino were hunted, and between 1747-1749, an additional 526 Javan rhinos were hunted (Sody 1959, Hoogerwerf 1970).

Due to excessive hunting and habitat loss, Javan rhinos (Figure 3.2) have only survived in Ujung Kulon National Park (UKNP), which remained the only population (Hariyadi et al. 2011; Haryono et al. 2015, 2016; Payne & Yoganand 2017) (Figure 3.2). The IUCN/SSC Asian Rhino Specialist Group attributed Javan rhino decline to excessive demand for rhino horn/body products for the Chinese and associated traditional medicine trade (Khan 1989).

Figure 3.2: Male Javan rhino captured moving on camera trap in 2014. (Image: Courtesy Ujung Kulon National Park Authority).

Conservation of the last persisting population and its habitat is a major management priority for the species survival (Hariyadi et al. 2016). In Ujung Kulon and other parts of the world local participation and regular communication with local community are key in ensuring effective protected area and threatened species management (Harada 2003; Triguro-Mas et al. 2010; Karanth & Nepal 2012; Aryal et al. 2017; Moreto et al. 2017). Numerous challenges to Javan rhino conservation remain, with many anthropogenic pressures. For example, habitat encroachment due to human population growth and need for farming land to disease risk from domesticated stock (mainly water buffalo *Bubalus bubalis*), and vulnerability of the remaining rhino population. To mitigate these risks, in 2010, authorities launched the 5,100 ha Javan Rhino Study and Conservation Area (JRSCA) including installing an eight-kilometre-long rhino proof fence at the base of the eastern Gunung Honje range (Figure 3.3) to protect the habitat area, exclude domestic stock and keep rhino protected (Ellis 2010). The field work of frontline staff is critical to the successful management and conservation of the species.

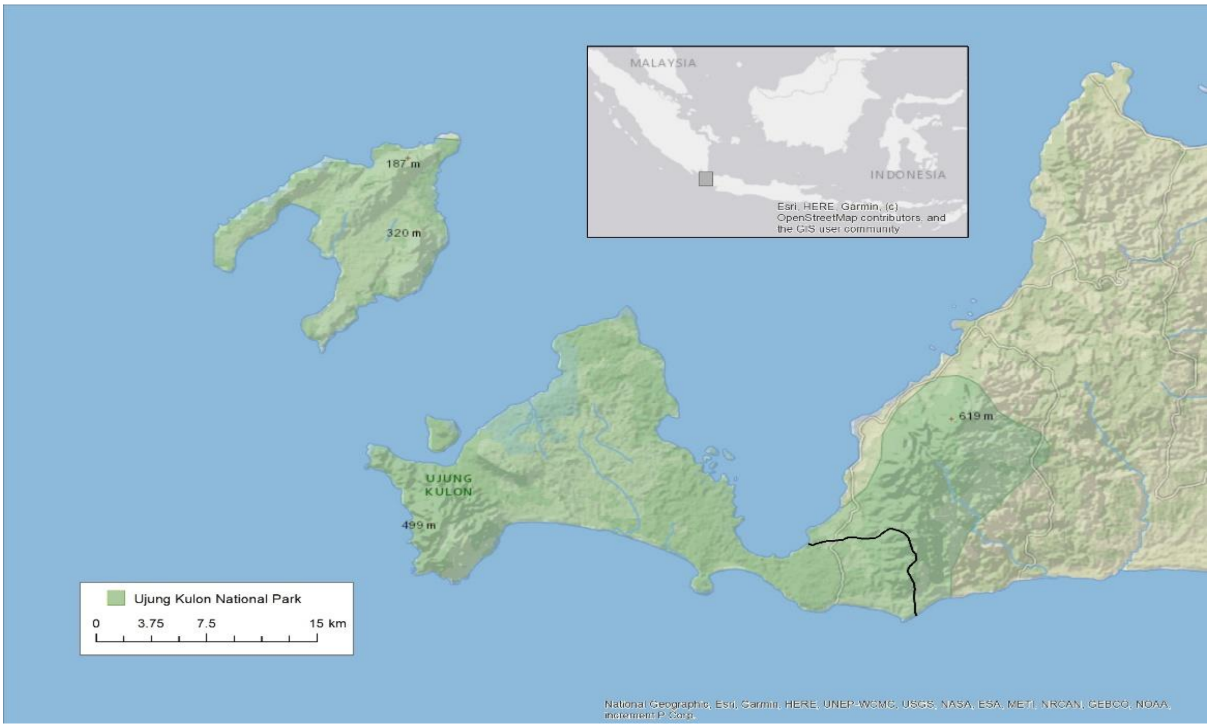

Figure 3.3: Map of Ujung Kulon National Park, West Java, Indonesia. (Map: Courtesy Ujung Kulon National Park Authority 6º44’48” S 105º20’1” E). Note: dark line indicates main rhino fence line bordering village areas.

However, their perceptions about management and conservation actions and their outcomes have not been evaluated, may help inform planning future actions. This study aimed to address this gap. The objectives of this study were to a) identify frontline management operations, including staff recruitment, training and patrol cycles; b) identify the perceptions of frontline staff to Javan rhino conservation, including the current operating and management environment; c) identify risks to rhinos and determine any gaps in conservation approaches; d) examine frontline staff perceptions of local community impacts and their understanding of national park management and conservation activities, and e) use these perceptions and informed opinions to support future management actions that can benefit conservation outcomes for the conservation and management of Javan rhino (Triguero-Mas et al. 2010; Moreto et al. 2017). To address these aims, we interviewed 14 of 16 national park rangers and 22 of 25 rhino protection staff (Figure 3.1) at their operational bases asking a series of themed focus questions that allow us to better understand frontline approaches to ongoing Javan rhino conservation and management.

3.3 Methods

3.3.1 Study area

The neighbouring communities living adjacent to Ujung Kulon National Park (UKNP), West Java, Indonesia (Figure 3.2), reside in the highly populated Banten Province, one of 34 provinces across Indonesia. Banten is the westernmost province on the island of Java, Indonesia. In 2019, the human population of Banten was officially estimated at 14,269,391 noting a population census is carried out every five years (Statistics Indonesia Banten Province 2019). The population of the 19 villages surrounding the eastern boundary of Ujung Kulon (Figure 3.4) has grown by 21.5% since 2010, increasing from 52,599 to 63,936 as of May 2015, a population increase of 11,337. This local population data was sourced from interviews undertaken during 19/5/2015 - 25/5/2015, with each of the 19 local village community leaders. As part of their leadership duties, village leaders annually record local population growth.

The 1998 instigation of rhino protection units (RPUs) (Ramono et al. 2009) in Ujung Kulon has effectively stopped poaching of rhino (Nardelli 2016), for over 30 years but remains an ongoing risk given the small population size. Rhino poaching persisted in Ujung Kulon up until the late 1980’s and early 1990’s (Lessee 1994; Van Strien & Sadjudin 1995). The Indonesian Rhino and International Rhino Foundations currently employ and manage the Javan rhino protection unit staff and work in partnership with Ujung Kulon rangers, who in turn, are employed by the Indonesian government through the Ujung Kulon NP Authority (Ramono et al. 2009; AsRSG 2012; Haryono et al. 2015, 2016).

Today, Ujung Kulon Authority’s focus is *in situ* protection of Javan rhino supported by a policy of non-disturbance. The total global population of the Javan rhinos (74 individuals) (Gokkon 2020) persists only in this one park encompassing 30,000 ha of terrestrial area (Indonesian Ministry of Forestry 2010). Therefore, management in the region is crucial towards the species persistence. Any increase in the rhino population requires the strong and continuing protection from anthropogenic pressures such as poaching, harvesting and habitat encroachment. Rhino conservation is supported by active patrolling of the Ujung Kulon peninsula since 1998 (Figure 3.3) and park environs by rhino protection units and national park staff to identify and control for illegal activities (Haryono et al. 2015).

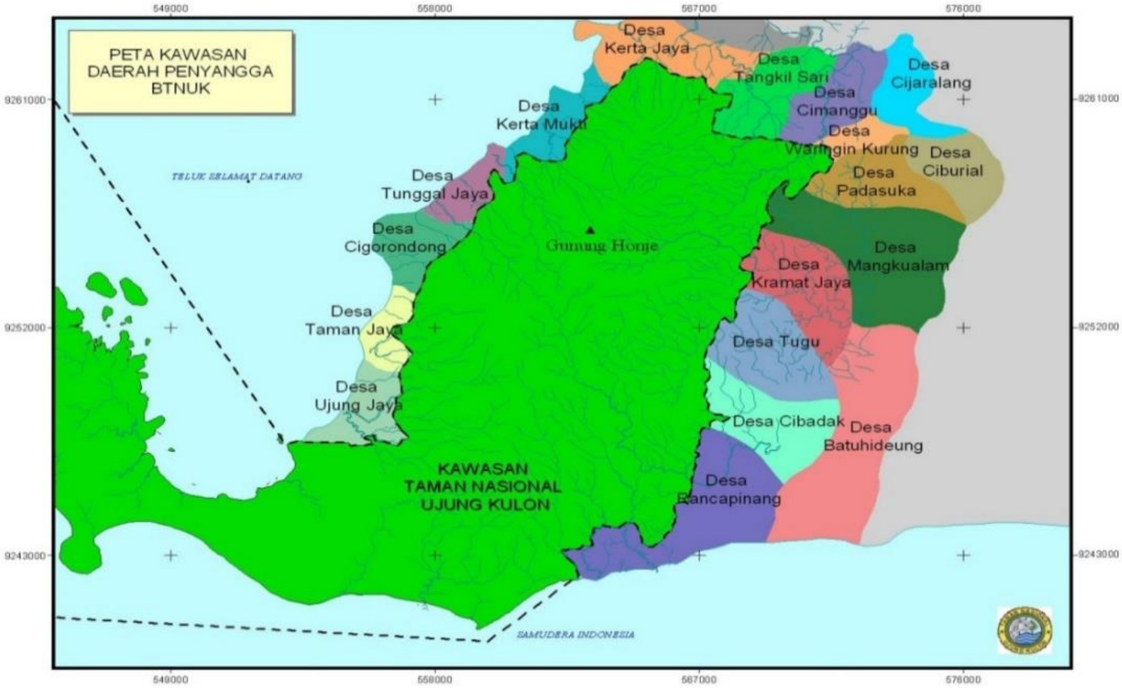

Figure 3.4: Map of the 19 village precincts surrounding eastern section of Ujung Kulon National Park. (Map: Courtesy Ujung Kulon National Park Authority 6º44’48” S 105º20’1” E).

Five frontline units (four staff each) were operational in Ujung Kulon NP at the time that this study began in 2015. Each unit has three members recruited from local communities, and one national park staff member who is authorised to make arrests. Four frontline units operate across the western peninsula area (main rhino population), the fifth unit operates across the eastern Gunung Honje area (Javan Rhino Study Conservation Area). The Ujung Kulon rainforest landscape has limited accessibility; hence all *in situ* patrol activity is currently undertaken on foot, with staff regularly camping out on extended patrols that vary between five and 20 days per month. Patrol tasks are determined by the level of threat as well as assigned and routine activities. Monitoring of the rhino population and other endangered species, such as the Javan leopard *Panthera pardus melas* is a core function of the frontline patrol units (rhino protection unit and national park staff) and undertake duties such as camera trap surveillance, rhino track recording and dung collection (for DNA sampling) across the park. Patrol operations of frontline units aim to have staff in the field at most times, with the exception being the December - January monsoon period, when access to most of the park becomes difficult due to heavy rainfall.

3.3.2 Surveys of National Park rangers and rhino protection unit staff

During September 2015, 22 of 25 rhino protection unit staff and 14 of 16 UKNP rangers completed dedicated survey questionnaires and were interviewed by SW.

The interviews were conducted with national park management and Indonesian Rhino Foundation support and with the assistance of an Indonesian interpreter. The questionnaire was first developed in English and then translated into Bahasa Indonesia. We pre-tested the questionnaire with a rhino protection staff manager, a rhino protection unit staff member, and a national park ranger, all of whom came from local villages, as well as the interpreter. The questionnaire included 42 questions (see Figure B.1, Rhino protection unit and national park ranger questionnaire, Appendix B). The first 15 questions focused on determining the rhino protection unit and ranger operating environment such as tenure (Table 1).

The following 27 questions included eight open focus questions related to staff knowledge of community understanding of conservation activities and perceived risks which required the participant to respond on a four-point Likert scale (2-5) (see Table B.2, Appendix B), noting the 1 value on the Likert scale = 0 (do not know) response. Interviews took approximately 30-40 minutes each and were conducted between 15/9/2015 - 22/9/2015 with the help of a local interpreter at the UKNP operations headquarters in Taman Jaya, and rhino protection base offices in the villages of Cigorondong and Ujung Jaya. These three villages are located on the western edge at the Gunung Honje eastern section of UKNP (Figure 3.4). Staff were interviewed individually, except for one group of three staff being interviewed together due to time constraints and need for these staff to go on active long patrol. For consistency, the same interpreter helped in all interviews. We used chi-square (χ^2) tests of independence to examine differences in their perceptions of local community views on conservation amongst the frontline staff (rhino protection and national park staff), then a comparison of frontline (all staff), and specifically rhino protection unit and national park staff (Table B.2) responses to the eight Likert scale questions. Analysis predictor variables included frontline staff perspectives of local community knowledge of Javan rhino conservation status, rhino behaviour and ecology, knowledge of conservation initiatives, differences in perspectives of rhino protection staff and national park rangers and views of risk factors.

3.4 Results

Overall, the surveyed frontline staff included 36 people, all of whom are male. Staff length of service results for rhino protection staff in their organisation averaged 5.4 years (SD ± 3.75) and for national park staff was 21.9 years (SD ± 8.63) (Table 1). Seventeen (77%) of the 22 rhino protection unit staff came from villages within the Ujung Kulon precinct (19 villages) while five came from villages outside of the Ujung Kulon area. Eight (57%) of the 14 national park rangers came from the villages Taman Jaya (n = 5), Ujung Jaya (2) and Sumur

(1) within the Ujung Kulon precinct, while six of the rangers came from outside the Ujung Kulon area. Most rhino protection staff (86%) were recruited from local villages near Ujung Kulon, including Cibadak (1), Kerta Jaya (1), Kerti Mukti (1), Rancapinang (2), Cigorondong (2), Ujung Jaya (5) and Taman Jaya (6). Four rhino protection staff (14%) came from other areas including Radar Lampung (1), Indramaya (1), Pandelang (1) and Panimbang (1). Responses to the eight Likert scale questions (see Table B.2 in Appendix B).

Responses to questions on patrol cycles, recruitment, and training (Table 3). The question (Q24 Table B.2) ‘Do local community have knowledge of Javan rhino ecology and behaviour’ found both rhino protection and national park staff acknowledging community knowledge of rhino was low based on responses on a four-point Likert scale score, 2.71 (no knowledge) to 3.13 (some knowledge) out of 5. Likert responses to the question (Q32 Table B.2) ‘Community involvement in conservation activities such as arenga palm control being a positive exercise’ also produced low results, scoring 2.35 (not important) and 3.36 (some importance) out of 5. When asked, rhino protection and national park staff suggested community involvement in arenga palm control as a way of getting palm leaves for the roofs of their houses. Community, despite involvement in arenga control activities, did not understand the negative impacts of the palm and reasons for its clearance. Twenty-four staff (67%) were positive about the recently installed rhino fence and its purpose (i.e. to protect rhino from conflict and disease). However, during post survey discussions, some staff expressed concern of local community regularly illegally breaching the fence to graze buffalo and domestic stock.

The rhino protection staff drew statistically positive responses regarding ‘If conservation activities such as the newly erected fence and community involvement in arenga palm control work was working’ drew less confidence from them compared to national park staff (Q32, Q27 Table B.2). This may be due to rhino protection staff having more direct involvement in fence protection, breaches of the fence by local livestock, arenga palm control work and dealing with community conflict. National park staff have broader management issues to contend with, such as park administration and visitor management. Additionally, national park staff were found to have significantly more experience, averaging 21.9 years than rhino protection staff who averaged 5.4 years. On average, national park staff were more reserved in their question responses, which may be related to their years of experience on what is effective and what isn’t. For example, the question (Q27 Table B.2) ‘Will the fence make a difference to Javan rhino conservation’ drew a stronger statistically significant response from rhino protection staff (mean 4.68, $P = 0.000$), compared to the national park staff (mean 3.5, $P = 0.042$). Overall, clear differences in perspectives between the national park and rhino protection unit staff were observed. Therefore, our results did support the hypothesis that national park rangers with more years of experience than rhino protection unit staff will have different perspectives on the conservation of Javan rhino. Several threats were raised by frontline staff included the expansion of rice fields and gardens, followed by illegal collection of firewood, forest resources, wild honey, birds, fish, and grazing of stock (Figure 3.5). Staff acknowledged human population growth in and around Gunung Honje and broader west Java was a risk to both the National Park and rhino (Q40, Table B.2). In relation to threats, (Q34 Table B.2) the question of ‘Whether local villagers assist with intelligence gathering regarding poaching and other illegal activity in the national park’ elicited a 100% “yes” response from staff, who did not elaborate further on this question.

A mixed response came from staff on the question on what the risks of improved roads and infrastructure to the national park and its wildlife are (Q41, Table B.2), with 13 (36%) of staff saying illegal activity will increase, and 23 (64%) were unsure of the impacts. With respect to motivation and training, 86% of rhino protection unit staff joined to protect the Javan rhino, and 64% of national park staff joined to protect the national park and Javan rhino (Table 3). The training environment was explored, and questions were asked on the benefits and types of training. For example, 100% of staff said the training was beneficial and had helped them, and they had good opportunity to learn a broad range of skills such as navigation and survey techniques.

When the frontline staff patrol operating environment was examined including current patrol cycles, patrol destination determination, and observations of Javan rhino and other wildlife, we found that patrol cycles varied between 5-20 days and patrol destination is determined by level of threat as well as assigned and routine duties (Table 4). For example, 82% of rhino protection unit staff spent 20 days of every month on active patrol, and 36% of national park staff supported rhino protection units for 20 days per month as well. All staff said they regularly see other wildlife and 78% of staff had observed rhino. Frontline staff felt that local community members had a substantial impact on UKNP and its resources, including poaching (Refer Table 5). For example, 29 (81%) of staff said illegal poaching of biota was of concern, 7 (19%) of staff were more specific stating poaching of birds, honey, sea turtle, shrimp and rusa deer was an issue.

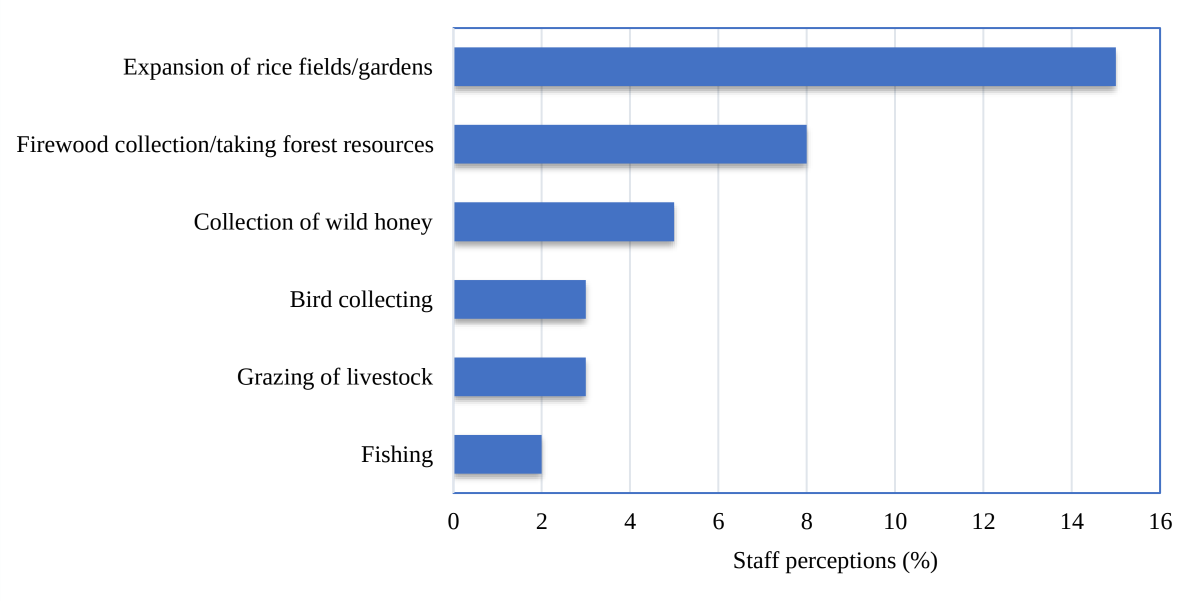

Figure 3.5: Frontline staff (n=36) perceptions of local community reliance on Ujung Kulon National Park natural resources in order of threat (% of 36 staff perceptions).

Responses to questions related to frontline staff commonly encountered issues such as poaching and illegal activity, encroachment into the national park and local community conflict were listed in order of concern (Figure 3.6). When asked about commonly encountered issues such as illegal fishing, bird collecting, wild honey and firewood collection, staff indicated increased protection was needed due to the combined collective impact of these common issues on rhino and habitat. Conflict with local community was noted by six rhino protection unit staff. Conflict issues included illegal grazing of domestic buffalo, forest timber extraction, and community damage to the rhino fence (to allow domestic livestock access). Poaching of Javan Banteng *Bos j. javanicus* was noted as an ongoing issue by two of rhino protection unit staff and one staff member said rumour of illegal activity was a commonly encountered issue (Figure 3.6). Staff listed competition with other herbivore species such as banteng as a concern.

It remains unclear if banteng is competing with rhino for food and or space (Khan et al. 1997; Muntasib 2000), however, recent studies indicate territorial competition between banteng and Javan rhino may be occurring (Harjanto 2017). Frontline staff concern about the range of threats and risks to rhinos have been raised by other authors. For example, other prominent threats to the rhino include the single population being open to outbreaks of poaching, disease risk from domestic stock (Haryono et al. 2015, 2016), and natural stochastic events in the form of volcanic activity or tsunami, as in the 1883 Krakatoa eruption (Van Strien & Rookmaaker 2010; Emslie et al. 2016; Setiwan et al. 2017).

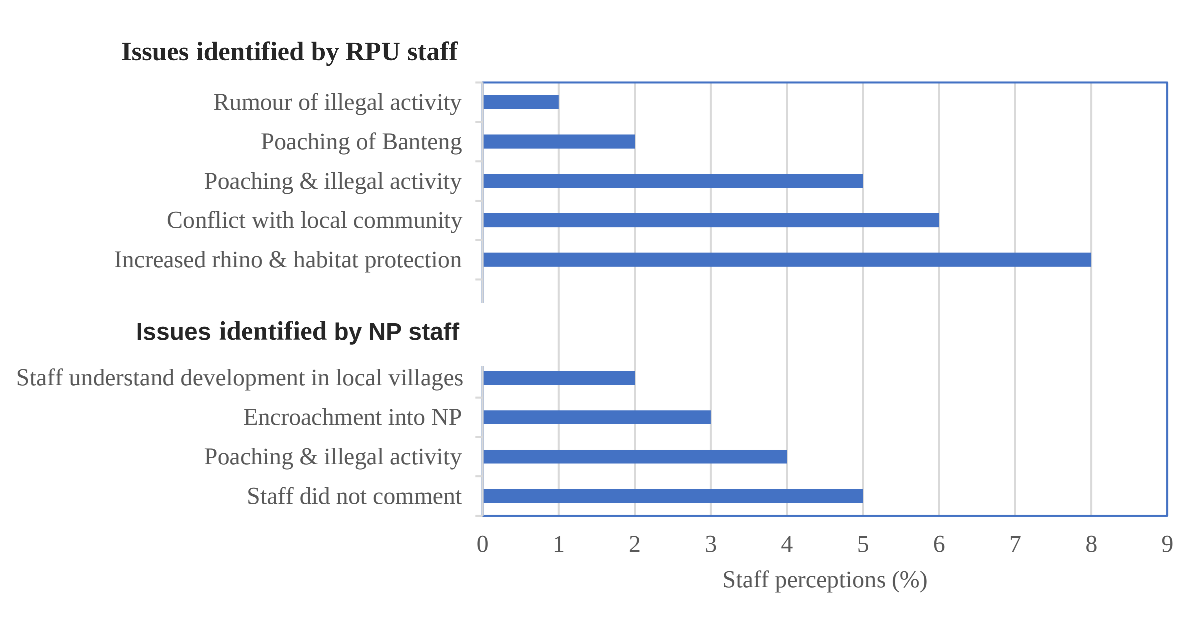

Figure 3.6: Common issues identified rhino protection (RPU) staff in order of concern (% of 22 staff), and National Park (NP) staff (% of 14 staff).

3.5 Discussion

Human-wildlife conflict is an ongoing concern and acknowledged as a challenge to conservation objectives worldwide (Acharya 2018). Globally, the extent of these conflicts and interactions vary considerably (Rissman et al. 2007; Angelicic 2015). Negative interactions occur when humans and wildlife compete for food resources (Distefano 2015) and space (Carter et al. 2012). This often results in either the killing of wildlife (Paudel et al. 2012), death or injury to people (Gurung et al. 2008), crop damage and associated destruction (Thapa 2010; Sapkota et al. 2014), property damage (Peterson et al. 2010) and losses of livestock (Dar et al. 2009; Karanth & Nepal 2012).

Effectively engaging local communities and influencing them to embrace conservation initiatives in such environments is no easy task. Globally, rhino populations continue to be threatened by human population growth, habitat loss and ongoing development in and around rhino habitat (Aryal et al. 2017). For example, in Nepal despite recently celebrating its fourth year of zero poaching (Acharya 2016), and 21% increase in its rhino population (DNPWC 2015) has moved to increase its cross-border alliances, sharing intelligence and experiences to share responsibility with other rhino-range countries given ongoing threats (Aryal et al. 2017). Nepal is a country with acknowledged high biodiversity values (Woodroffe et al. 2005; Dickman et al. 2011) with 23.24% of its land mass in protected areas and approximately 29% of its forested land is managed by community forestry practices (Acharya et al. 2016).

Despite Nepal’s significant conservation successes, conflicts still remain between wildlife and the human population and strategies need to be adaptive to adjust to limited resources for both wildlife and people (Woodroffe et al. 2005; Dickman et al. 2011; Acharya et al. 2016).

3.5.1 Are current conservation approaches in Ujung Kulon sufficient to meet the perceived requirements for the ongoing protection of Javan rhino?

Frontline staff acknowledged the current conservation and management approach was working positively. Despite this success, staff raised multiple challenges that remain for conservation inherent to the survival of the small persisting rhino population. These included ongoing anthropogenic threats and risks, ranging from habitat encroachment from human population growth, local development pressure to disease impacts on rhino from domestic stock. Rhino poaching was not identified as a major threat, understandable given over 30 years of frontline patrolling in reducing this threat. Several gaps and key areas for conservation action were identified, including threat mitigation, aimed at reducing the identified risk of disease transfer and increased support to community education and awareness programs.

This study has highlighted that whilst a conservation program can be viewed as effective, the value of frontline staff input into conservation management is an asset, offering insight that may reduce future risk impacts and improve conservation objectives. Frontline staff acknowledged the inception of rhino protection units and working partnership with the Ujung Kulon National Park Authority, is meeting the needs of rhino protection. Staff attributed this success to regular patrol cycles and high awareness of such in local communities. Despite this success, staff noted challenges remain notably natural resource competition. This concern over natural resource competition and use is also documented at a higher strategic level by rhino range countries. For example, the Strategy and Action Plan for the Conservation of Rhino in Indonesia (Rhino Century Program 2007-2017), is the Indonesian Government’s official conservation policy for the country’s rhino populations (Indonesian Ministry of Forestry 2007). Anthropogenic pressure driven mainly by poverty (encroachment and need for more agricultural land) is putting pressure on rhino populations and habitat (Indonesian Ministry of Forestry 2007; Haryono et al. 2016). For example, during 1979-1980 and again be 2010-2011 (Widodo Ramono, personal communication) the Indonesian Government removed over 300 illegal settlers living within Ujung Kulon’s eastern Gunung Honje area.

This removal has reduced, but has not eliminated, ongoing threats due to illegal activities engaged in by local communities largely for subsistence reasons (Haryono et al. 2016). A study of local community attitudes to the Gunung Halimun National Park in West Java, Indonesia identified a lack of understanding between local people and authorities of protected area concepts creates challenges in achieving conservation objectives (Harada 2003). The issue of balancing such objectives and the needs of local community is challenging (Karanth & Nepal 2012; Allendorf & Gurung 2016). Frontline staff residing in local villages can inform and educate local community through their presence.

3.5.2 Rhino protection and national park staff view on the main threats to Javan rhino?

Frontline staff perceptions of the biggest risks to rhinos moving forward included concerns of increased human population growth, encroachment, improved infrastructure, and development, highlighted the importance of understanding the effectiveness of conservation initiatives. For example, community involvement in Javan rhino conservation work such as arenga palm control, was noted as being a positive exercise, however, staff identified a need for increased education and awareness to community of the conservation benefits to the clearing of arenga palm. Given the focus of patrolling is in core Javan rhino habitat areas, it remains unclear as to how much impact human population growth is occurring in areas of the park that see little regular patrol activity. The national park border areas where they interface with village cultivation and agricultural land is worth examining, noting an incremental edge effect into national park land would be occurring and exacerbating habitat decline (Gunawan et al. 2012).

Despite ongoing issues with illegal settlements in the National Park, none of the staff commented on this as a threat or issue (Gunawan et al. 2012). The combination of limited law enforcement, intelligence services and poor penalty outcomes for offenders was viewed by staff as a frustration to their work and an ongoing risk to rhino conservation. This frontline management frustration is not uncommon in many rhino range countries. For example, in Mozambique strict penalties for rhino poaching and possession of rhino horn are virtually non-existent due to weak legislation and penalties and poaching as a crime is considered only a misdemeanour offence (Save the Rhino International 2016c). Staff acknowledged rhino poaching is an ongoing threat, however, staff cited the biggest threat and risk to Javan rhino was disease from domestic livestock, and most staff noted the importance of the new fence as a preventative structure.

The disease risk is well documented, as Ujung Kulon National Park experiences periodic tending of domestic livestock, mainly buffalo and goats on the national park fringes and within the park (Van Merm 2008; Haryono et al. 2016). The tending of livestock in or near the national park increases the risk of disease being transferred from livestock to wildlife, especially large herbivores such as Javan banteng *Bos j. javanicus*, Javan deer *Rusa timorensis russa*, red muntjac *Muntiacus muntjac*, Javan wild pig *Sus scrofa vittatus* and Javan rhino.

Diseases have been linked to past Javan rhino deaths, including *haemorrhagic septicaemia*, anthrax, and *trypanosomiasis* (Mohamed et al. 2004; Rachet et al. 2011). Disease transmission from buffalo and other domestic livestock appears a plausible hypothesis for these rhino deaths because rhino horns were intact with no evidence of poaching (UKNP 2012). During 2017 Indonesian authorities tested 104 water buffalo *Bubalus bubalis* from the Rancapinang village precinct, one of 19 villages that reside around the eastern edge of Ujung Kulon for disease prevalence (Khairani et al. 2018). This disease surveillance was testing for *Haemorrhagic septicaemia*, *Brucellosis, Trypanosoma evansi* (surra), and intestinal parasites. Blood (serum and whole blood), faecal samples, nasal swabs and soil samples were examined. The blood parasite *Theileria* sp. was identified in 9.61% (10 individuals) of the buffalo population, 29.8% (31 individuals) contained intestinal parasites including *Fasciola* sp., *Paramphistomum* and *Strongyloides* (Khairani et al. 2018).

The Department of Animal Disease and Veterinary Public Health at Bogor University, Banten Province authorities were surprised to discover a high prevalence of *trypanosomiasis surra* in 87% (91 individuals) of the buffalo population. Anthrax, *Haemorrhagic septicaemia*, and *Brucellosis* were not found in this testing (Khairani et al. 2018). The prevalence of *trypanosomiasis surra* in the water buffalo population is of major concern given this result occurred in just one tested village area, with the other 18 villages yet to be tested an escalated potential risk of cross-infection to Javan rhino and banteng *Bos javanicus* populations remains. A well-managed vaccinated domestic buffalo population around Ujung Kulon would minimise disease spread to Javan rhino (Khairani et al. 2018). The disease risk highlights concern from rhino protection staff on the question of will the fence make a difference to Javan rhino conservation and identified the ongoing issue of the need for increased community compliance regarding domestic stock fence breaches. This could be addressed via increased enforcement, supported by an education and awareness program highlighting the risks of disease impacts on local wildlife, including rhino.

3.5.3 Frontline staff perspective of local community impacts, and their understanding of national park management and conservation activities.

Multiple communities neighbouring Ujung Kulon face daily challenges owing to the remoteness of their location, living a mostly subsistence existence (farming/fishing) and enduring poor socio-economic services. For example, power outages are a common occurrence, coupled with ongoing transport and access issues. The main access road and smaller feeder roads that edge around the National Park's boundary quickly deteriorate with distance from the township of Sumur (Figure 3.3). In extended wet periods the road network becomes virtually impassable, slowing motorbike, foot, and vehicular traffic to slow walking pace. Hence road conditions dominate and influence village life. Staff responses to risk related questions (Q41 Table B.2) 'Impact of improved roads and infrastructure on the National Park' staff may have been conflicted about responding openly to the benefits of improved roads and infrastructure knowing the potential risk of increased illegal activity on rhino and park resources. This is understandable given the impact poor roads have on local community and village life. The growing human population around Ujung Kulon is a significant risk given there is no additional land available to support this growth. Competition between the national park, rhinos and human settlements will continue, unless viable alternative livelihoods can be found, which could include frontline conservation work (Gunawan et al. 2012; Haryono et al. 2016).

3.5.4 Benefits of employing rhino protection and national park staff that come from local villages, and does coming from a local village assist them in their work?

Staff acknowledged that coming from a local village and its proximity to UKNP offered opportunities for local people to be potentially employed as a frontline member of either rhino protection units or the national park staff. Nearly seventy percent of staff stated coming from a local village did assist their duties, without elaborating why, the remaining 30% of respondents were unsure in responding to this question. However, on the related question regarding if community ever assisted staff with intelligence gathering re poaching or negative activity in the park the response was 100% yes. We suspect some staff preferred to respond with an unsure response given sensitivities around local people who they share a village and possible relationship with and having to implicate them for undertaking in illegal activity. Staff did acknowledge there was strong importance placed on the involvement of local community in conservation activities such as arenga palm control. Those staff would be well placed to influence local community not only regarding the benefits to locals gaining work, but also the work itself and its role in assisting the conservation of Javan rhino and their habitat. Beginning 19/05/2015 to 26/03/2016 I interviewed four local people, including each village leader from each of the 19 villages that reside around the eastern end of UKNP. The most informed communities regarding knowledge of the conservation effort came from the villages of Ujung Jaya, Taman Jaya and Cigorondong (Figure 3.4) which averaged 3.4 (some knowledge) on the Likert scale (2 no knowledge to 5 high knowledge). This may be due to community being more likely to interact with National Park and rhino protection unit staff based at the UKNP Authority operations headquarters in Taman Jaya and the rhino protection staff bases situated in Cigorondong and Ujung Jaya. UKNP activities including routine patrolling and conservation management activities such as arenga palm control and plant propagation and tree planting are coordinated out of these bases. National Park and rhino protection staff live in these local villages, increasing communication channels of sharing conservation and park activity information with locals.

3.5.5 Implications for rhino management

The outcomes of this study can be directed to increase conservation actions that deliver improved outcomes for frontline management of this highly threatened mammal and provide a model for other species with focal protection units and located in areas around which rural human populations are active. The value of frontline staff insight into conservation management and effectiveness offers practical exposure to the issues perspective and real insight that may reduce future risk impacts and improve conservation outcomes, especially when species are in high risk of extinction and located in remote areas. One of the key challenges facing managers of frontier protected area and conservation areas is the way natural resources are managed within central government systems.

Since 2000, the Indonesian Government has decentralised and allocated much of the responsibility for the management of natural resources to local provinces and districts (Indonesian Ministry of Forestry 2007). The high priority given to economic growth in Indonesia, has led to policies driven by local short-term economic growth objectives, with little consideration to conservation needs. This has resulted in substantial increases in encroachment into protected areas, including some conversion of protected land into agricultural land (Indonesian Ministry of Forestry 2007; Gunawan et al. 2012). Based on frontline staff responses, we provide recommendations for management of rhinos in Java. The research identified that local communities should understand (and preferably own) the conservation objectives as outlined by authorities. An ongoing community education and awareness program will assist in building this understanding.

The 2016 instigation of a dedicated four-person community engagement unit is an important step to building stronger links and awareness in local communities. As acknowledged by more than half of frontline staff, the ongoing risk of disease from domestic stock to Javan wildlife is significant. The instigation of an annual domestic stock vaccination program across all 19 villages in the Ujung Kulon precinct is warranted. Supporting this action, undertake regular soil and faecal analyses to identify the presence, location, and type of pathogenic agents both within local villages and the National Park and develop an emergency plan in the event of a disease outbreak. Additionally, an education and awareness program be instigated to highlight the risks and benefits to both domestic animals and local wildlife of such an initiative. As a biosecurity measure, a stock fence be built with gates across the narrow isthmus area (1.5 km wide) separating the peninsula from the eastern Gunung Honje area of the park which can be closed off in the event of a disease outbreak (Figure 3.3). This fence would at least contain any disease outbreak from infiltrating the main peninsula rhino population. Outside of a disease outbreak the fence would remain open to allow natural movement of animals. Regular risk assessments should be undertaken by authorities to review current and future risks and assess their ability to respond to conservation issues. A risk assessment would also include a review of staff training needs. A long-term strategy to create buffer zones around Ujung Kulon should be examined. Buffer zones would create areas that could be used by, for example, community's water buffalo, thus reducing the illegal use of Ujung Kulon for wallowing and grazing.

This work provides the first study of frontline staff perspectives and insight of Javan rhino conservation and management. Beyond frontline staff key responsibilities of surveillance, monitoring and protection of Javan rhino and the park. The value of this study is threefold. Firstly, participants can provide frontline assessment of current approaches and threats. For example, staff acknowledgement of the fence as a preventative structure and the associated risk of disease spread from stock to rhino remain high risk concerns. Secondly, this information can be used by authorities and conservation planners to improve and prioritise management actions. Thirdly, given that interviewed staff live in local communities, understand local community impacts and insight may reveal opportunities to improve relationships and develop conservation-based programmes with local community input. This holds true for not only Ujung Kulon rhino protection and National Park staff, but also for protected area management in similar contexts elsewhere.

This study has highlighted that whilst a conservation program can be viewed as effective (e.g., rhino poaching has been stopped), the value of frontline staff input into conservation management is an asset, which has offered unique insight that potentially reduce future risks and ultimately achieve conservation objectives.

Table 1 Rhino protection unit and national park staff (n = 36) years of service.

Variable	Mean	Median	Std Dev
All frontline staff years of service (n = 36), range (0.5 months - 35 years)	1.847	8	10.132
How long have you been a member of the rhino protection unit? (n = 22)	5.431	5.5	3.755
How long have you been a national park ranger? (n = 14)	21.928	25	8.633

Note: Table B.2 Responses to eight Likert (2-5) questions examining differences in their perceptions of local community views on conservation for all frontline (both rhino protection and national park rangers), individual rhino protection unity and NP staff. Chi-squared (χ^2) tests for independence (n = 36) is shown comparing the groups, refer Appendix B.

Table 2 Summary of frontline (rhino protection unit (RPU) and national park (NP)) staff recruitment and training question responses (n = 36).

Questions	Staff comments	No & % of frontline (RPU & NP) staff responses
What attracted you to become part of the RPU/UKNP team?	To protect Javan rhino	19 (86%) RPU staff
	Joined for money	2 (9%) RPU staff
	To learn about rhino	1 (4%) RPU staff
	Protect rhino and NP	9 (64%) NP rangers
	Proud to serve	2 (14%) NP rangers
	Joined for reliable job, protect marine areas, and help community	3 (21%) NP rangers
How were you recruited?	Via application and offered positions	28 (78%) via application and eventual selection, 8 (22%) had applied and were offered positions
What training have you completed?	Navigation, survey techniques, survival, physical education, intelligence gathering, community outreach, protection, tourism guiding, GIS, patrol, animal behaviour, DNA sample collection (dung), plant propagation, leadership (Level II), wildlife and habitat management, first aid, field camera technology and recording	Note: all frontline staff were given the opportunity to undertake training across the suite of skills-based subjects on offer and to specialise in areas of interest.
How has it (training) helped you on the job?	Increased knowledge, opportunity to study and learn	100% of all frontline staff said their training has helped them on the job

Table 3 Summary of frontline (rhino protection unit (RPU) and national park (NP)) staff to Patrol operating environment and observations of wildlife, including Javan rhino (n = 36).

Questions	Staff comments	No & % of frontline (RPU & NP) staff responses
What is your current patrol cycle and how long do you go out for?	20 days per month	18 (82%) RPU staff
	15 days per month	4 (18%) RPU staff & 5 (36%) NP rangers
* RMU (rhino monitoring unit - *in situ* remote camera management team)	5 days per month (RMU)*	3 (21%) NP rangers
	10 days per month	2 (14%) NP rangers
	7 days per month	2 (14%) NP rangers
	5 days per month (marine patrol)	10 (71%) NP rangers
How is the patrol destination determined?	By level of threat as well as assigned and routine duties	100% of staff stated this
Do you ever see Javan rhino, if yes in what situation? What was the animal doing?	Seen in forest, or in wallow, sleeping, wallowing, swimming, and standing Observed behaviours, walking, feeding, one observation of rhino feeding on salt sprayed vegetation on the beach	28 (78%) of staff said they had seen rhino 8 (22%) of staff said they had not seen rhino yet
Do you ever come across other wildlife, if yes which species?	Banteng *Bos j. javanicus*, Javan leopard *Panthera pardus melas*, Javan gibbon *Hylobates moloch*, Dhole *Cuon alpinus sumatrensis*, Javan langur *Presbytis c. comata*, saltwater crocodile *Crocodylus porosus* and Javan fishing cat *Prionailurus viverrinus rizophoreus*	100% of staff said yes, they regularly come across many species

Table 4 Frontline staff perspective of current conservation approach and impact (n = 36)

Questions	Staff comments	No & % frontline staff responses
In terms of poaching activities what do you find is the most common issue you come across?	Staff interpretation of biota is bush meat (e.g. monkey, deer, wild pig) and vegetable material (e.g., bamboo, forest fruits, fungi). Staff noted community relied on NP resources in some way	29 (81%) of staff said illegal poaching of biota 7 (19%) of staff stated poaching of birds, honey, sea turtle, shrimp and rusa deer
Does coming from a local village assist your duties?	Coming from a local village and its proximity to the NP offered opportunities, e.g. activities such as. arenga palm control	25 (69%) of staff that came from local villages said yes, but in most cases did not elaborate why 11 (31%) of staff were unsure
Given no rhinos have been poached since 1994, why do you think the rhino protection (RPU) program has been successful?	Active patrol work, increased monitoring, intelligence networks and socialisation with community has helped	100% of staff attributed this to regular patrol cycles and high awareness of such in their local communities.
Is there anything you believe the RPU units could be doing that they are not doing now?	Combination of limited law enforcement, and poor penalty outcomes for offenders was viewed by staff as a frustration and risk	100% of staff acknowledged the current management structure and approaches were working and meeting the needs of rhino protection.
What do you see as the biggest threats to Javan rhino moving forward?	Disease risk from domestic stock to rhino	19 (53%) of staff
	Human population growth, consequent need for land, and loss of habitat	8 (22%) of staff
	Need for stronger penalties for illegal activities as ongoing threats	7 (19%) of staff
	Decline in rhino genetic variation as an ongoing threat	2 (5%) of staff

Chapter 4 Understanding the implications of Arenga palm *Arenga obtusifolia* dominance for the conservation and management of Javan rhino

Figure 4.1 Image of cleared arenga palm *Arenga obtusifolia* site in Ujung Kulon National Park, West Java, Indonesia showing regrowth of rhino food plants. Image: Steve Wilson.

4.1 Abstract

Only 74 Javan rhinos *Rhinoceros sondaicus* remain on Earth, persisting in a single population in their last stronghold in Ujung Kulon National Park, West Java, Indonesia. Human encroachment and the increasing dominance of arenga palms *Arenga obtusifolia* are key factors impacting this rare species' persistence. Arenga palms have substantially expanded in the region since the explosion of the Krakatoa (Krakatau) Volcano in 1883 and now dominate the rainforest canopy in many areas of the park, substantially limiting the growth of native rhino food plants and available rhino foraging activity and threatening Javan rhino persistence. However, the impacts of arenga palm management on rhino activity and their conservation prospects has not been studied. To fill this gap, I set up a large-scale experiment in eastern Ujung Kulon in which all arenga palms were manually cleared. This included 15 experimental and 15 control plots each 15 x 1 ha in size. I monitored the impact of arenga palm removal on both native vegetation recruitment and post clearing visitation frequency of Javan rhinos. I found that arenga palm removal led to increased richness and abundance of native Javan rhino food plants and a rapid increase in rhino visitation to cleared sites that were previously avoided by the rhinos. Within five months of clearing of the arenga palms, the experimental sites included 67 rhino food plant species belonging to 37 plant families compared with no native plants in any of the 15 control sites. Furthermore, all arenga palm sites were visited by Javan rhinos over the two-year recording period following the arenga clearing compared with no visitation at all before these sites had been cleared. These findings suggest for the first time that rhino habitat manipulation and clearing of arenga palm in rainforest patches is an important management technique for increasing the remaining Javan rhino foraging habitat and enhancing the persistence of the highly threatened Javan rhino.

4.2 Introduction

As one of the rarest mega-herbivores on Earth, the Javan rhino *Rhinoceros sondaicus* currently persists only in a single peninsula, namely in Ujung Kulon National Park in Western Java, Indonesia (Emslie et al. 2019). One of the main threats to the remaining 74 Javan rhinos (Gokkon 2020) is their limited suitable habitat, which is mitigated by the increasing dominance of the arenga palm *Arenga obtusifolia* in the park. A member of the Arecaceae family and widely distributed across Thailand, Malaysia, and the Indonesia archipelago, the arenga palm (locally known as *langkap*) is an evergreen, cluster-forming species that grows rapidly up to heights of 16 metres (GISD 2011).

Arenga palms spread by subterranean root growth, (root extension) (Hariyadi et al. 2012), constraining and outcompeting the growth of other native plants (Supriatin 2000). Arenga palms also produce large quantities of seeding fruits, which enhances their dominance over other native species (Hariyadi et al. 2012). Able to disperse rapidly, arenga palms establish monocultures by reducing light due to canopy dominance and reduce the reduce the growth of understorey native food plants used by Javan rhinos for feeding (Hariyadi et al. 2012; Haryono et al. 2015, 2016). One theory that explains the arenga palm spread in the Ujung Kulon peninsula is that volcanic ash deposition following the volcano Krakatau's eruption in 1883, which increased soil fertility across Ujung Kulon and was followed by the proliferation of arenga palm in the area since (Haryono et al. 2015, 2016).

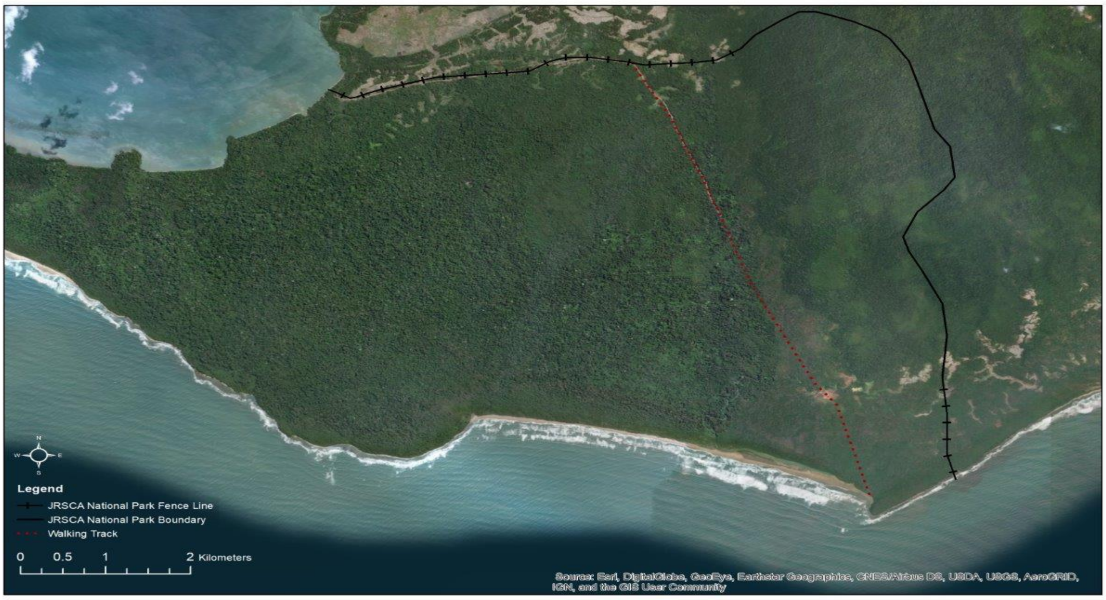

Figure 4.2: Map of eastern Gunung Honje region of Ujung Kulon National Park showing the Javan Rhino Study and Conservation Area (JRSCA) and rhino fence location.

Mammalian dispersers of arenga palm seeds and fruits include the Southern palm civet *Paradoxurus musanga javanicus* and long-tailed macaque *Macaca fascicularis* who spread palm seeds through faeces or by dropped seeds during and after eating the fruit (Lucas & Corlett 1992; Putro 1997). Other arenga palm dispersers potentially include avian frugivorous birds such as hornbills (e.g., *Buceros, Anthracoceros*) and small mammals such as the black giant squirrel *Ratufa bicolor*. Due to its diverse seed dispersal mechanism and ability to spread via its subterraneous root system, the arenga palm gains dominance over other plant species in plant succession processes (Hariyadi et al. 2012) (Figure 4.1).

Arenga palms cover an estimated 60% (>18,000 ha) of the western peninsular section of the park (Haryono et al. 2016) (Figure 4.3). There are an estimated >1,500 ha of arenga palms scattered across the 5,100 ha eastern Gunung Honje area of the park (Sectionov, pers. comm. 12th August 2016) (Figure 4.2).

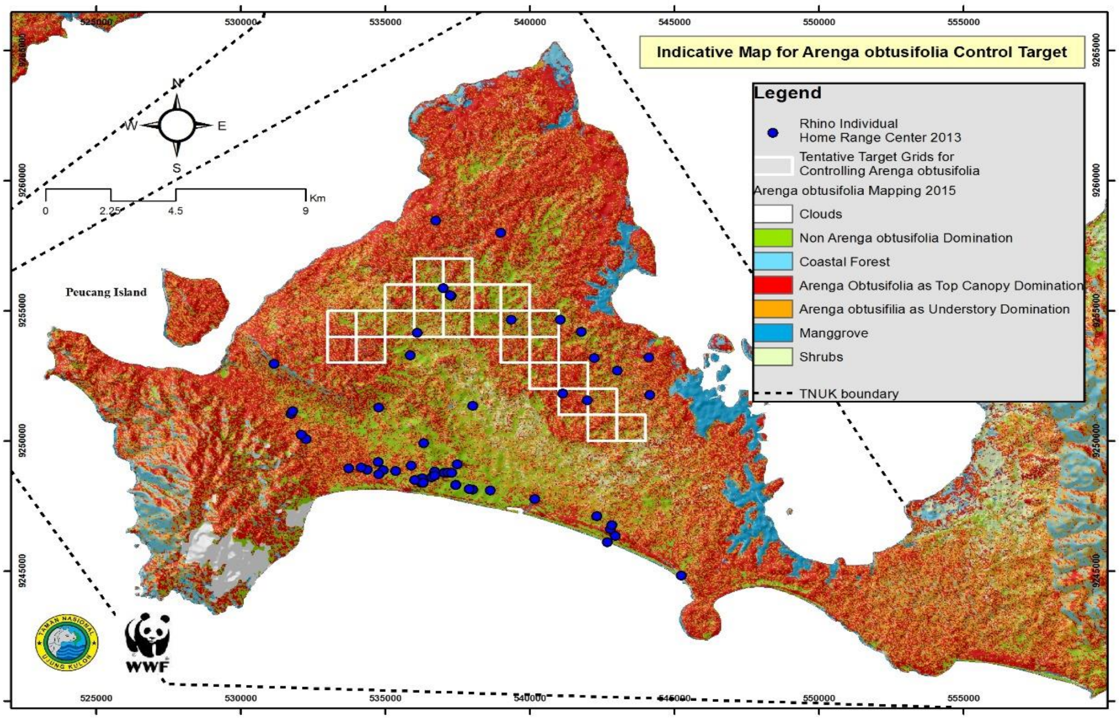

Figure 4.3: Land cover map of Ujung Kulon National Park showing Arenga palm *Arenga obtusifolia* distribution (in red). Note white squares identify future arenga palm control areas. Map: Courtesy Gadjah Mada University, Yogyakarta, Indonesia, Ujung Kulon National Park Authority and World Wildlife Fund.

Previous arenga palm control undertaken by the Ujung National Park Authority and Indonesian Rhino Foundation during the period 2011-2014 across the 5,100 ha JRSCA site focused on stimulation of rhino food plant growth and increasing available foraging (Figure 4.2). This habitat improvement is important because the current population appears to have reached its carrying capacity (AsRSG 2012). Efforts to increase available habitat for Javan rhino appeared to be working and given the increasing amount of arenga clearing occurring investigation was needed and I started to record post clearing plant response and rhino activity for a two-year period (April 2016 to April 2018) at the 15 x one ha 2016 cleared sites and 15 x one ha control sites.

4.2.1 Javan rhino ecology in the eastern Gunung Honje study area

At least nine rhinos (approximately 15% of the population) periodically use the eastern Gunung Honje area, including three resident males which bodes well for future arenga palm management within the park and its positive effects on rhinos (Haryono et al. 2015). Javan rhino prefers to eat the leaves, shoots, and twigs of woody species, with little to no consumption of grass or herbaceous species (Sody 1959; Schenkel & Schenkel-Hulliger 1969a; Hoogerwerf 1970; Ammann 1985; Santiapillai et al. 1993a, 1993b). An earlier study by Hoogerwerf (1970) suggested Javan rhino are highly dependent on the shrub and sapling layers found in secondary vegetation. The highest densities of Javan rhino are found in coastal areas (Setiawan et al. 2017). It is presumed most mineral requirements are satisfied through the consumption of salt-sprayed vegetation, halophytes (e.g., mangroves) or by drinking sea or brackish water which has been observed (Ammann 1985).

Its preferred habitat is open or tree-fall areas containing primary lowland and secondary rainforest (Ammann 1985) (Figure 4.5). Males are generally solitary and separate themselves spatially and temporally through olfactory communication using dung, urine (spray) and pedal scent gland (cutaneous) secretions to convey scent signals (Schenkel & Schenkel-Hulliger 1969b). Wallowing, the immersion of the body in water or mud, is a widespread behaviour among large mammalian herbivores (Owen-Smith 1988). Javan rhino utilises wallows in Ujung Kulon National Park that are often well concealed by rainforest vegetation (Ammann 1985). A recent study using a large dataset of camera video clips discovered strong evidence that home range size varied between males and females and across seasons (Setiawan et al. 2017). Females maintained the smallest home ranges (14.20 km^2) during dry seasons, typically June - July. Male home ranges were largest (105.53 km^2) during the period from dry to wet season, usually September-October. Seasonal female home ranges were on average half the size of males (Setiawan et al. 2017).

4.2.2 What are Javan rhinos eating?

As generalist browsers Javan rhinos feed on a broad suite of plant species. As mega-sized hind-gut fermenters (perissodactyls, elephants), Javan rhinos can consume small quantities of low-quality forage throughout the day and survive under conditions were similarly large, bodied ruminants (e.g., water buffalo) may not get adequate nutrition for their daily requirements (van der Made & Grube 2010; Nardelli 2013). Hind-gut fermenters are able to extract more nutrition from smaller quantities of food than ruminants (Budiansky 1997). The plant species preferred by Javan rhino have been studied, with some variation among studies, ranging for example, from 150 food plant species (Hoogerwerf 1970, Schenkel & Schenkel-

Hulliger 1969a, 1969b) to 190 species (Ammann 1985), 200 plant species (Putro 1997), and up to 252 species (Muntasib 2002). Generalist species tend to adapt and survive more successfully due to their occupying a broader ecological niche, food plant species can be interchangeable and there is less reliance on a few plant species (Colles et al. 2009).

Rhinos have been recorded as preferring particular plant species including *Spondias pinnata, Amomum sp, Leea sambucina* and *Dillenia excelsa* which made up 44% of the forage of the 190 food plant species recorded (Ammann 1985). It is worth noting these are pioneer species and often appear rapidly in disturbance regimes (e.g., tree fall or storm damage) and successional habitats. Research analysis on the nutritional quality and food digestibility of rhino food plants determined through proximate analysis of dried food plant samples *Spondias pinnata* as the food plant with the highest calcium (4.70 g/100 g) and *Hibiscus tiliaceus* with the most phosphorus (0.3 g/100 g) (Hariyadi et al. 2016). Identified high palatability food plant species were *Leea sambucina*, *Dracontomelon puberulum, Amomum megalocheilos*, *Spondias pinnata*, *Zanthoxylum rhetsa*, *Diospyros macrophylla* and *Ficus hispida* (Hariyadi et al. 2016). Known rhino food plant species *Dracontomelon puberulum, Zanthoxylum rhetsa, Diospyros macrophylla* and *Ficus hispida* contained much higher nutritional quality, for example greater % protein, % fat and energy (kcal/kg) than many of the other high palatability species (Hariyadi et al. 2016). Highlighting the ongoing variability and availability of these plants in rhino home ranges and the importance of having a diverse and balanced diet.

Under a variety of prevailing conditions Javan rhinos can experience shortages of specific nutrients caused by periodic reductions in certain nutritionally valuable plant species (Amman 1985; Hariyadi et al. 2016). For example, *Zanthoxylum rhetsa*, is a rhino food plant species known to be high in protein (17.11%), fat (1.94%) and energy (3.667 k/cal/kg) (Hariyadi et al. 2016). During poor plant growth periods Javan rhino home range size may fluctuate and change, most likely expand and potentially limit population density. As highly mobile generalist browsers, and not being restricted to certain plant species, Javan rhino have the ability to adapt, move and seek alternative food plant species during lean periods. Studies estimate Javan rhinos moved within their home ranges between 1.4 to 3.8 km each day (Muntasib 2002). Active *in-situ* management measures, such as supplementary planting of suitable rhino food plant which increase the availability of nutritious plant material is a practical way of ensuring rhino populations continue to thrive and get the adequate nutrition they need. It remains unclear if Javan rhino play any role in plant seed and fruit dispersal. Presumably, they may incidentally ingest seeds and fruit during their foraging behaviour.

The congeneric greater one-horned rhino is a known dispersal agent of plant seeds and fruit, notably the plant species *Trewia nudiflora* (Euphorbiaceae) (Dinerstein 2003). I suspect at healthy densities, Javan rhino, given their mega-size and browsing behaviour, it is reasonable to expect them to have an impact on seedling and sapling recruitment of woody plants, similar to congener the greater one-horned rhino.

4.3 Methods

4.3.1 Study area

Ujung Kulon National Park (UKNP) is located on a peninsula on the southwest end of mainland Java, to which it is joined by a low isthmus some 1-2 km wide (Ramono et al. 2009) (Figure 4.4). The Ujung Kulon peninsula with an area of 30,000 ha provides the core rainforest habitat for the remaining Javan rhino population (Nardelli 2016; Haryono et al. 2016). The rainforest vegetation is a complex mosaic of dense broadleaf evergreen forest - primary or old secondary forest including palms, bamboo, Zingiberaceae (ginger family e.g., *Amomum*), and open broadleaf evergreen forest - young, open secondary forest, with shrub jungle (Hoogerwerf 1970) interspersed with arenga palm. The topography of Ujung Kulon is flat to mountainous, with the highest peaks Gunung Honje (620 m) in the east and Gunung Payung (480 m) in the western peninsula area (Haryono et al. 2015).

The focal area of this study within the park was the eastern Gunung Honje region of Ujung Kulon, situated at the base of the Gunung Honje massif (620 m) (Figure 4.4). This area was selected due to its mix of monoculture arenga palm, healthy rainforest, and access for monitoring. The landscape ecology of the eastern Gunung Honje region of the park was described by Hommel (1987) as three distinct landscapes. These include limestone plateau - arenga slopes and dissected plateaus; Coastal plains - Syzigium plain and Calcareous sandstone beach ridges and sand dunes - Dendrocinide beach ridge and sand dunes.

The climate of Ujung Kulon is tropical with a seasonal mean average rainfall of 3250 mm, mean temperature range of 25-30°C and relative humidity of 65-100% (Ramono et al. 2009). Rainfall is typically heaviest between December and January, with a drier period occurring between May and September. Rainfall and temperature patterns in Ujung Kulon are remarkably stable and even throughout the year (see Table C.1 Average annual climate data (temp/rainfall) for Ujung Kulon NP, Appendix C). Ujung Kulon National park was formally gazetted in 1980 and in 1992, the park, along with the Krakatau archipelago, was declared Indonesia's first UNESCO World Heritage Site (Haryono et al. 2016) (Figure 4.4).

Figure 4.4: Map of Ujung Kulon National Park (UKNP), West Java, Indonesia showing key Javan rhino habitat areas (dark circles). Map: Courtesy Ujung Kulon National Park Authority.

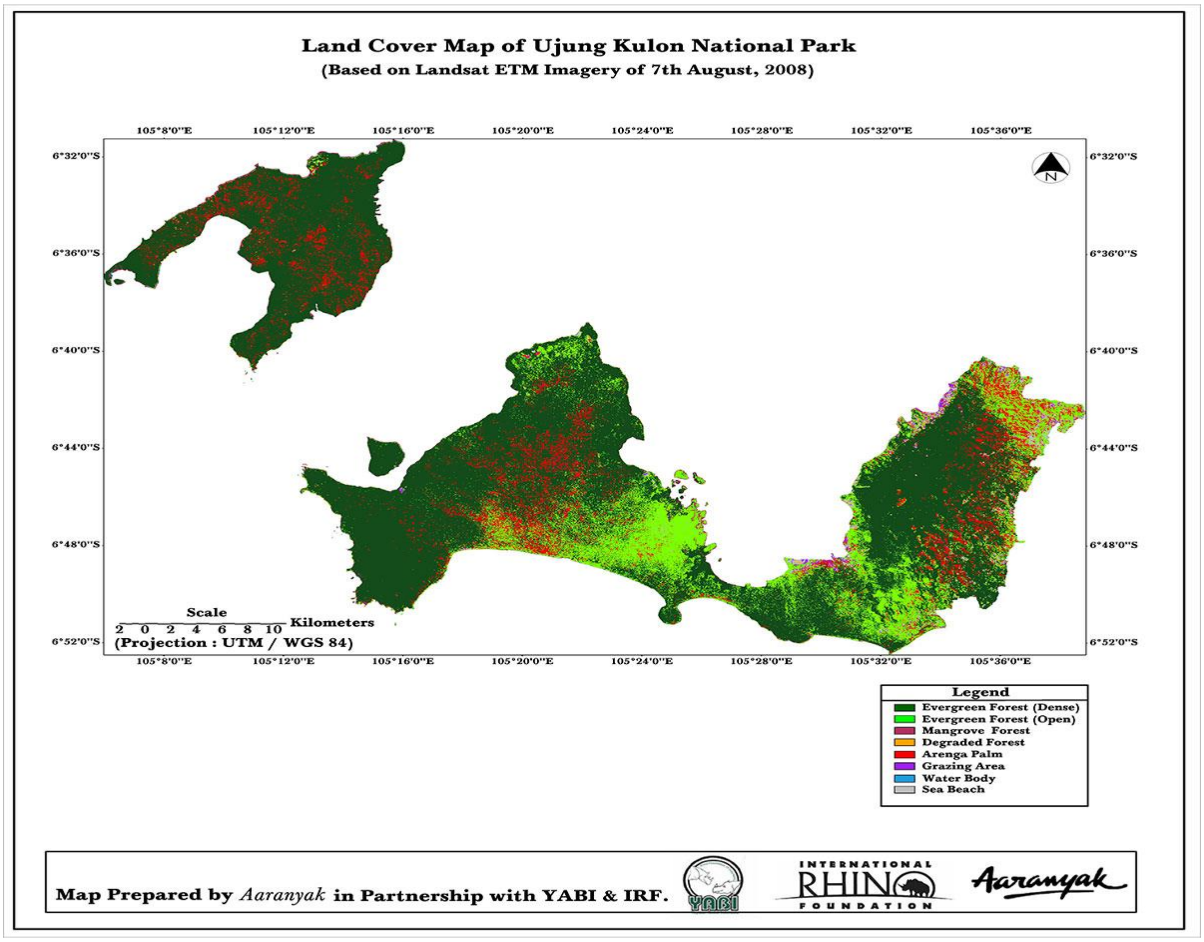

Figure 4.5: Map of land cover (vegetation type) of Ujung Kulon National Park. Courtesy of Indonesian and International Rhino Foundations.

In April - May 2016, in collaboration with the Ujung Kulon National Park Authority and Indonesian Rhino Foundation (NGO) and community members we selected and manually cleared 15 one ha plots of predominantly monoculture (75-80% crown cover) arenga palms within the 5,100 ha Javan Rhino Study and Conservation Area (JRSCA) in the eastern section of UKNP (Figure 4.2). We also set up 15 one ha control sites with similar features. Local community was recruited and paid ($1,000 AUD per ha/per 10 people) from the 19 villages living adjacent to the park to manually clear each site due to World Heritage and Ujung Kulon National Park Authority restrictions on using any form of herbicide such as isopropyl ammonium glyphosate, an active component of modern weed treatments (e.g., Round-Up™) in the park. The teams of ten local community members would cut palms by chainsaw and hand saw and, in most cases remove fallen palms from each site often at densities up to 650-750 palms/per ha. Wherever possible arenga palms with fruits were carefully removed after cutting due to risk of regrowing through seed spillage or dispersal. Where possible palm roots were also dug up and removed to prevent root regrowth. During September 2016, five months after site clearing each site I visited and marked out quadrats. A Garmin GPS Maps 62 sc GPS unit was used to record latitude and longitude at all sites. Maps were created using ArcMap 10.5 software (ESRI). I used a World Imagery spatial layer, supported with data layers from ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

4.3.2 Experimental study design

In order to monitor plant growth within each one hectare cleared plot, four 20 m^2 quadrats were marked out using an eight-meter Lufkin autolock tape measure and staked out using fluorescent pink ribbon on each staked corner so the quadrat stake could be found in the future once plants grew taller than the stakes. I used Flouro string to define the quadrat boundary and record within each 20 m^2, smaller squares of 2, 5 and 10 m^2 to allow for vegetation analysis of the four stages of growth: seedling, shrub, sapling, and older tree. Each of the smaller squares of 2, 5 and 10 m^2 within each of the four 20 m^2 quadrats was recorded four times (Figure 4.6). During the five months since cutting and clearing, each site had responded with plant growth due to increased exposure to available sunlight and the elements. The rapid growth response over the five months period since clearing enabled plant species to be identified and counted in each respective quadrat. Recorded variables included number plant species, number plant families, number plants/stems per plot and any rhino sign including dung, spray urination sign, footprints and feeding sign (e.g., damage to food plants from browsing rhino.

Signs of rhino visitation were recorded only when there was clear evidence that a rhino had visited the site i.e., up to 40 hours fresh dung (Figure 4.18) and/or spray urination (Figure 4.13). Other signs included were clearly defined fresh footprints (Figure 4.17) and feeding sign (Figure 4.16) at foraging height and evidence of rhino using their bulk to knock over small trees and saplings and the frayed cut marks characteristic of browsing rhino. Heavy rain readily degrades rhino activity signs. Direct observation of Javan rhinos is very rare as rhinos are shy, in very small numbers and tend to stay away from humans. Therefore, animals were identified based on camera trap imagery and videos following Griffith’s (1983) identification criteria which compares morphological features including horn size and shape, footprint size, eye wrinkles, ear shape and distinct features such as scars, damaged skin folds or skin pigmentation (Hariyadi et al. 2011). The UKNP Authority has been actively monitoring the rhino population across the national park since 2010 using its network of permanent video cameras and has built up a considerable database of each individual rhino and its identification characteristics (Haryono et al. 2016).

Other large and small herbivores such as Javan Banteng *Bos j. javanicus*, Javan wild pig *Sus scrofa vittatus*, Southern red muntjac *Muntiacus m. muntjac*, Javan mouse deer *Tragulus javanicus* and Javan rusa deer *Rusa timorensis russa* also utilise these cleared areas, their sign (e.g., footprints and dung) is readily distinguished from rhino. Additionally, carnivores such as Javan leopard *Panthera pardus melas*, leopard cat *Prionailurus bengalensis*, Southern palm civet *Paradoxurus musanga javanicus* and Javan *Tupaia javanica* or Horsfield’s tree shrew *T. hypochrysa* were also recorded as visiting cleared arenga sites. On one occasion I observed a resting Javan Sunda colugo *Galeopterus v. variegatus* (family Cynocephalidae), high in a large 30m+ *Baccaurea* sp. tree. Totally arboreal, Sunda colugo prefer areas with low vine densities with tall trees (Janečka & Janečka 2018), a cleared arenga plot would provide good open habitat for gliding between trees. Local people call colugo ‘*tando*’. Colugo are known to spend up to 60% of their time resting (Janečka & Janečka 2018).

Initially, Bushnell Trophy Cam HD eight-megapixel remote cameras were set up at 10 of the cleared arenga sites to record any rhino visitation, however this was discontinued due to local community regularly interfering with cameras, presumably local wildlife poachers not wishing to be filmed. National park and rhino protection unit staff assisted with plant identification along with various rhino food plant identification sources such as Putro (1997) and Hommel (1987).

A similar methodology was used by Hariyadi et al. (2012) on initial arenga palm trial sites undertaken on the Ujung Kulon peninsula and in other species determination and richness studies undertaken by Whittaker et al. (2001) and Whittaker & Heegaard (2003). In order to compare the plant response at cleared arenga sites, I also marked out 15 individual non-cleared arenga dominated 20m^2 quadrats and recorded as per the cleared sites as control sites, following the same recording procedure of examining the number plant species/family and number plants per 20 m^2, and inside each 2, 5 and 10 m^2 square quadrat, enabling comparison of plant numbers (stems) and species composition (no species/no families) between cleared and control quadrats. These sites were established approximately two km from the cleared sites (Figure 4.7). I used a Canon 50D digital camera to take images of plant growth response and individual rhino food plant species.

Both cleared and non-cleared sites were visited at least twice annually between April 2016 and April 2018 checking for rhino visitation taking into consideration *in situ* field time was limited by climatic conditions i.e., monsoon period November - March, best access usually found during April - October, respecting staff limitations of Ramadan (April/May) and regular regional religious events. Plant growth (height/cm) was recorded at cleared sites in April 2018, approximately two years post clearing (Table 4). As an ongoing management measure rhino protection staff routinely check and hand cut any arenga regrowth and have an annual program of visiting cleared sites on their monthly routine patrol cycles to cut palm regrowth.

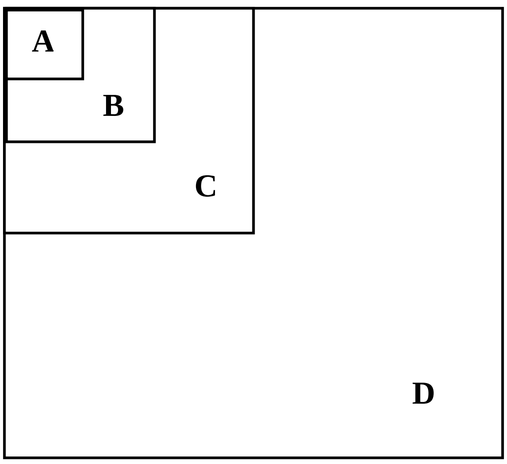

Figure 4.6: Quadrat layout for each one hectare cleared control sites. **A.** 2 m^2 (seedling), **B.** 5 m^2 (shrub), **C.** 10 m^2 (sapling/young tree), **D.** 20 m^2 (older tree) to property assess various growth stages of vegetation.

4.3.3 Data analysis

One-way analysis of variance (ANOVA) and t-tests were undertaken testing the statistical significance of 15 cleared arenga sites to the non-cleared control sites across the variables of plant numbers, number of plant species, number of plant families in each of the 2 x 2, 5 x 5, 10 x 10, and 20 x 20 metre quadrats. Additionally, ANOVA tests were done to compare each of the individual (recorded four) in each cleared quadrat within each 2 x 2, 5 x 5, 10 x 10, and 20 x 20 areas. For example, in Site 1, 4 x (2 x 2) quadrats were each examined for plant numbers, and an ANOVA was applied comparing all four recorded 2 x 2 quadrats (e.g., A, B, C, D).

The aim of this chapter was to determine the implications for conservation and management of arenga palm on rhino, habitat, and food plants, by asking the following questions and hypothesis including what are the conservation implications of arenga palm dominated habitat for Javan rhino habitat use and distribution? Does removal of arenga palm increase the availability of rhino food plants? The time period over which rhino food plants grow, and rhino visitation occurs? I hypothesised that habitat manipulation of arenga palm in selected forest patches is a viable management technique to increase foraging for rhinos.

To analyse any correlations, patterns and relationships bivariate data scatterplots were used. I examined the relationships between the following factors:

- Distance from cleared arenga site to nearest wallow (in km) vs. distance from cleared arenga site to coast (km)
- distance from cleared arenga site to nearest wallow (km) vs. distance from cleared site to nearest waterway in (km)
- non-cleared control site plant numbers vs. cleared arenga site plant numbers
- non-cleared control site number of plant families vs. cleared arenga site number of plant families
- non-cleared control site number of plant species vs. cleared arenga site number of plant species.

To interpret patterns in the data, the following attributes were used. Linearity (linear or non-linear), slope (positive (up) or negative (down), strength (strong or weak relationship) and unusual features (e.g., outlier).

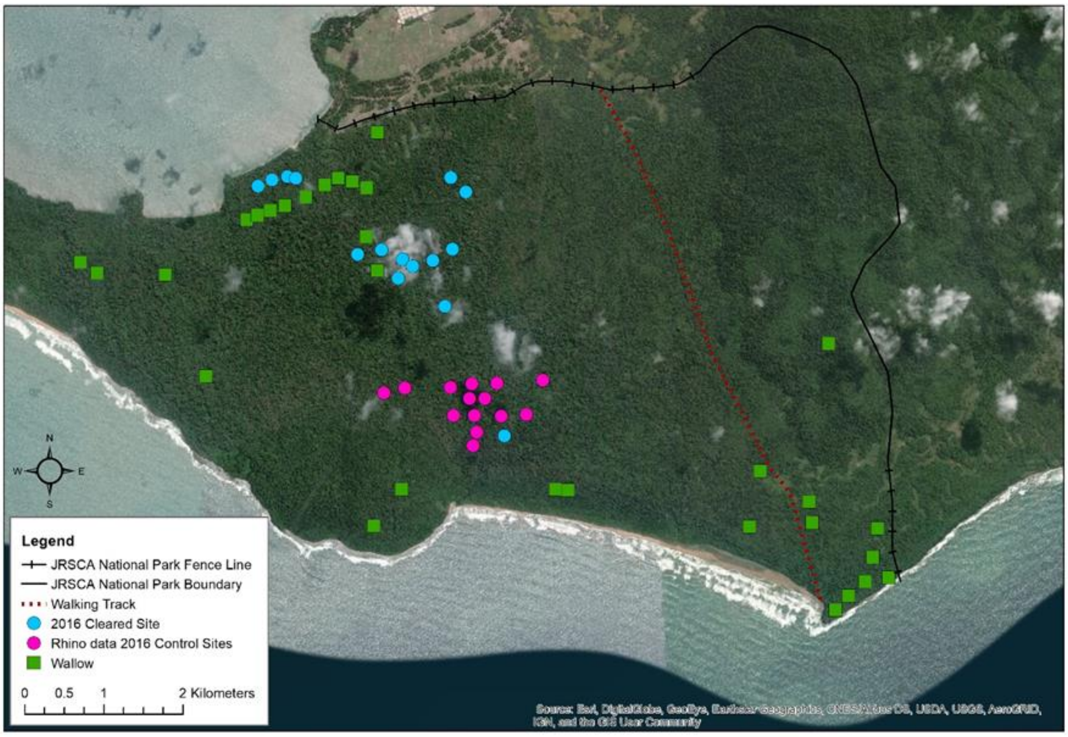

Figure 4.7: Map of eastern Gunung Honje region of Ujung Kulon National Park showing 2016 cleared (blue dots) and control (pink dots) arenga palm sites and locations of wallows (green squares).

4.4 Results

We discovered that arenga palm removal resulted in increased richness and abundance of native rhino food plants and rapid increase in rhino visitation to cleared sites by Javan rhinos in areas previously covered by arenga palms. In all cleared sites there was growth of native plants. A comparison of the number of plant species and plant families across both cleared and uncleared sites showed similar results (Table 1). For example, cleared sites had 67 plant species from 37 plant families compared to 71 plant species from 41 plant families at non-cleared (Table 1). The average plant growth rate (height/cm), two years post clearing (April 2016 - April 2018) was highest in older tree (20 m^2) sites averaging 113.48 cm, the plant family Aristolchiaceae (26%) the most recorded (Table 2). Arenga palm regrowth dominated plant growth in shrubs (5m^2) and saplings (10 m^2) sites, highlighting the importance of regrowth removal by rangers on regular patrols (Table 2). Post clearing the number of arenga palms to number of rhino food plants was lower at cleared sites than uncleared control sites (Table 3). For example, 15 cleared 20 m x 20 m small, treed sites collectively had no arenga palm plants compared to 755 small trees (rhino food plants), a trend that presented across most cleared sites.

A comparison of the average number of plant species and number of plant families across sites showed similar plant species and family diversity (Table 4). A comparison in the number of stems across cleared and uncleared sites showed higher averages of seedlings (2 m^2) 18.47 in cleared sites compared to 4.15 in uncleared and shrubs, (5m^2) 156.11 in cleared sites compared to 2.74 in uncleared (Table 4). The number of stems at uncleared sites for saplings (10 m^2) and older tree (20 m^2) was higher than cleared sites. For example, uncleared sapling sites (10 m^2) averaged 14.86 stems compared to 3.86 at cleared sites (Table 4). Camera video footage and rhino tracks moving around arenga palm stands shows rhino tend to avoid these monoculture areas given there is no reliable food source within them. Prior to clearing the sites were dominated by arenga palms.

4.4.1 Statistical analysis results

Results comparing numbers of plant species and plant families between cleared and non-cleared sites for 2 x 2 (seedlings), 5 x 5 (shrubs), 10 x 10 (saplings) and 20 x 20m (older tree) (refer Table 5). ANOVA tests compared each of the individual (recorded four) in each cleared quadrat within each 2 x 2, 5 x 5, 10 x 10, and 20 x 20. For example, in Site 1, 4 x (2 x 2) quadrats were each examined for plant numbers, and an ANOVA was applied comparing all four recorded 2 x 2 quadrats (e.g., A, B, C, D). This same approach was also applied comparing number of species, number of families and number of. arenga palms (Table 5). There was no statistically significant difference between the number of plants across respective quadrats (4 per site), each recorded similar numbers of plant numbers (Table 5). These same patterns were seen when comparing plant richness (Table 5), and the number of plant families at cleared and uncleared sites (Table 5).

Results for the average distance from known wallows in the JRSCA study site to the coast was 0.64 km; SD ± 0.52; average distance from cleared sites to control sites was 2.23 km; SD ± 1.068; average distance from cleared sites to wallows was 0.98 km; SD ± 0.779; average distance from cleared sites to the coast was 1.39 km; SD ± 0.883 and, the average distance from cleared sites to the nearest waterway (often seasonal) was 0.653 km; SD ± 0.366. Results of the scatterplots for the following bivariate data included the distance from cleared arenga site to nearest wallow (km) vs. distance from cleared arenga site to coast (km) was linear, positive slope, strong with outliers, $y = -0.4791x + 1.8661$, $R^2 = 0.1785$ (Figure 4.8). Distance from cleared arenga site to nearest wallow (km) vs. distance from cleared site to nearest waterway (km) was linear, positive slope, weak with outliers, $y = 0.053x + 0.601$, $R^2 = 0.0127$ (Figure 4.9).

Scatterplot results for non-cleared control site plant numbers vs. cleared arenga site plant numbers were linear, zero slope, weak, y = 0.0006x + 31.399, R^2 = 1E-05 (Figure 4.10). Non-cleared control site number of plant families vs. cleared arenga site number of plant families was linear, positive slope, weak, y = 1.3209x + 1.8661, R^2 = 0.5075 (Figure 4.11), and non-cleared control site number of plant species vs. cleared arenga site number of plant species was linear, positive slope, weak, y = 0.3043x + 2.7217, R^2 = 0.0448 (Figure 4.12).

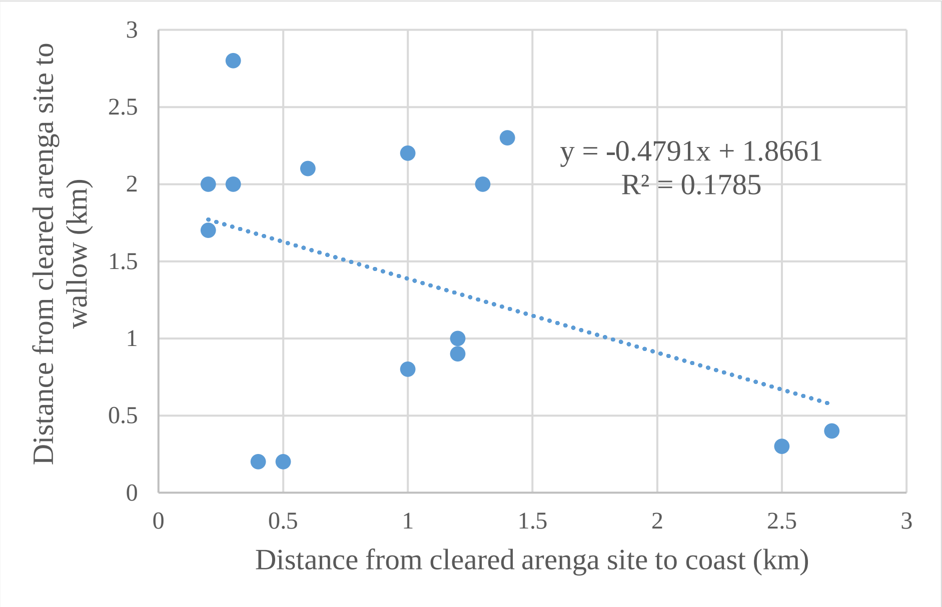

Figure 4.8: Scatterplot of distance from cleared arenga site to wallow (km) vs. distance from cleared arenga site to the coast.

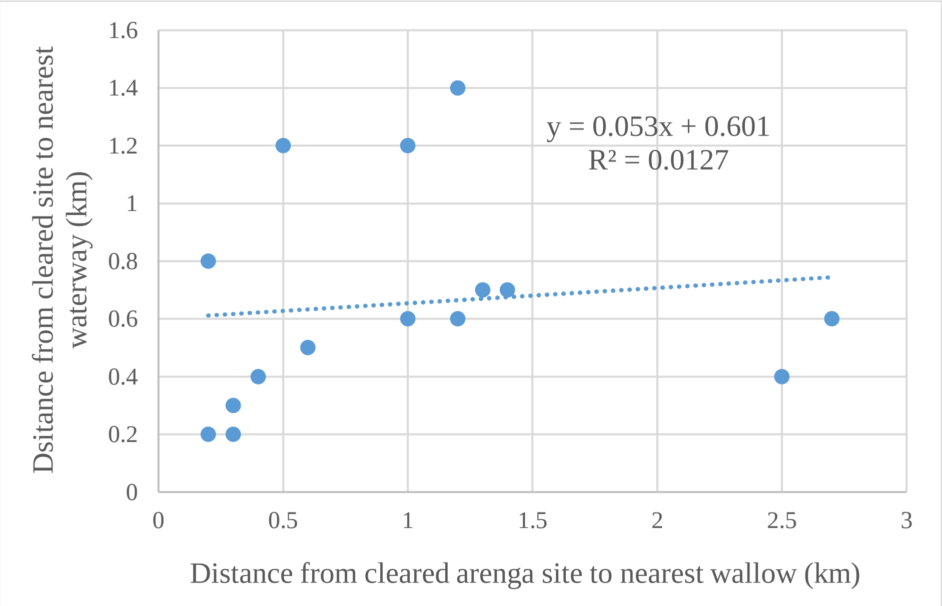

Figure 4.9: Scatterplot of distance from cleared arenga site to wallow (km) vs. distance from cleared arenga site to nearest waterway.

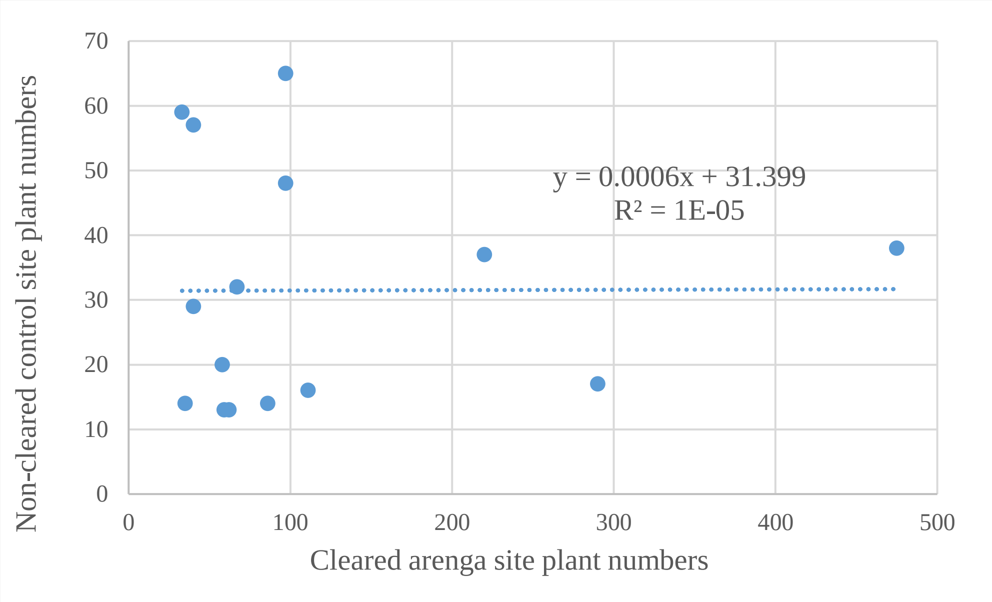

Figure 4.10: Scatterplot of non-cleared control site plant numbers vs. cleared arenga site plant numbers.

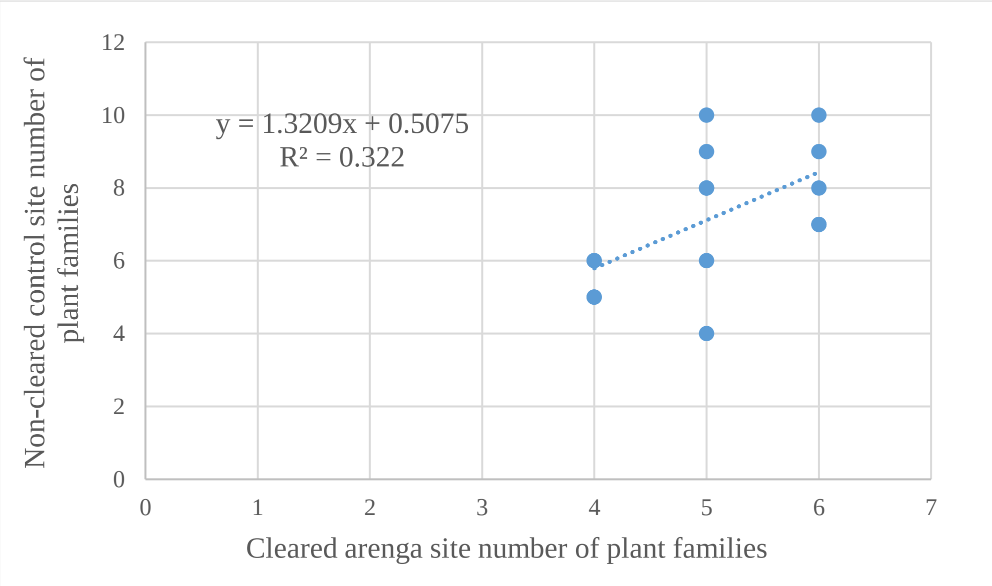

Figure 4.11: Scatterplot of non-cleared control site number of plant families vs. cleared arenga site number of plant families.

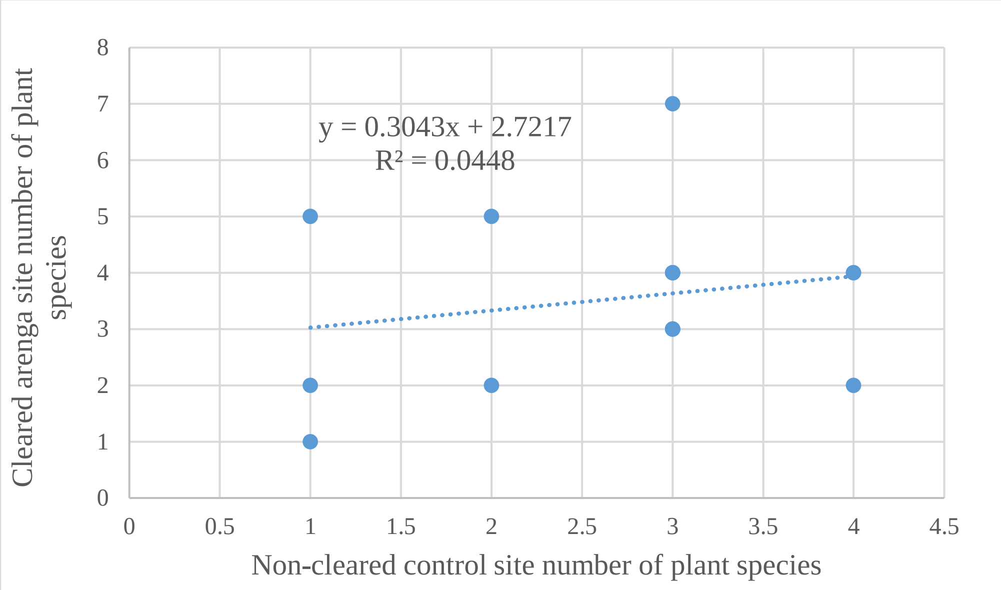

Figure 4.12: Scatterplot of non-cleared control site number of plant species vs. cleared arenga site number of plant species.

4.4.2 Rhino visitation to cleared and non-cleared sites

Rhino visits to post cleared sites were recorded on 32 occasions, compared to zero visits to uncleared controls sites during the September 2016 - April 2018 period. Rhinos were detected visiting cleared sites and feeding on secondary growth (Figure 4.16). All of the 15 cleared sites were visited by at least three different individual rhinos based on the footprint variation. There have been four resident males using the eastern Gunung Honje area for some time and I suspect at least three of these four males have been visiting the cleared sites. A fourth rhino known to utilise the south-eastern Gunung Honje area 'Samson' a 30+ year old male was found dead of natural causes on one of the park's beaches on April 23rd, 2018 (Gokkon 2018). Of the 32 visitation records recorded during 20/09/2016 - 19/09/2018, 27 were of feeding sign, two records of dung deposition, three of spray urination, three records of wallowing evidence (e.g., mud on vegetation) and 32 records of tracks and footprints (see Table C.2 Records of fresh rhino sign and visitation to cleared arenga palm sites, Appendix C). Sixteen (n=16) food plants were identified and recorded as eaten at cleared sites included *Dillenia obovata, D. aurea, Amomum coccineum* (Figure 4.24), *Leea sambucina* (Figure 4.31), *Spondias pinnata* (Figure 4.33), *Ficus montana, Baccaurea javanica, Oxymitra cunneformis, Sumbaviopsis albicans, Largerstroemia flos-regime* (Figure 4.25), *Cladium bicolor* (Figure. 4.30), *Vitex pubescens, Barringtonia gagantostachua, Donnax cunnaeformis, Apama tomentosa* and *Diospyros javanica* (see Table C.1, Appendix C).

The 15 control sites were also sampled by our field team twice a year (April and September) to determine if rhinos had visited any of the sites. I did not record any evidence of rhino visitation at any of the control sites over the same 20/09/2016 - 19/09/2018 period. The fact that rhinos were both spray urinating and depositing dung at cleared sites highlights the fact animals were also actively communicating via olfactory means as they would in their feeding habitat. Presumably, the spray urination (Figure 4.13) and possibly the dung deposits (Figure 4.18) were left by a dominant male. There was no evidence of rhino visitation to the non-cleared sites which were visited twice annually presumably due to the dominance and monoculture stands of arenga palms.

Figure 4.13: Fresh rhino urine (spray) on vegetation at cleared arenga palm site. Rhinos can spray urinate up to several metres across vegetation. Image: Steve Wilson.

Figure 4.14: 'Langkap' Arenga palm *Arenga obtusifolia* (Arecaceae) produce copious amounts of fruit, which is consumed and spread by long-tailed macaques *Macaca fascicularis* and Asian palm civet *Paradoxurus hermaphroditus javanica*.

Figure 4.15: 'Langkap' Arenga palm (Arecaceae) can out compete and dominate the rainforest canopy to the detriment of rhino food plants.

Figure 4.16: Recently browsed rhino food plant at 2016 cleared site 'Sulangkar' *Leea sambucina* (Vitaceae) knocked over by rhino (using chest and body weight) and stripped of leaves.

Figure 4.17: Fresh rhino footprint in 2016 cleared arenga site (April 2018). Print is from adult male `Rawing’.

Figure 4.18: Decomposing rhino dung approximately 10 days old at 2016 cleared arenga site. Rhino dung breaks down rapidly in the humid conditions.

Figure 4.19: Evidence of rhino visitation to cleared arenga site by mud smear on vegetation from nearby wallow.

Figure 4.20: Fresh mud on sapling in 2016 cleared arenga site. Rhinos often wallow then travel to feeding sites. Mud deposits on vegetation contain scent impregnated information of the depositing animal, most likely sex, possible dominance status and reproductive state i.e. oestrus female.

Figure 4.21: Rhino horn marks on sapling in 2016 cleared arenga site. Rhinos often rub and shape their horns on trees and stumps.

Figure 4.22: Rhino food plant `Centre' *Lantana camara* (Verbenaceae). This invasive species native to Central and South America (Sanders 2012) is known to be toxic to domestic stock, rhinos appear to eat this species with no ill effects.

Figure 4.23: Rhino food plant `Patat' *Phyrnium parviflorum* (Maranthaceae) emerging at 2016 cleared arenga palm sites.

Figure 4.24: Rhino food plant `Tepus' *Amomum coccineum* (Zingiberaceae) emerging at 2016 cleared arenga palm site.

Figure 4.25: Rhino food plant `Bungur' *Largerstroemia flos-reginae* (Lythraceae) can grow into a large tree (note purple flowers), the low shrubs in the foreground are `Cente' *Lantana camara*.

Figure 4.26: Immediate post cleared arenga palm site (April 2016). Note palm fronds are cleared away by community allowing secondary plant response.

Figure 4.27: Cleared (April) 2016 arenga site, five months (September 2016) post cutting, emergent regrowth starting to appear, note cut arenga palm stumps.

Figure 4.28: Cleared (April) 2016 arenga site, seven months (November 2016) post cutting, emergent regrowth starting to spread.

Figure 4.29: Re-growth at 2016 cleared arenga palm site two years post clearing (April 2018), note high plant diversity, some plants are more than two metres high.

Figure 4.30: Rhino food plant `Cariang' *Cladium bicolor* (Araceae) at 2016 cleared arenga palm site.

Figure 4.31: Saplings of `Sulangkar' *Leea sambucina* at 2016 cleared (12 months after cutting) arenga site, see remnant stumps of cut arenga palm. *Leea sambucina* (Vitaceae) is a highly palatable pioneer species eagerly sought after by rhino.

Figure 4.32: Author in stand of secondary regrowth in 2016 cleared arenga site (two years after cutting), saplings are mostly `Sankar' *Leea sambucina* (Vitaceae).

Figure 4.33: Rhino food plant `Kedondong' *Spondias pinnata* (Anarcardiaceae) this rapid growing pioneer species contains high levels of calcium and is eagerly eaten by rhino.

4.5 Discussion

The arenga palm control resulted in increased diversity and abundance of rhino food plants, and visitation to cleared sites by rhinos within one month of clearing. Prior to clearing the sites were dominated by arenga palm. Five months after cutting and clearing of arenga palms, cleared sites were showing native plant species diversity comparable to the control sites (Figure 4.27). Rhinos have been recorded as visiting and feeding at all 15 cleared sites. From a management perspective the clearing process activated long dormant arenga palm seedbanks which can be easily cut by rhino protection staff enabling activation and competition from rhino food plants. As part of their patrolling duties rhino protection staff now routinely visit cleared sites and cut any arenga regrowth which reduces in number with every site visit. Additionally, the UKNP Authority has now instigated an annual arenga palm clearance program which is focussed on the western peninsula area (main rhino population lives here), to date 60 ha have been cleared (Sectionov, pers. comm.). Both the Indonesian and International Rhino Foundations continue to support palm clearance in the eastern Gunung Honje area of the park with 106.5 ha cleared to date. Four of the five bivariate scatterplots (Figures 4.9, 4.10, 4.11, 4.12) showed limited correlation and although linear, were negative in slope and statistically weak with outliers. The strongest statistical correlation (Figure 4.8) was linear, positive in slope and strong with outliers. This correlation, the distance from cleared arenga site to nearest wallow (km) vs. distance from cleared arenga site to coast (km) is understandable. Rhinos would naturally utilise a wallow site near foraging areas, once cool would move to a feeding area, then move to a cooler coastal area which also has the added foraging value of salt-sprayed vegetation.

4.5.1 Implications of arenga palm dominated habitat for Javan rhino habitat use

Over 60% (>18,000 ha) of the Ujung Kulon peninsula (Indonesian Ministry of Forestry 2007; Haryono et al. 2016) and an estimated >1,500 ha of the eastern Gunung Honje area are covered by monoculture stands of arenga palm (Ramono et al. 2009). This potential rhino foraging habitat is successionally changing to a closed canopy forest with little to no plant diversity and very limited rhino forage ((Hariyadi et al. 2012). Camera video footage and rhino tracks moving around arenga stands shows rhino tend to avoid these monoculture areas given there is no reliable food source within them. The study has demonstrated cleared sites respond quickly with plant diversity comparable to non-cleared sites and with large numbers of desirable food plants. Rhino visitation records showed animals were feeding on pioneer

species that colonise disturbance and successional habitats (e.g., *Dillenia obovata, Amomum coccineum*, *Leea sambucina* and *Spondias pinnata*) (see Table C.2, Appendix C).
The clearing of arenga palm sites is relatively cost-effective at $1,000 AUD per ha given the remoteness of the site, the work undertaken is by hand, and often in difficult terrain and climatic conditions. The $1,000 AUD per ha costs include labour, food, and transportation for 10 people to clear one ha over a 10-day period. These costs can be further reduced to $600 AUD per ha if chainsaws are used, reducing the labour requirement to six people, and shortening the per ha clearance rate to six days (Sectionov, pers. comm.). Importantly, local community can be used as a viable labour force and their contribution builds important understanding of the conservation effort. The current restrictions on the use of chemicals in the park is worth trying to change given chemical trials injecting using isopropyl ammonium glyphosate into arenga palm was found similarly cost effective and you could inoculate more hectares of arenga palm than manual cutting over the same time period (Sectionov 2013).

Despite this treatment method having significant potential, authorities remain concerned over chemical residues in the landscape. This concern remains despite strong evidence isopropyl ammonium glyphosate is non-residual and has no long-term effect on native flora (Carlson & Gorchov 2004), even after a five-years of use and testing (Hochstedler et al. 2007). It is worth noting that for arenga palm clearing to be effective other habitat components need to be available. The proximity and access to wallows is important given Javan rhinos need to wallow daily (Ramono et al. 2009; Wilson et al. 2020). Fortunately, the eastern Gunung Honje area supports 35 wallows which I identified and recorded during my study with the average distance from cleared arenga sites to wallows is 0.98 km (Wilson et al. 2020). Evidence of rhinos using nearby wallows as shown by mud on saplings and vegetation at cleared arenga sites showed animals were wallowing and moving to and from to feed at the cleared sites (Figures 4.19, 4.20).

Javan rhino are known to urinate in wallowing sites which helps impregnate their bodies with distinctive odours; the odours are then spread throughout the habitat as mud on saplings and as the animals move through vegetation and are presumably recognised by others (Schenkel & Schenkel-Hulliger 1969a, 1969b). Access to water sources is equally important and the average distance from cleared sites to the nearest waterway (often seasonal) is 0.653 km. Proximity to coastal areas was considered important by Setiawan et al. (2017) who found Javan rhino was found mostly in coastal areas presumably due to cooler conditions and access to salt-sprayed mineral rich vegetation.

The average distance from cleared arenga sites to the coast is 1.39 km. The study showed a significant rate of plant growth and diversity at cleared sites replacing areas previously covered by mostly monoculture arenga palm. This habitat restoration approach increases habitat for foraging and space for resident and importantly visiting rhino. The focus of this research was to understand and determine the implications of the management of arenga palm on Javan rhino, and conservation benefits to habitat and food plants. The research results support the proposal that active habitat manipulation of arenga palm in selected forest patches is a viable management technique to increase foraging for rhinos when resources to clear are available.

4.5.2 Time period rhino food plants grow, and rhino visitation occurs

Five months after cutting and clearing of arenga palms, the native plants had grown from existing seedbanks sufficiently large enough that I was able to distinguish and identify individual plant species at each site. Two years post clearing many plant species were over two metres tall and the ground was barely visible due to active competition from many plant species. Rhino protection staff informed me rhino tracks were found at four cleared sites one-month post clearing (Syamsudin personal communication May 28th, 2016). During September 2016, I collected evidence rhinos had visited seven different cleared sites and were feeding on various plant species (e.g., *Dillenia obovata, Dillenia aurea, Amomum coccinea* and *Leea sambucina*). Dung piles (Figure 4.18) and evidence of spray urination (Figure 4.13) at cleared sites demonstrated the sites were now being used as habitat areas with rhinos communicating via olfactory means.

4.5.3 Impact of Arenga palm on Javan rhino food resources

Patterns of both natural and human disturbance in Ujung Kulon have created a mosaic of successional stages of vegetation regeneration. These early to mid-pioneer secondary stages provide valuable foraging sources of rhino food-plants, with patches of mature primary and secondary forest providing cover (Ramono et al. 2009). Earlier studies undertaken by Supriatin (2000) identified the growing dominance of arenga palm, impacting forest successional processes through competition and consequent reductions in available rhino food plants (Supriatin 2000; Hariyadi et al. 2012). Examination of vegetation cover both on ground and via remote sensing approaches suggest that these vegetation mosaics are becoming increasingly arenga palm monocultures as plant succession moves toward closed forest (Hariyadi et al. 2012, 2016). As a result, it was concluded that rhino food-plant resources are declining, especially where closed forests are dominated by arenga palms. Javan rhinos are solitary and highly mobile, and dependent on food availability in their restricted habitat (Hariyadi et al. 2016). With an ability to rapidly spread, arenga palm, arguably, poses the most major threat to Javan rhino habitat and animals through the loss of available food plants, forest succession moving to a closed system, with little to no light on the forest floor for secondary and understory growth processes (Hariyadi et al. 2012, 2016). The eastern Gunung Honje area historically recorded only periodic visitation by rhino (Ramono et al. 2009). Today the area supports at least three resident males and occasional visits from other animals. Females with calves have been captured on camera trap videos but have not stayed in the area (Hariyadi et al. 2012). Camera trap videos demonstrate how females with calves are extremely vigilant and prefer to stay and travel in areas with good cover. Movement pathways from the western peninsula area of the park to the eastern Gunung Honje site need to be well-vegetated to assist this need. This has been recognized by park authorities and supplementary planting of rhino food plants is occurring along the corridor linking the peninsula to the eastern Gunung Honje area which may enhance and generate the right conditions for single females to stay and ultimately breed with the resident males. The ongoing clearance of arenga palm is enhancing rhino habitat and has value for rhino management as a tool and option to increase access and probability of connecting isolated rhinos to breeding opportunities and importantly, improving the quality of habitat in rhino home ranges (Hariyadi et al. 2012).

The positive impact and involvement of local community who are employed to manually clear arenga palm (cutting palm trunks, clearing fronds, and collecting fruits) not only has an immediate effect on the landscape, but it also importantly engages community into the rhino conservation effort. The data collected from the cleared and non-cleared sites has increased our understanding of how Javan rhino use and respond to successional habitats, both natural and manipulated. As a proven and important management technique, habitat manipulation of arenga palm in selected forest patches increases foraging for rhinos. Removal of mostly dominant monoculture arenga palm patches also increases available space through increased habitat for rhino use. As highly mobile generalist browsers, and not being restricted to certain plant species, Javan rhinos have the ability to adapt, move and seek alternative food plant species during lean periods, which makes them an ideal species for translocation.

Table 1 Comparison of plant response between number of plant species and number of plant families at cleared (15 x 1ha) and non-cleared (15 x 1ha) arenga sites after two years (2016-2018).

Cleared sites	15 x 1ha sites	Uncleared sites	15 x 1ha sites
Family (n=37)	Species (n=67)	Family (n=41)	Species (n=71)
Apocynaceae	*Anadendrum microstachyum, Alstonia sp.*	Apocynaceae	*Anadendrum microstachyum, Alstonia sp.*
Boraginaceae	*Cordia sp.*	Boraginaceae	*Cordia sp.*
Palmae	*Daemonorops melanochaetes, Caryota mitis*	Palmae	*Daemonorops melanochaetes, Caryota mitis, Calamus sp., Pinnanga coronata, Areca pumida*
Combretaceae	*Terminalia arborea*	Combretaceae	*Terminalia arborea*
Dilleniaceae	*Dillenia aurea, D. obovata, Tetracera scandens*	Dilleniaceae	*Dillenia excelsa, D. obovata, Tetracera scandens*
Aristolchiaceae	*Apama tomentosa*	Aristolchiaceae	*Apama tomentosa*
Maranthaceae	*Phrynium parviflorum, Donnax cunnaeformis*	Maranthaceae	*Phrynium parviflorum, Donnax cunnaeformis,*
Anarcardiaceae	*Dracontomelon pubarulum, D. dao, Spondias pinnata*	Anarcardiaceae	*Dracontomelon dao, Spondias pinnata*
Euphorbiaceae	*Baccaurea javanica, Glochidion sp., Alchornea ruguss, Bischofia javanica, Homolanthus populneus, Claoxylon polot, Aporoa autita, Antidesma bunius, Mallotus peltatus*	Euphorbiaceae	*Baccaurea javanica, Alchornea ruguss, Claoxylon polot, Aporoa autita, Antidesma bunius, Mallotus peltatus, Bridelia monoica*
Arecaceae	*Arenga obtusifolia, Salacca edulis*	Arecaceae	*Arenga obtusifolia, Licuala spinosa*
Myristicaceae	*Knema glauca*	Myristicaceae	*Knema glauca*
Annonaceae	*Oxymitra cunnaeformis, Uvaria littoralis, Canagium odoratum, Stelechocarpus barahol*	Annonaceae	*Oxymitra cunnaeformis, Canagium odoratum, Stelechocarpus barahol*
Vitaceae	*Leea sambucina*	Vitaceae	*Leea sambucina, L. rubra*
Costaceae	*Costus specistus*	Melastomataceae	*Mellastoma affine*
Verbenaceae	*Vitex pubescens*	Verbenaceae	*Vitex pubescens, Lantana camara*
Lauraceae	*Sumbaviopsis albicans, Litsea sp.*	Lauraceae	*Sumbaviopsis albicans, Litsea sp., Paederia scadens, Cainnanomum iners*

Moraceae	*Artocarpus elastica, Ficus callosa, F. montana, F. sagitata*	Moraceae	*Artocarpus elastica, Ficus gibbasa, F. montana*
Ranunculaceae	*Pterospermum diversifolium*	Ranunculaceae	*Pterospermum javanica*
Myrtaceae	*Eugenia polyantha, Decasperum fructicosum, Syzgium polyantha*	Myrtaceae	*Eugenia subglauca, E. polyantha, Decasperum fructicosum,*
Ebenaceae	*Diospyros pendula, D. macrophylla, Saccopetalum heterophylla*	Ebenaceae	*Diospyros macrophylla, D. frutescens, Saccopetalum heterophylla*
Rutaceae	*Zanthoxilum rhesta, Evodia latifolia*	Rutaceae	*Evodia latifolia*
Rubiaceae	*Anthocephalus chinensis*	Rubiaceae	*Anthocephalus chinensis, Uncaria sp.*
Bignoniaceae	*Radermachera gigantean*	Cyperaceae	*Tetrania sp.*
Hypoxidaceae	*Curculigo onchiodes*	Hypoxidaceae	*Curculigo onchiodes*
Musaceae	*Musa acuminata*	Schizazeae	*Lygodium circinatum*
Fabaceae	*Derris thyorsifolia*	Connaraceae	*Rourea minor*
Araceae	*Cladium bicolor*	Araceae	*Cladium bicolor*
Tilliaceae	*Microcos panniculata, Pentara polyanthra*	Tilliaceae	*Microcos panniculata, Pentara polyanthra, Microcosm comentosa*
Sterculiaceae	*Sterculia sp.*	Sterculiaceae	*Sterculia coccinea*
Violaceae	*Rinorea sp.*	Meliaceae	*Aglaia argentea*
Lythraceae	*Lagerstroemia flos-regime*	Lythraceae	*Lagerstroemia flos-regime*
Thymelaceae	*Phaleria octendre*	Thymelaceae	*Phaleria octendre*
Lechytidaceae	*Barringtonia gagantostachua, Planconia valida*	Lechytidaceae	*Barringtonia gagantostachua, Plachonia valida*
Clusiaceae	*Garcinia parvifolia*	Clusiaceae	*Garcinia parvifolia, G. diodica*
Olaceae	*Strombossia javanica*	Olaceae	*Strombossia javanica*
Myrsinaceae	*Ardisia humilis*	Myrsinaceae	*Ardisia humilis*
Zingiberaceae	*Amomum coccineum*	Kuliaceae	*Neonanchea calcina*
		Flaccurtiaceae	*Flcourtia rukem*
		Graminaeae	*Symplocus sp.*
		Sapindaceae	*Pometia pinnata*
		Piperaceae	*Piper bantamense*

Table 2 Average plant growth rate (height/cm) across all cleared quadrats (n = 15).

Quadrat (plot size)	Plant stage & type	Mean & SD of plant growth (height/cm) across all plots	Highest growth single species/family & % of species across all plots
2m x 2m	seedlings	Mean 4.27; SD ± 2.32	species - *Apama tomentosa* family - *Aristolchiaceae* 33%
5m x 5m	shrubs	Mean 3.20; SD ± 2.11	species - *Arenga obtusifolia* family - *Arecaceae* 66%
10m x 10m	saplings	Mean 33.29; SD ± 15.71	species - *Arenga obtusifolia* family - *Arecaceae* 46%
20m x 20m	older tree	Mean 113.48; SD ± 59.05	species - *Lagerstroemia flos-regime* family - *Aristolchiaceae* 26%

Table 3 Comparison of arenga palm and rhino food plant numbers (stems) recorded at all (n = 15) cleared and uncleared arenga palm sites.

Quadrat (plot size)	Plant stage & type	No of arenga palm plants across all plots (n=15)	No of rhino food plants across all plots (n=15)
2m x 2m Cleared	seedlings	473	1297
2m x 2m Uncleared	seedlings	71	401
5m x 5m Cleared	shrubs	6349	5617
5m x 5m Uncleared	shrubs	87	145
10m x 10m Cleared	saplings	0	457
10m x 10m Uncleared	saplings	1677	1931
20m x 20m Cleared	older tree	0	755
20m x 20m Uncleared	older tree	1398	9,266

Table 4 Summary of quadrat plant response data collected at each of 15 x one ha (n = 15) cleared and uncleared arenga palm sites (Sept 2016 - Sept 2018).

Quadrat (plot size)	Plant stage & type	Mean & SD of no plant species across all plots (n=15)	Mean & SD of no plant families across all plots (n=15)	Mean & SD of no stems (plants) across all plots (n=15)
2m x 2m Cleared	seedlings	Mean 4.93; SD ± 1.14	Mean 4.8; SD ± 1.14	Mean 18.47; SD ± 14.86
2m x 2m Uncleared	seedlings	Mean 7.4; SD ± 1.84	Mean 7.2; SD ± 1.85	Mean 4.15; SD ± 2.22
5m x 5m Cleared	shrubs	Mean 2.73; SD ± 1.19	Mean 2.71; SD ± 1.18	Mean 156.11; SD ± 46.14
5m x 5m Uncleared	shrubs	Mean 3.53; SD ± 1.50	Mean 3.2; SD ± 1.20	Mean 2.74; SD ± 1.62
10m x 10m Cleared	saplings	Mean 1.86; SD ± 0.74	Mean 1.86; SD ± 0.74	Mean 14.45; SD ± 7.13
10m x 10m Uncleared	saplings	Mean 3.33; SD ± 1.23	Mean 3.2; SD ± 1.14	Mean 31.86; SD ± 12.89
20m x 20m Cleared	older tree	Mean 2.5; SD ± 0.98	Mean 2.48; SD ± 0.98	Mean 19.60; SD ± 70.10
20m x 20m Uncleared	older tree	Mean 5.13; SD ± 1.76	Mean 4.4; SD ± 1.12	Mean 104.76; SD ± 3.20

Table 5 Statistical analysis results for number of plants, number of plant species, number of plant families, comparison (ANOVA) of number of plants (4 x quadrats per site), number of plant species (4 x quadrats per site), number of plant families (4 x quadrats per site) and number of arenga palms between cleared and non-cleared sites for 2 x 2, 5 x 5, 10 x 10 and 20 x 20m quadrats.

ANOVA/t-test results - number of plants				
Plant group	*df*	*F*	*Fcrit*	*P-value*
2 x 2 seedlings	1	7.378	4.195	0.01
5 x 5 shrubs	1	38.36	4.195	1.11
10 x 10 saplings	1	26.871	4.195	1.68
20 x 20 older tree	1	51.561	4.195	8.16
ANOVA/t-test results - number of plant species				
2 x 2 seedlings	1	15.256	4.195	0.000
5 x 5 shrubs	1	3.351	4.195	0.77
10 x 10 saplings	1	8.45	4.195	0.007
20 x 20 older tree	1	22.716	4.195	5.25
ANOVA/t-test results - number of plant families				
2 x 2 seedlings	1	16.669	4.195	0.000
5 x 5 shrubs	1	2.904	4.195	0.099
10 x 10 saplings	1	9.633	4.195	0.003
20 x 20 older tree	1	20.633	4.195	0.000
ANOVA (4 x quadrats per site) - comparison of number of plants				
2 x 2 seedlings	3	0.230	2.769	0.874
5 x 5 shrubs	3	1.095	2.769	1.095
10 x 10 saplings	3	0.765	2.769	0.518
20 x 20 older tree	3	0.477	2.769	0.699
ANOVA (4 x quadrats per site) - comparison of number of plant species				
2 x 2 seedlings	3	2.713	2.769	0.053
5 x 5 shrubs	3	0.655	2.769	0.053
10 x 10 saplings	3	0.933	2.769	0.430
20 x 20 older tree	3	1.031	2.769	1.031
ANOVA (4 x quadrats per site) - comparison of number of plant families				
2 x 2 seedlings	3	1.642	2.769	0.189
5 x 5 shrubs	3	0.366	2.769	0.777
10 x 10 saplings	3	0.983	2.769	0.407
20 x 20 older tree	3	2.769	2.769	0.548
ANOVA (4 x quadrats per site) - comparison of number of arenga palms				
2 x 2 seedlings	1	21.833	4.195	6.78
5 x 5 shrubs	1	0.072	4.195	0.789
10 x 10 saplings	1	0.864	4.195	0.360
20 x 20 older tree	1	24.177	4.195	3.48

Chapter 5 More than just mud: The importance of wallows to Javan rhino ecology and behaviour

Figure 5.1 Camera trap image of an adult female Javan rhino and calf wallowing in Ujung Kulon National Park, West Java, Indonesia (Image: Courtesy Ujung Kulon National Park Authority).

Note: The peer reviewed, and accepted paper has been incorporated into **Chapter 5**

Wilson, S.G., Hockings, G., Deretic, J.M. & Kark, S. (2020). More than just mud: The importance of wallows to Javan rhino ecology and behaviour. *Pachyderm*, Vol. 61, August/September 2020.

5.1 Abstract

All members of the family Rhinocerotidae have the need to wallow in mud or water to protect their skin from sun damage, remove ectoparasites and for thermoregulation. Wallows are critically important in the habitat and behavioural repertoire of all Asian rhinoceroses. The critically endangered Javan rhino *Rhinoceros sondaicus* use wallows in Ujung Kulon National Park, West Java, Indonesia that are often well concealed by jungle vegetation. Javan rhinos need to wallow regularly throughout the year, yet the role wallows play in their behaviour and the importance to the species remains little understood. In this study, we identified, mapped, and studied 35 wallows in eastern Ujung Kulon National Park, where rhinos were active. We spatially mapped and recorded each wallow's characteristics. We examined rhino wallowing behaviour using 392 remote camera trap videos, taken across Ujung Kulon during a five-year study from 2011 to 2016. We identified and categorised eight behavioural patterns at and near wallows related to rhino daily activities and found that wallows have several key features for the Javan rhinos. Findings revealed that Javan rhinos who construct the wallows themselves, choose sites with 75% shade cover and often at an elevation. Analysis of the rhino calls from camera trap videos taken at and near wallows, identify seven vocalisation descriptors with accompanying sonograms, a first for this rare and shy rainforest species. We discovered that Javan rhino utilise wallows not only for thermoregulatory function, but also as sites of interaction and communication. This has important implications for conservation and potential translocation of rhinos and will require finding sites with suitability for the construction of wallows.

5.2 Introduction

Wallowing, is the immersion of the body in small water holes or mud (termed wallows), is a widespread behaviour among large mammalian herbivores (Owen-Smith 1973, 1975, 1988). The main known reasons for wallowing include protection against the sun (Varada & Alessa 2014), thermoregulation (Dinerstein 2003), removal of ectoparasites (Hoogerwerf 1970), skin conditioning (Ammann 1985), and olfactory advertisement by impregnating the skin with the urine-rich mud or water of the wallow (Sody 1959; Schenkel & Schenkel-Hulliger 1969a, 1969b). Wallowing is critical to protect the integrity of the skin (Shadwick et al. 1992), failure to wallow increases the risk of skin conditions (Munson et al. 1998). Wallows are an important component in the habitat and behavioural repertoire of all Asian rhinos (Blyth 1862; Hoogerwerf 1970; Groves & Kurt 1972; Laurie et al. 1983; Ammann 1985).

The Javan rhino regularly utilises wallows in Ujung Kulon, which are often concealed by rainforest vegetation (Ammann 1985) (Figure 5.1). Javan rhinos wallow throughout the year, and the role that wallows play as communication hubs may be underestimated and of greater importance than they are to other species (Dinerstein 2011). We suspected wallows may be important interaction and communication sites. Based on camera trap evidence Hockings (2016), suggested that more than one animal may share and use the same or multiple wallows, which increases the potential of interaction, or at minimum be able to find olfactory messages left by other rhinos at those sites. Javan rhino are known to urinate in wallows impregnating their bodies with distinctive scents; the scents are then disseminated throughout the habitat as the animals move through forest vegetation and are presumably recognised by others (Schenkel & Schenkel-Hulliger 1969a, 1969b).

The 30,000-ha peninsula (main rhino population area) and the 5,100-ha eastern Gunung Honje areas comprises several land cover types, primarily dominated by secondary broadleaf evergreen forest and primary broadleaf evergreen forest (Ramono et al. 2009) (Figure 5.2). Coastal and intertidal areas also support mangrove and swamp forest habitat (Santosa et al. 2013). The dominance of arenga palm *Arenga obtusifolia* across the park may be influencing rhino habitat use through plant succession and competition with rhino foraging areas (Hariyadi et al. 2012; Haryono et al. 2015, 2016). It is estimated up to 60% (>18,000 ha) of the peninsular is covered by arenga palm (Indonesian Ministry of Forestry 2007).

Javan rhino habitat preference is determined by a broad suite of biophysical factors, including sensitivity to human disturbance (Haryono et al. 2015, 2016). While vegetation and elevation are important determinants of rhino habitat, their influence is strongly modified by proximity to water, to mineral salt (e.g., salt-sprayed vegetation) and especially to site conditions that favour the maintenance of long-term wallows (Ramono et al. 2009). Wallows can be detected by distinctive paths, muddied vegetation, and trees that have been repeatedly rubbed with the head and horns of visiting and departing rhino (Groves & Leslie Jr, 2011). Research, specifically on Javan rhino behaviour at wallows has been very limited to date, due to their rarity, shy nature, and highly protected status. Most wallow data collected to date has been included as a component of broader ecological and habitat studies (e.g., Schenkel & Schenkel-Hulliger 1969; Hoogerwerf 1970; Griffith 1983; Sadjudin 1984; Ammann 1985; Ramono et al. 1993; Muntasib 2002; Rahmat 2007; Chandradewi 2011; Santosa et al. 2013).

Preliminary behaviour observations of Javan rhino based on video trap surveys were undertaken by Hariyadi et al. (2010) including surveillance at some wallows in the peninsula area of Ujung Kulon. The use of camera traps in the Hariyadi et al. (2010) study has assisted in providing a basis for setting up monitoring protocols based on behaviour and how they interact with the surroundings, and at sites such as wallows. The wallowing behaviour of the related greater one-horned rhino *Rhinoceros unicornis* has been well researched (Dinerstein 2003, 2011; Laurie 1982; Laurie et al. 1983; Dutta et al. 2015), as has the two African species (Owen-Smith 1973; 1975; Kiwia 1989; Shrader & Owen-Smith 2002; Dinerstein 2011).

This study was aimed at understanding the importance of wallows to Javan rhino ecology and behaviour, determine wallow characteristics and their use for conservation planning. The key objectives of this research were to a) find and spatially map (estimated 35+ wallow locations), and record characteristics of each rhino wallow in the 5,100 ha Javan rhino study and conservation area (JRSCA) section of Ujung Kulon National Park, and; b) record rhino wallow visitation frequency and behaviour at active wallows in the Ujung Kulon peninsula area and adjacent 5,100 ha Javan rhino study and conservation area using video camera traps.

5.3 Methods

5.3.1 Study area

In 2010, a 5,100-hectare Javan Rhino Research and Study Conservation Area (JRSCA) was established within the greater Gunung Honje area of Ujung Kulon National Park (Ellis 2010). This included installation of an 8 km long rhino proof fence (Figure 5.2) to protect the habitat area, exclude domestic stock and keep rhino in the park. The 5,100 ha JRSCA site was established as a staging area for translocation of a subset of the rhino population to an appropriate site, preferably within its historic range (Haryono et al. 2016). We found, identified, and spatially mapped rhino wallow locations across the eastern Gunung Honje 5,100-ha JRSCA site using a Garmin GPS Maps 62 sc GPS unit and maps were created using ArcMap 10.5 software (ESRI). We used the World Imagery spatial layer and sourced spatial components from ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, USDA, USGS, AeroGRID, IGN, and the GIS User Community. We took photographs using a Canon 50D digital camera of each of the 35 wallows to quantify the wallow features.

A Lutron LT Temperature and Humidity Reader Model HT-305 was used to take readings at rhino wallows to determine whether relative humidity and ambient temperature are factors in wallow choice and creation. The physical characteristics of wallows included their location, topography, vegetation, soil type, shade/canopy cover, elevation and concealability characteristics were recorded quantitatively and examined qualitatively.

Figure 5.2: Map of eastern Gunung Honje region of Ujung Kulon National Park showing the Javan Rhino Study and Conservation Area (JRSCA) and rhino fence location (black line).

5.3.2 Camera trap recording of wallowing behaviours

Direct observation of Javan rhino is extremely difficult due to its rarity, currently 74 animals (Gokkon 2020) and remote rainforest habitat. Therefore, motion sensor camera traps are a valuable remote sensing tool for studying Javan rhino behaviour in the wild. All rhino vocalisations (hereafter called ‘calls’) were recorded using Bushnell eight-megapixel Trophy CAM HD™ cameras as part of an ongoing monitoring program used by Ujung Kulon managers to monitor Javan rhino populations and other endangered species. Across the Ujung Kulon peninsula 120 cameras have been strategically placed in 1000 m^2 quadrats to best capture rhino activity, and each quadrat has been given a coded number and letter, for example, 34AQ (Figure 5.3). Each camera is set at a height of 1.7 metres, then angled 10 degrees to cover a field of view out to 5 metres (see Table D.1 Camera site number (n=32) and no of videos (n=137) recorded at each site (UKNP peninsula), Appendix D). The video camera footage was provided by the Ujung Kulon National Park Authority.

To reduce disturbance to the rhinos and other animals, the cameras were placed high above rhino eye level with a downward angle that enables capture of details of rhino behaviour. The cameras were programmed to record sound and imagery both day and night when an animal is in the field of view. The camera video records in 30 second intervals whilst an animal remains in camera vision. Ujung Kulon rangers and rhino protection unit staff collect and download camera memory cards each month (while on routine patrol), except for December and January when the whole area becomes inaccessible due to monsoonal conditions. Initially, ten Bushnell Trophy Cam HD eight-megapixel remote cameras were set up at active wallows utilising the 5,100-ha eastern Gunung Honje area. This is due to the low numbers of animals (i.e. estimated nine animals) periodically utilising the area and rhino moving from wet wallows to waterways when dry conditions occur (Ramono et al. 2009).

However, after several months this was discontinued due to regular camera interference by local community, presumably local wildlife poachers not wishing to be filmed. Prior to removal of the cameras, I was able to capture approximately 30 days of rhino activity, specifically the solitary male ‘Samson’ wallowing activity. In this study, apart from the individual male ‘Samson’ all rhinos were identified only to determine their sex due to individual identification limitations of the video clips. Although direct observation of animals rarely occurs, animals are identified using Griffith’s (1983) identification criteria which compares morphological features including horn size and shape, footprint size, eye wrinkles, ear shape and distinct features such as scars, damaged skin folds or skin pigmentation (Hariyadi et al. 2011). The UKNP Authority monitors the rhino population across the national park using its network of permanent video cameras and has built up a considerable database of each individual rhino and its identification characteristics.

5.3.3 Sound and visual recording

Each video was converted into a sound file using Adobe Audition CC 2015 to create a sonogram of each call (e.g., Figures 5.9, 5.10, 5.11, 5.12). The video file was opened in Adobe Audition, sample type was then converted, and a sample rate of 32,000 Hz was used with, Channel to Mono and Bit Depth of 16 bits. The files were originally recorded in stereo at a sample rate of 48,000 Hz with a 32-bit depth. The file was converted to a mono sample at 32,000 Hz with a 16-bit depth to show the vocal characteristics more clearly. Rhino calls of adult male, female, sub-adult, and calves were then sampled by using the cursor to measure length and frequency of the rhino’s call. Headphones with a noise cancelling function are used to listen to calls to ensure good quality sound.

A video of the sound recording was made using Microsoft Office PowerPoint and then the video of the rhino was attached to this using Adobe Premier. The sample rate indicates the number of digital snapshots taken of an audio signal each second and determines the frequency range of an audio file. The higher the sample rate, the closer the shape of the sound wave is that to the original waveform. The bit depth determines the dynamic range of the sound wave. (Adobe 2011).

Amplitude is shown as intensity of either grey scale or colour. Sonograms of each different call were identified and distinguished using Adobe Audition CC 2018. Calls were compared to the video vision to ensure they were correct, isolated, and saved as wav. files into a new window within Audition. Individual calls were then opened in Raven Lite 2.0.0™ showing the time (s) and frequency (kHz) scales. These calls were then converted to colour scale for clarity and snipped using the snipping tool in Microsoft Office 2016. Images were saved as jpeg files. Collected data from each video included gender of rhino, age, date, time of day, location, vocal type, duration of call (sec), frequency of call and behavioural activity (see Table D.2, List of characteristics measured from camera trap videos, Appendix D).

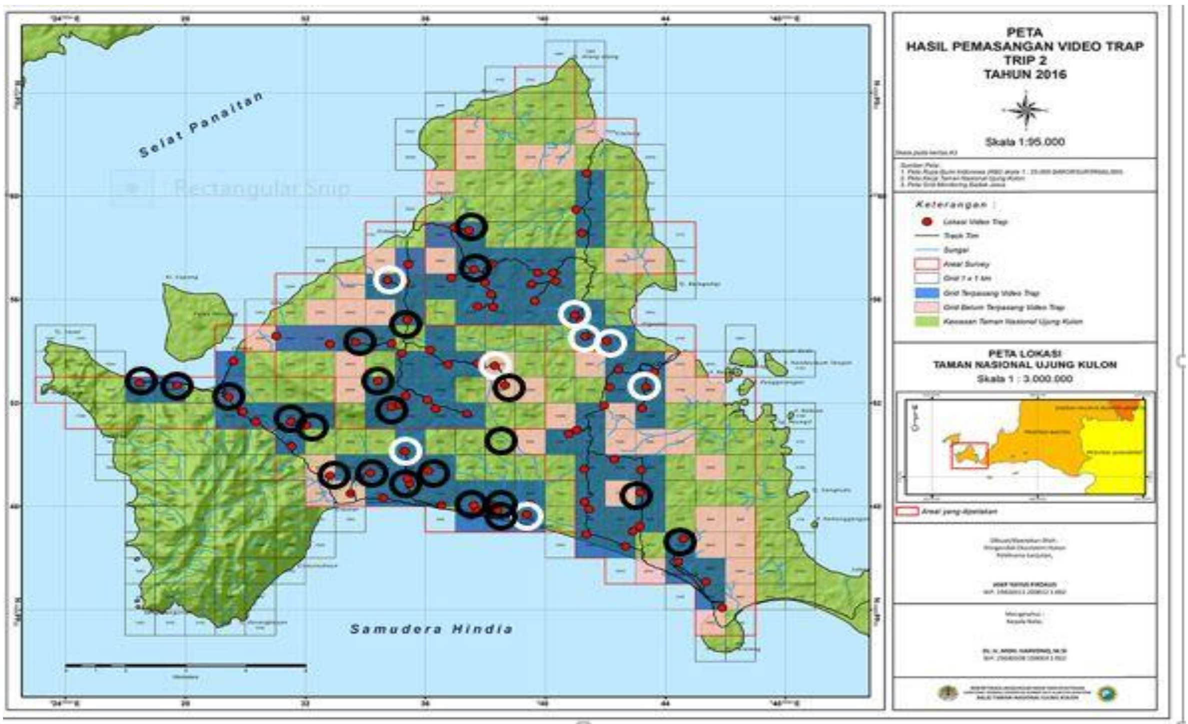

Figure 5.3: Map of Ujung Kulon NP (peninsula) West Java, Indonesia, with grid system overlaid, and locations of camera traps (red dots). White circles = wallow locations of camera recordings. Black circles = forest locations of camera recordings. Map: Courtesy Ujung Kulon National Park Authority.

5.3.4 Data analysis

To test whether there was temporal variation, the categories Early Morning (EM, 24:00 - 06:00), Morning (M, 06:00 - 12:00), Afternoon (A, 12:00 - 18:00), and Evening (E, 18:00 - 24:00) were used. To test for seasonal variation in wallow use, we used wet season (November - May), and dry season (June - October) observations. We also examined the frequency of sightings in four vegetation types, open broadleaf, dense broadleaf, open broadleaf/arenga palm and dense broadleaf/arenga palm forest. Behavioural aspects of wallow activity i.e. sitting, lying, rolling, sleeping, neck rubbing, and calls were also recorded (Table 1). Test statistics were considered significant with P values < 0.05. A total of 157 calls (2011-2016) were examined. To test for seasonal variation, we used wet season (November - May), and dry season (June - October) observations. We also examined the frequency of sightings in four vegetation types, open broadleaf, dense broadleaf, open broadleaf/arenga palm and dense broadleaf/arenga palm forest. Behavioural aspects of wallow activity i.e. sitting, lying, rolling, sleeping, neck rubbing, and calls were also recorded (Table 1). To analyse any correlations, patterns and relationships bivariate data scatterplots were used. We examined potential correlations and trends in collected data including percentage of shade cover at wallows vs. elevation at wallow sites, and distance from wallow to coast vs. elevation at wallow sites. To interpret patterns in the data, the following attributes were used. Linearity (linear or non-linear), slope (positive (up) or negative (down), strength (strong or weak relationship) and unusual features (e.g., outlier).

5.4 Results

We examined 137 peninsula camera trap videos taken during 2011-2015 and 255 eastern Gunung Honje camera trap videos taken during 2016 (Table 4). We determined eight active wallow sites comprising 68 videos (Figure 5.4) and 23 forest locations with rhino activity captured via 69 videos (Table 5). In the peninsula area of Ujung Kulon, we described and identified eight behavioural patterns and 11 sub-behavioural pattern categories (Table 1) at and near wallows from the 68 videos taken during the 2011-2015 period (Table 2). Chi-squared (χ^2) tests identified significant < 0.05 statistical differences between observed and expected results for temporal (time of day) and seasonal (wet/dry) differences. No statistically significant differences < 0.05 (χ^2 tests > 69.29, P = 6.04, df = 3) were identified for vegetation types where the frequency of Javan rhino were captured on camera trap. The relationship between temporal (time of day) observations (χ^2 tests > 19.17, P = 0.00, df = 3), seasonal (wet/dry) observations (χ^2 tests > 17, P = 0.00, df = 1) were significant.

Table D.1 (Appendix D) lists the 32-camera trap video quadrat peninsula locations and the total 137 videos of recorded rhino activity at both wallow and forest areas. Chi-squared (χ^2) analysis for the number and frequency of individual vocalisations (calls) used by year showed no statistical differences between observed and expected results. Results for the years 2011, n=53 (χ^2 tests > 29.35, P = 1.884, df = 2), 2013, n=42 (χ^2 tests > 35.71, P = 1.756, df = 5), 2014, n=14 (χ^2 tests > 7.142, P = 0.674, df = 1), 2015, n=14 (χ^2 tests > 5.285, P = 0.152, df = 2) and 2016, n=24 (χ^2 tests > 31.75, P = 5.908, df = 2). Of the total 196 individual calls recorded, the wallow sites recorded increased calling by rhinos, including 157 individual calls compared to 39 calls by rhino in forest (Table 5). Presumably, this occurred due to increased opportunities for animals to interact with conspecifics at wallow sites, an often-shared habitat feature.

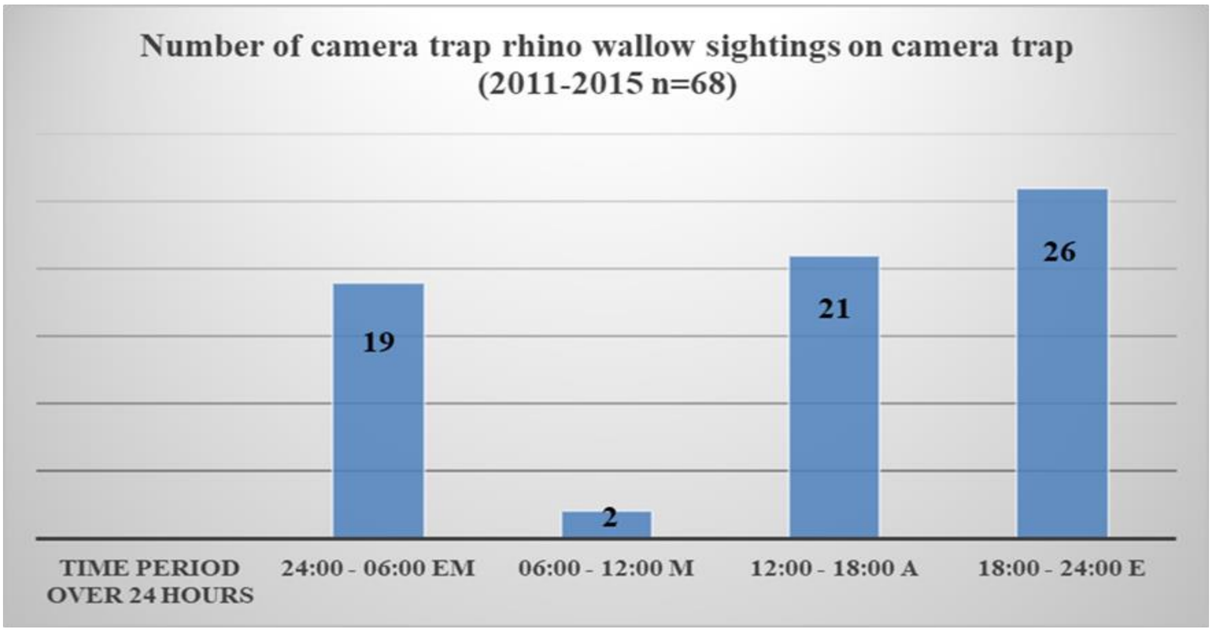

Figure 5.4: Bar graph of peninsula population wallowing activity patterns 2011-2015 (n = 68) clips taken by camera trap video. Note: EM = early morning, M = morning, A = afternoon, E = evening.

A greater diversity of calls occurred at wallowing sites compared to in forest recordings. For example, at wallows the number of different call recordings, n=16, mean 3.2; SD ± 1.643, median 3, mode 2,3. In forest the number of different call recordings, n=5, mean 1.25; SD ± 0.5, median 1, mode 1. Additionally, we observed the wallowing pattern of the male rhino 'Samson' (curved leaf shaped left ear) in the eastern Gunung Honje area of the national park via 255 videos taken during the period 12/11/2016 - 16/12/2016. Over this 30-day period we recorded 14 calls and observed bouts of wallowing behaviour ranging between 15 minutes and 6 hours, 9 minutes. The male 'Samson' visited the same wallow (06° 49'640''S 105° 28'728'' E) eight times (n=8) during this period (Figure 5.5).

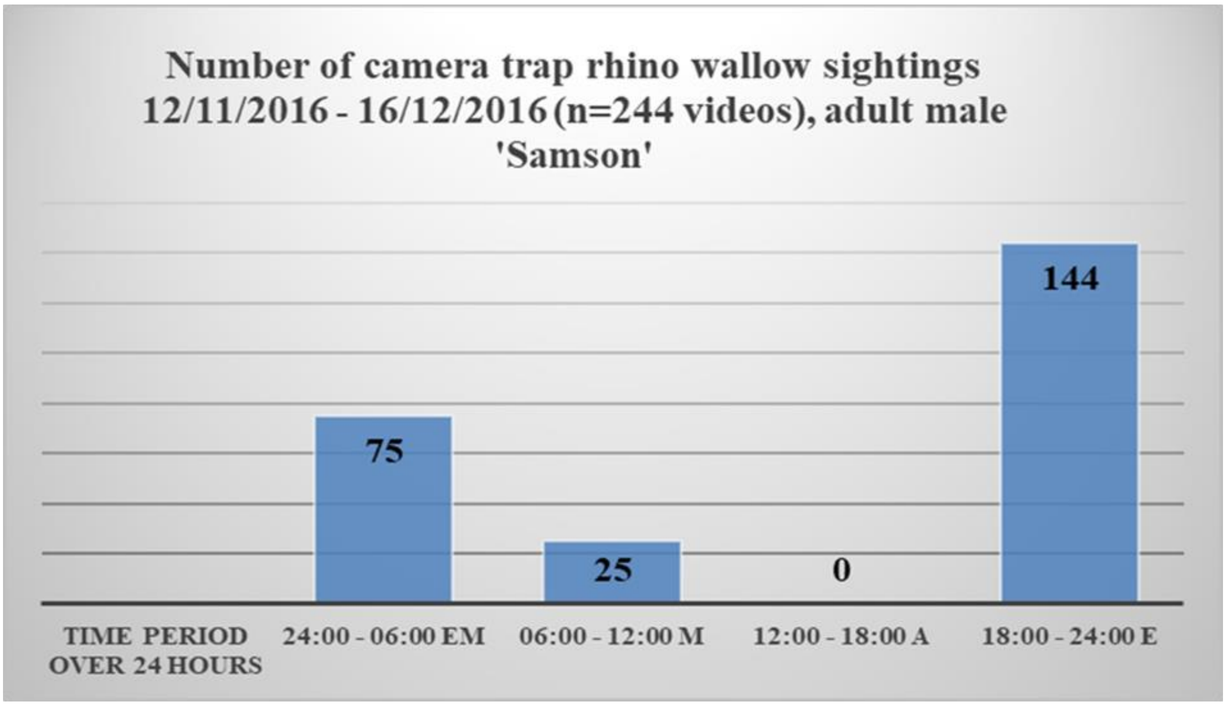

Figure 5.5: Bar graph of the Javan Rhino Study and Conservation Area (JRSCA) in the eastern section of Ujung Kulon National Park, solitary male 'Samson' wallowing activity taken between 12/11/2016 - 16/12/2016 (n=244) clips taken by camera trap video. Note: EM = early morning, M = morning, A = afternoon, E = evening.

Wallowing duration averaged (hrs/min) (mean 2.71; SD ± 2.40, median 2.64, mode 0.48, 5.09, 1.29, 6.09, 0.15, 4.00, 0.35, 4.28). Temporal (time of day) observations (χ^2 tests > 87.83, P = 8.46, df = 2). Thirty-five wallows (n=35) were found and spatially mapped (Figure 5.6) and characteristics recorded between 1/02/2015 - 13/06/2017 in the eastern Gunung Honje Javan Rhino Study Conservation Area (JRSCA). Recorded characteristics included, wallow length and width, water and mud depth, no entry/exit points, percentage shade cover, elevation, wallow type (permanent or temporary) and plant species at each site (Table 3). Scatterplot analysis of percentage (%) of shade cover at wallows vs. elevation at wallow sites (Figure 5.7) were linear, positive slope and weak (y = 0.5937x + 56.281, R^2 = 0.0487), and distance from wallow to coast vs. elevation at wallow sites (Figure 5.8) were non-linear, negative slope and weak (y = -0.0022x + 0.718, R^2 = 0.0017). Overall, the scatterplot analysis results were mixed with no strong correlations identified between variables.

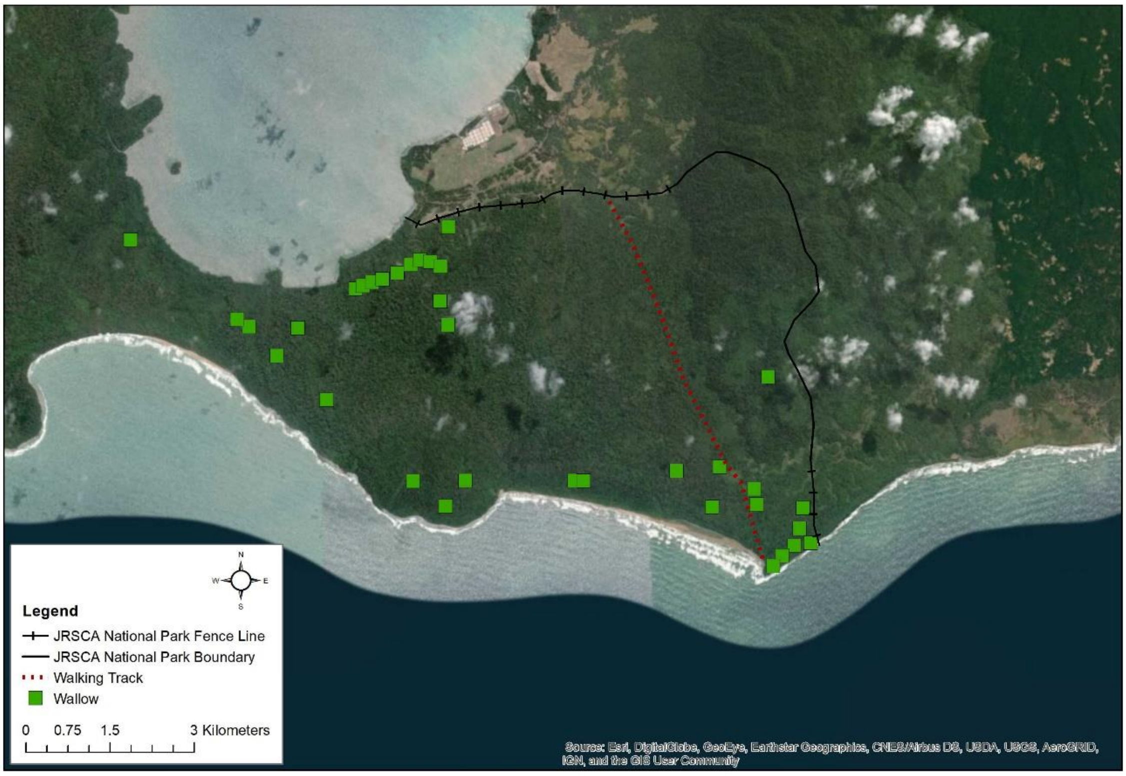

Figure 5.6: Map of wallow locations (n=35) in the Javan Rhino Study and Conservation Area (JRSCA) (green squares) in the eastern section of Ujung Kulon National Park.

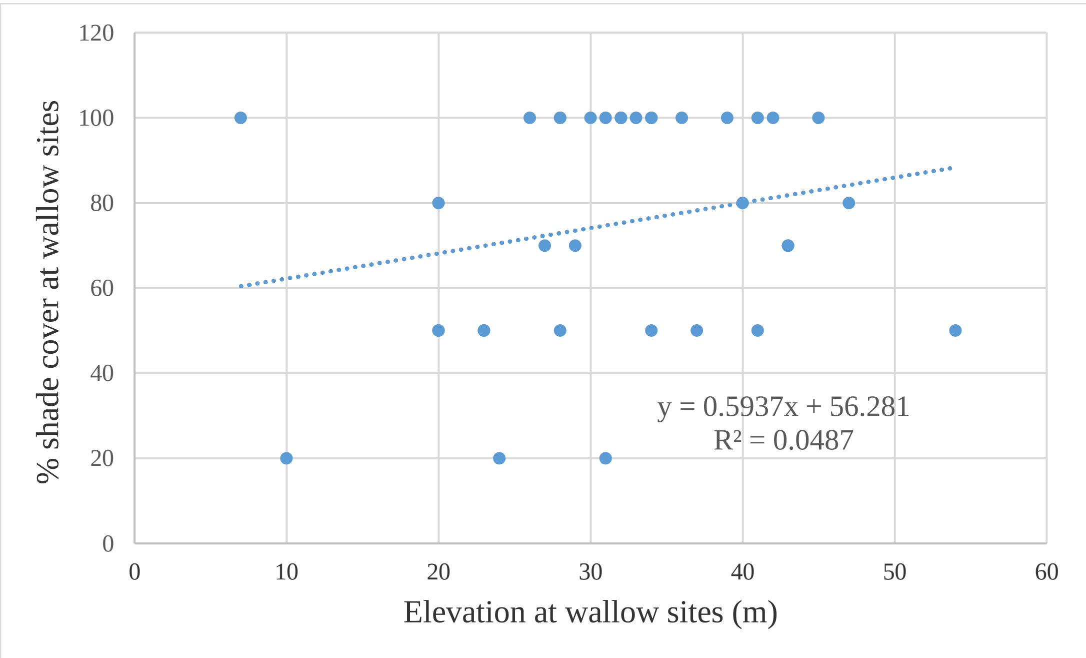

Figure 5.7: Scatterplot of percentage (%) shade cover at wallows (km) vs. elevation (m) at wallow sites.

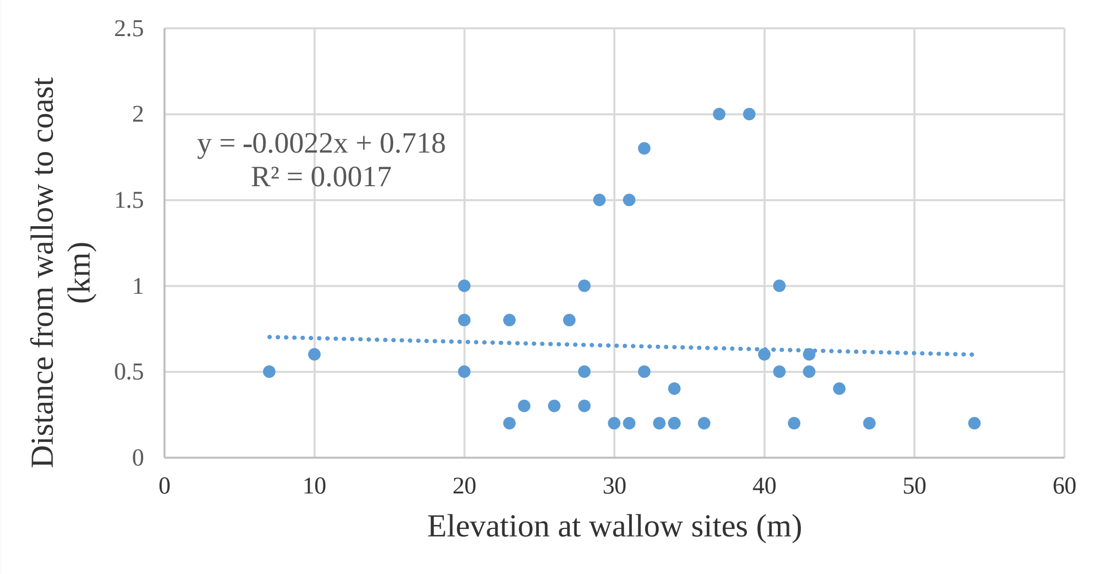

Figure 5.8: Scatterplot of distance from wallow (km) to coast vs. elevation (m) at wallow sites.

5.4.1 Behaviours recorded at wallows

Table 1 Description of eight (n=8) behavioural patterns exhibited by Javan rhino at wallows and recorded on camera trap videos 2011-2016. Adapted from Hazarika & Saikia (2010) descriptions.

Behaviour category	Description
Non-breeding	
1) Feeding	Behaviour associated with consumption of vegetation or water and techniques for intake of different vegetation types.
Drinking	Rhino would place its mouth in water and suck it into its mouth. Drinking often occurred soon after entering a wallow, flehmen (lip curl/facial grimace) was often displayed post drinking by both sexes, presumably in response to other rhino scent in the wallow.
Geophagy	Soil licking or ingestion of soil by rhino in habitat. For example, was observed on two occasions in wallows. In both cases the animal licked and appeared to eat soil from the edge of a wallow. Often followed by a flehmen response.
Browsing	Browsing was the only form of food intake observed and involved consumption of leaves and small twigs from understorey vegetation. Observed using their prehensile upper lip to either bring leaves from standing vegetation directly into their mouth or to pull a branch down and then strip leaves along the length of the branch. Animals would 'taste' leaves, either eating or moved on.
2) Locomotion	Behaviour that resulted in the rhino moving from one place to another.

Walking	Slow movement from one place to another, using the alternate fore and hind limbs simultaneously.
Entering water/wading through water/mud	Entering water/wading through water/mud was characterised by movement from dry land into a mud or water body.
3) Comfort	Behaviour that gave relief to the rhino, related to energy levels or relief from ectoparasites and/ or the sun. Comfort behaviour were sometimes characterised by a lack of motion within the body.
Resting	Lack of physical activity, rhino lying or sitting down in the wallow.
Sleeping	Rhino lying in a recumbent position on their hunches and being in a relaxed state (i.e. ears not alert and erected, eyes closed).
Rubbing	Vigorous rubbing of a section of the rhino's body or head against a tree stump or tree trunk.
Mud and water wallowing	Rhino lying or standing in the wallow. Either motionless while in the wallow or when lying down, often moved/rolled to cover themselves in mud. Wallowing rhinos periodically shake their heads allowing mud and water to penetrate the skins folds on the neck.
4) Vigilance	Behaviours suggesting 'alertness'. Included raised head, scanning with the eyes and head, erect ears and swivelling of ears, likely to determine the source of sound disturbance. Solitary females and females with calves demonstrated this behaviour the most.
5) Investigating environment	Scanning of surrounding environment and sniffing the ground, vegetation, and any structure either while stationary or while walking along. Tracks leading into and away from wallows were often investigated via sniffing the ground and vegetation.
6) Calls (vocalisation)	Call sound or sounds emitted by rhino. Refer Fig 5.8 -5.14 series for call descriptions.
7) Smelling/sniffing	Males would smell/sniff and call a 'sniff-huff' when close to females in wallows. Mud on structure e.g. tree stumps, trees/vegetation would be smelt/sniffed presumably in response to scent left by other animals.
8) Breeding (courtship)	Courtship took place between adult male and female before mating.
9) Touching	Males approaching females in wallows would lightly touch females with nostrils and lips, and sometimes their horns. A flehmen response would often occur soon after touching.

Table 2 Peninsula rhino population wallow video behaviour observation results 2011-2015 (n = 68 videos).

Variable	Result	% of records
Season (Wet = Nov - May), (Dry = June - Oct)	Wet season (n=51)	75%
	Dry season (n=17)	25%
Habitat where observation occurred	Wallows (n=8 locations), (n=68)	100%
Vegetation type where observation occurred	Open broadleaf evergreen (n=4)	6%
	Dense broadleaf evergreen (n=17)	25%
	Open broadleaf evergreen/arenga palm (n=45)	66%
	Dense broadleaf evergreen/arenga palm (n= 2)	3%
Number and descriptor of calls (vocalisations) recorded at wallows	Calls (n=157)	80%
	Call descriptor (n=7), sigh, lip vibration, short pant, long hiss, bleat, sniff-huff, and snort	
Behaviour category, no and percentage of behaviours recorded at and near wallows on camera traps (2011-2015)	Non-breeding	
	Feeding: Drinking (n=6)	9%
	Geophagy (n=2)	3%
	Browsing (n=3)	4%
	Locomotion: Walking (n=4)	6%
Note the percentages are based on the % of video clips for a particular behavior against the total 68 video clips reviewed	Entering/wading through water/mud (n= 3)	19%
	Comfort: Resting/standing/sitting (n=5)	7%
	Rubbing (on structure) (n=5)	7%
	Wallowing (mud/water) (n=68)	100%
	Vigilance (n=4)	6%
	Investigating environment (n=4)	6%
	Flehmen response (n=3)	4%
	Non-breeding play (n=4)	6%
No. of observations (n=70) and sex of rhinos at and near wallows	Solitary male (n=1)	31%
	Solitary female (n=17)	25%
	Female & sub adult calf > 2yrs (n= 1)	31%
	Female & calf < 2yrs (n=2)	3%
	Male & female (n=4)	6%
	Male, female & calf (n=5)	7%
Distance from coast where observation occurred (km)	Mean 1.81; SD ± 1.47	
Distance from nearest waterway from where observation occurred (km)	Mean 0.22; SD ± 0.19	

5.4.2 Wallow types

Based on and adapting Ammann's (1985) descriptions of wallows recorded in the Ujung Kulon peninsula, and my dataset of 35 wallows, we identified two wallow types (Figures 5.16, 5.18, 5.19, 5.20, 5.21, 5.22, 5.23, 5.24).

Mud wallow - Clay based and contained mud to a depth averaging 14 cm, (mean 14.31; SD ± 6.08, Table 1). Rhino using and leaving the wallows were clearly coated with a film of mud. In mud wallows animals were observed on camera video to periodically shake their heads and necks, presumably enabling mud to penetrate the deep skins folds.

Water wallow - Characterised as holding water to depth averaging 18 cm, (mean 18.31; SD ± 10.90, Table 1). Water wallows often had a soft base of mud which would be stirred up and mixed with active use. Rhino using and leaving the wallow were clearly coated with a film of water and the skin was clearly darkened by immersion in water.

Based on the dataset (n=35 wallows) we observed some common wallow characteristics. For example, wallows are often created at elevation (m), (mean 31.77; SD ± 10.05, Table 3), in slightly sloping areas. Often the rear of the wallow was dug out from a bank or edge which enabled the wallow to be enlarged and expanded as necessary, horn marks in banks were often observed (Figure 5.16). The soil being latosolic (highly leached due to heavy rainfall), and clay-based meant run off during rain helped maintain a level of water and mud in the wallow. Shade at the wallow site was important as it influenced the temperature of water and mud, the percentage cover averaged 75% (mean 75.14; SD ± 27.04, Table 3). The dominant over storey shade plant being arenga palm *Arenga obtusifolia*.

Wallow size depended on either single or multiple users, the latter often being many years old due to persistent use. The largest wallow recorded was eight metres long x seven metres wide. Average length (m), (mean 3.69; SD ± 3.12, Table 1), average width (m), (mean 3.17; SD ± 3.37, Table 3). Mud and water depth varied according to prevailing climatic conditions. We also recorded ambient temperature and relative humidity on seven occasions at seven wallows between 22/05/2015 - 21/09/2016. Readings were taken at each wallow and 25 metres away as a control. Despite the small dataset, we recorded consistent reductions although small in temperature and relative humidity at each wallow compared to recordings 25 metres away. Results for temperature (0°C) at wallow (mean 27.68; SD ± 1.78), compared to 25 metres away (mean 27.85; SD ± 1.84). Temperature difference (0°C) at wallow (mean 0.17; SD ± 0.09), compared to 25 metres away (mean 0.67; SD ± 0.83).

Results for relative humidity (%) at wallow (mean 88.6; SD ± 8.93), compared to 25 metres from wallow (mean 89.28; SD ± 8.75). Elevation at these seven wallows averaged (m), (mean 30.28; SD ± 17.33).

Table 3 Eastern Gunung Honje Javan Rhino Study Conservation Area (JRSCA) Ujung Kulon National Park wallow characteristics (n = 35).

Variable	Results
Wallow length (m)	Mean 3.69; SD ± 3.12
Wallow width (m)	Mean 3.17; SD ± 3.37
Wallow water depth (cm)	Mean 18.31; SD ± 10.90
Mud depth (cm)	Mean 14.31; SD ± 6.08
Number entry/exit points	Mean 2.62; SD ± 0.68
Percentage (%) shade cover	Mean 75.14; SD ± 27.04
Elevation (m)	Mean 31.77; SD ± 10.05
Permanent wallow (n=27)	77% (defined as existing in environment beyond climatic conditions, in active use)
Temporary wallow (n=8)	23% (defined as existing in environment only when conditions allow i.e. enough rainfall)
Plant species recorded at wallow sites Note: FP denotes rhino food plant	*Arenga obtusifolia*, *Callamus sp*, *Salacca edulis* (FP), *Leea sambucina* (FP), *Vitex pubescens* (FP), *Amomum coccineum* (FP), *Spondias pinnata* (FP), *Donnax cunnaeformis* (FP), *Phrynium parviflorum* (FP), *Dillenia obovate* (FP), *Barringtonia gagantostachua* (FP), *Anadendrum microstachyum* (FP).
Distance from coast (km)	Mean 0.64; SD ± 0.52
Dominant vegetation type	Complex mosaic of **1.** Dense broadleaf evergreen forest **-** primary or old secondary forest including palms, bamboo, Zingiberaceae (ginger family e.g., *Amomum*), and **2.** Open broadleaf evergreen forest **-** young, open secondary forest, with shrub jungle (Hoogerwerf 1970).

Rather than continue taking random recordings we decided not to continue recording these variables until temperature and relative humidity data loggers could be installed at wallowing sites for extended periods i.e. over 12 months, to enable far more accurate determination if in fact wallow sites are selected due to lower ambient temperature and relative humidity at the site.

5.4.3 Vocal communication recorded at wallow sites

Rhino call recording was greater in number and diversity at wallowing sites (n=157) compared to in forest recordings (n=39). For example, at wallows different call recordings averaged, mean 3.2; SD ± 1.643. In forest different call recordings averaged, mean 1.25; SD ± 0.5.

5.4.4 Sonograms of described calls recorded at wallows

We identified seven call types from the audio video data and categorised these where possible in a manner consistent with terms used by previous researchers (e.g., Schenkel and Schenkel-Hulliger 1969a, 1969b; Ammann 1985). The following seven sonograms identify and describe the characteristics of these new calls.

Bleat. Low intensity contact call made by calves to females. The bleat call is short, clear, and often repeated. Repeated bleats appear to imply urgency or uneasiness i.e. calf wanting to suckle, vocalising vulnerability, or seeking a contact or acknowledgement response from the mother (e.g., sigh or lip vibration). Frequency band width range = 100 Hz - 4.5 kHz, n=34, mean 0.293; SD ± 0.091 (Figure 5.9).

Sniff-huff. The sniff is a short nasal inhalation, followed by an exhaled huff. Used by both sexes, often used when investigating the environment i.e. sniffing vegetation, or possible scent trails left by conspecifics. Frequency band width range is shorter than the snort or sigh, and ranges between 100 Hz - 14.5 kHz, with most calls lasting less than half a second (e.g., 0.2 - 0.5 sec). Average based on dataset = 0.379 seconds, n=48, mean 0.322; SD ± 0.104 (Figure 5.10).

Short pant. A short, often repeated air sounding call. Circle (brown) indicates soft whistle sound at start of call (Figure 5.11). May be a contact/acknowledgement call, possibly infers sexual or dominance status. Recorded only in males to date.
The frequency band width range varies between 100 Hz - 12 kHz, with most repeated calls lasting less than half a second (e.g., 0.1 - 0.3 sec). Average based on dataset = 0.260 seconds, n=65, mean 0.278; SD ± 0.122 (Figure 5.11).

Long hiss. An extended single, strong, air sounding, almost ear-piercing call. May infer a warning/message i.e. I'm with calf or I'm non-reproductive. Only recorded in adult females near approaching males to date.

The frequency range varies between 100 Hz - 11.5 kHz, with the single call lasting more than half a second (e.g., 0.7 - 0.8 sec). Average based on dataset = 0.754 seconds, n=6, mean 0.754; SD ± 0.114 (Figure 5.12).

Sigh. An exhalation call, longer in duration to lip vibration, slow and softer in emphasis, comfort-like and may be used as an acknowledgement i.e. female response to calf bleat or infers comfort i.e. resting in a wallow. Lip vibrations occasionally follow the sigh call. Sighs appear to be used mostly as single calls. The frequency range varies between 100 Hz - 12 kHz, with most calls lasting less than one second (e.g., 0.2 - 1.056 sec). Average based on dataset = 0.610 seconds, n=32, mean 0.685; SD ± 0.285 (Figure 5.13).

Lip vibration. Softer than snort, may be a contact response i.e. from female to calf, or indicate comfort i.e. when feeding. Lip vibrations appear to be mostly single calls, rarely repeated and may be vocalised after a snort or sigh vocal. The frequency range varies between 100 Hz - 5 kHz, with calls lasting less than one second (e.g., 0.7 - 0.8 sec). Average based on dataset = 0.810 seconds, n=5, mean 0.987; SD ± 0.166 (Figure 5.14).

Snort. A strong exhaled loud call may infer vocal dominance from adult male or female. The frequency band width range varies between 100 Hz - 12 kHz, with a single vocal lasting more than one second (e.g., 1.148 sec), n= 2, mean 1.148 (Figure 5.15). Additionally, we recorded another different call in forest habitat away from wallows. This was the *Moo-bray*. A repeated single ‘bleat-like’ call exhibited by the female during courtship. Frequency band width range varies between 100 Hz - 12 kHz, with repeated calls lasting on average based on dataset = 0.596 seconds, n=4, mean 0.596; SD ± 0.041 (refer Chapter 6, Figure 6.10).

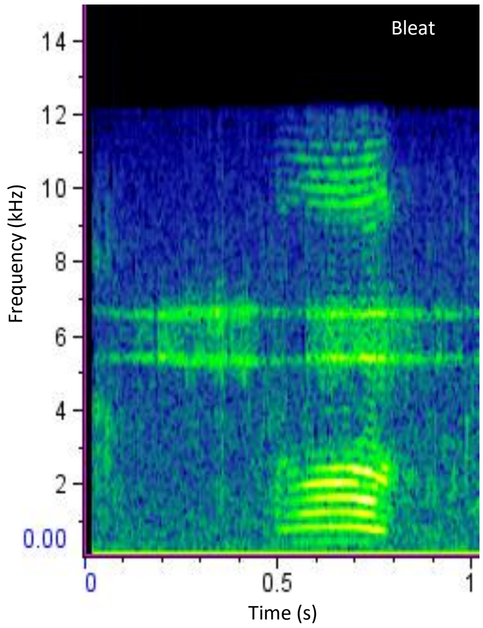

Figure 5.9 *Bleat* - low intensity contact call made by calves to females.

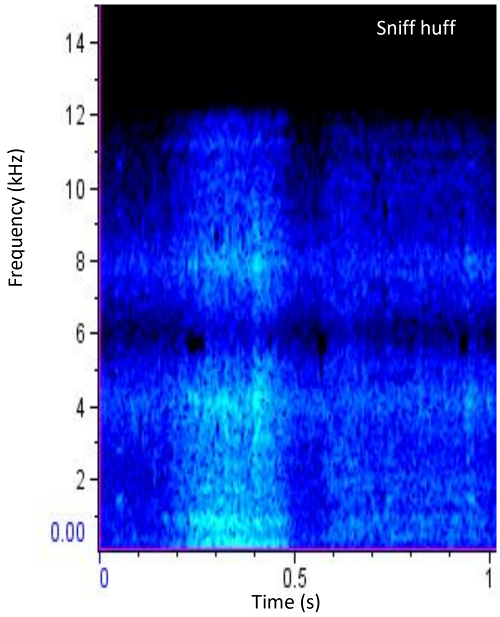

Figure 5.10 *Sniff-huff* - The sniff is a short nasal inhalation, followed by an exhaled huff.

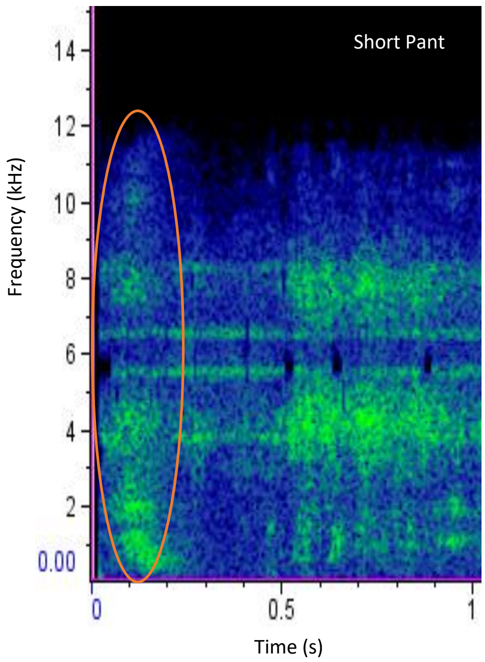

Figure 5.11 *Short pant* - A short, often repeated air sounding call.

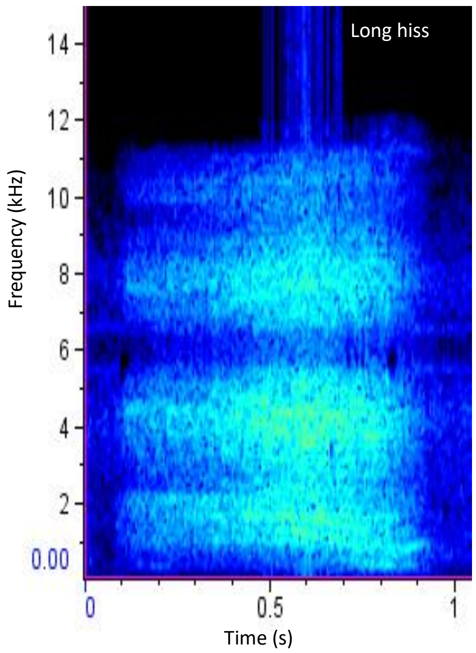

Figure 5.12 *Long hiss* - An extended single, strong, air-sounding, almost ear piercing call.

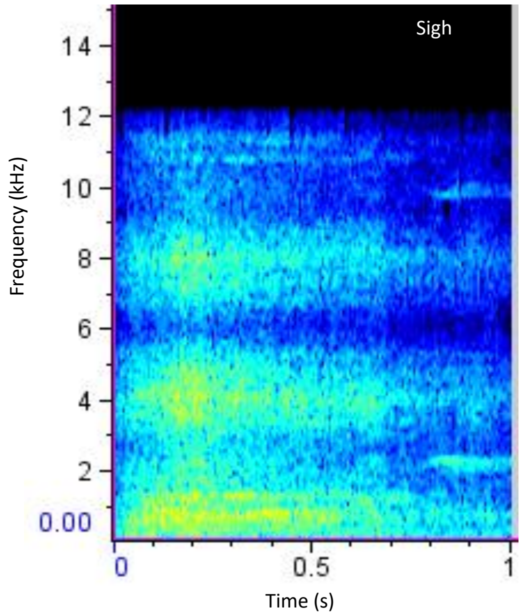

Figure 5.13 *Sigh* - An exhalation call, longer in duration to lip vibration, slow and softer in emphasis, comfort-like and may be used as a acknowledgement i.e. female response to calf bleat or infer comfort e.g. resting in wallow.

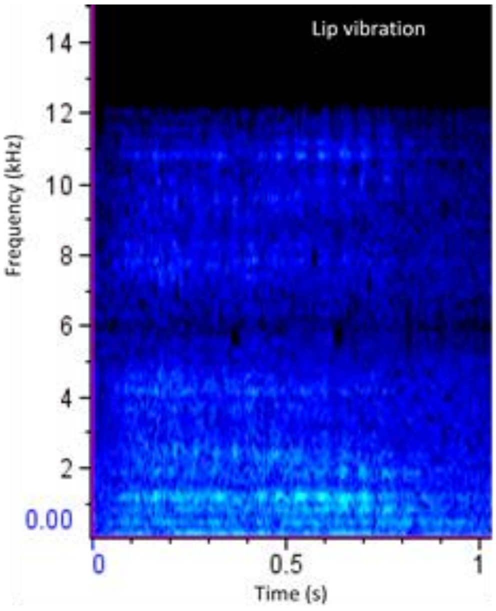

Figure 5.14 *Lip vibration* - Softer than snort, may be a response i.e. from female to calf, or indicates comfort e.g. when feeding.

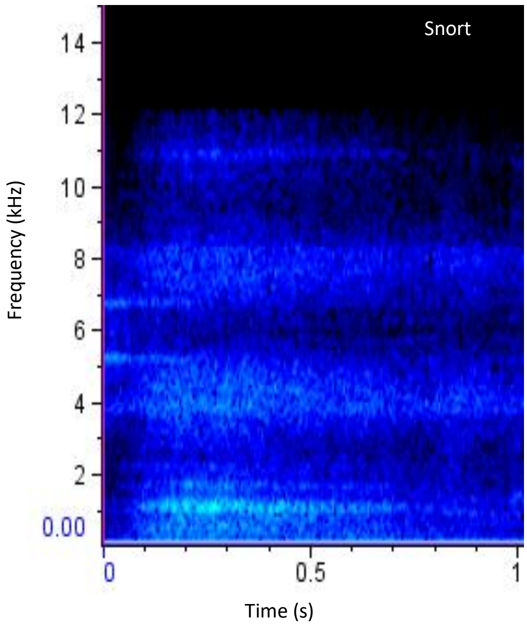

Figure 5.15 *Snort* - A strong, exhaled loud call, may infer vocal dominance from adult male or female.

Table 4 Summary table of Javan rhino camera trap video data (2011-2016).

Total no video clips	Year video recorded	Clip duration (min)	No clips with calls	Call clip duration (min)
6	2011	3.0	5	2.5
45	2013	22.5	13	6.5
32	2014	16.0	8	4.0
54	2015	27.0	15	7.5
255	2016	127.5	14	7.0
Total 392		183.5	55	27.5

Note: no camera trap data was collected by authorities during the 2012.

Table 5 Summary table of camera trap video Javan rhino call descriptor data (2011-2016).

Call descriptor	No. individual calls	Call frequency band width (Hz - kHz)
Short pant*	65	100 Hz - 12 kHz
Sigh*	32	100 Hz - 12 kHz
Snort*	2	100 Hz - 12 kHz
Sniff-huff*	48	100 Hz - 14.5 kHz
Long hiss*	6	100 Hz - 11.5 kHz
Lip vibration*	5	100 Hz - 5 kHz
Bleat*	34	100 Hz - 4.5 kHz
Moo-bray	4	100 Hz - 12 kHz
Total 8	196 (157 at wallows, 39 in forest)	

Note: no camera trap data was collected by authorities during the 2012 period. *Indicates call was recorded at or near wallow. The listed ‘Moo-bray’ call was recorded in forest and was vocalised by a female during courtship behaviour with a male (Refer Chapter 6, Figure. 6.10).

Figure 5.16: Large active three pooled wallow. This wallow has multiple users and has many entries and exit points. The wallow sits in a natural basin area and is kept wet due to regular rain run-off.

Figure 5.17: Rhino horn holes and skin imprint in wall of wallow. Rhinos use their bulk and horns to shape and expand suitable wallowing sites.

Figure 5.18: Newly established wallow on side of hill. Rhinos often shape a wallow starting with rear bank edge, then gradually enlarge and deepen using their bulk and horns to shape.

Figure 5.19: Twin wallow created in run-off area. Rain events keep this wallow wet and muddy for most of the year. Wallow was well disguised by vegetation.

Figure 5.20: Single wallow used by a resident male. Wallow is situated in a run-off area in partial shade.

Figure 5.21: Single wallow under vegetation, is well shaded and difficult to locate. Nearby tracks and mud on saplings and vegetation signify active use.

Figure 5.22: Ever expanding wallow used by at least two resident males. First observed in late 2014, by April 2018 this wallow covered an area of over 20m^2. This wallow sits in a natural hollow and benefits from rain run-off.

Figure 5.23: Typical water wallow, extended use increases muddiness through active use.

Figure 5.24: During extended dry periods rhino utilise local waterways to bath and keep cool, often digging our riverbanks to coat themselves in mud. This muddy ledge was created on the Cigenter River in the peninsula area of the park.

5.5 Discussion

Javan rhinos were recorded as wallowing throughout every month of the year. A study by Dinerstein (2003) on greater one-horned rhino hypothesised that wallowing behaviour is correlated with changes in vapour pressure density (measure of the ability of air to hold water at different temperatures). Additionally, Dinerstein (2003) hypothesised that days are longer during the monsoon period, and consequently total solar radiation is greater. During dry periods Javan rhino will utilise riverine habitats and tidal waterways to manage heat stress, when mud and water wallows are not viable (Santosa et al. 2013). Javan rhino will dig out banks and muddy ledges using their horns and large bodies along riverbanks as wallowing sites that provide the dual benefit of mud and full emersion in water (Figure 5.24). A study by Rahmat (2007) recorded that Javan rhino wallows were often located near water sources and areas of foraging. Our results support Rahmat's (2007) claim.

The significant statistical results for temporal (time of day) and seasonal (wet/dry) differences were not expected. This result is most likely due to the unexpected lower use of wallows in the morning period (06:00 - 12:00) compared to evening, early morning and afternoon which were all relatively even in their use patterns, and notably higher use during the wet season (November - May) when compared to the dry season (June - October). Due to the humid rainforest environment, both Javan and Sumatran rhinos occupy wallows year round, unlike other rhino species, and therefore these sites are likely more important for interaction and communication for these species (Dinerstein 2011). Other species directly observed using wallowing sites and on camera trap video include Javan wild pig *Sus scrofa vittatus*, Javan deer *Rusa timorensis russa* and Asian water monitor *Varanus salvator*. Understanding wallowing dynamics is a valuable tool and has implications for any future planned translocations.

Provision of enough wallowing opportunity for rhino is an important criterion in translocation site selection. Wallowing serves several functions in relation to thermoregulation: a) transfer heat from the body directly to the cool mud or standing water, both which offer cooling via evaporation, b) to cake and spread mud on the body surface to reflect solar radiation; and c) evaporate wallow water directly from the skin (Dinerstein 2003). Despite being unable to measure these variables, we have observed Javan rhino using all three thermoregulatory behaviours. Whilst yet to be confirmed it appears Javan rhino breed throughout the year so the use of wallows as scent-posts to communicate oestrus may be occurring.

On several occasions we observed on camera trap video adult males approaching females in wallows in situ, where they would vocalise a repeated ‘short pant’ (Figure 5.11) call as they approached females, and when close enough would use flehmen to determine the reproductive status of the female. Females with calves and non-receptive females would respond to males with an agonistically vocalised ‘long hiss’(Figure 5.12). Males would then subdue their attention and share the wallow in harmony. Females with calves approaching wallows with males in situ, would often demonstrate vigilance behaviour and often leave the wallow entirely without interaction. Single females would regularly drink wallow water, often followed by flehmen (Hart 1983), and on two occasions were observed eating mud (geophagy), followed by a flehmen response. Presumably, the drinking, geophagy and flehmen response is determining the presence, and possible dominance status of males.

5.5.1 Behaviours recorded at wallow sites

In this study several behaviours, other than wallowing, were recorded at wallow sites. These behaviours suggest that wallow sites are also an important site of communication for Javan rhino. On multiple occasions calling was recorded at a wallow site, several which could represent the rhino ‘announcing’ its presence to any rhino that might be in the vicinity. Investigating the environment, through sniffing at the ground, and vigilant behaviour were frequently recorded in and around wallow sites, suggesting the rhinos are receiving information about previous visitors and are possibly wary about whether another rhino is in the area. As rhinos have poor eyesight (Penny 1987), they rely on calling, urine, dung deposits and scent to communicate with conspecifics (Dinerstein 2011).

Earlier research by Yahya (2002) suggested there was little variation in the frequency of wallow use between male and female Javan rhino. Our observations support Yahya’s suggestion. We have observed on video camera recordings, Javan rhinos of both sexes periodically shaking their heads allowing water and mud to infiltrate the skin folds. The flehmen response or reaction is a mammalian behaviour displayed mostly by males and periodically by females of most hoofed ungulate (perissodactyls and artiodactyls) and felid (family Felidae e.g., tiger) species is a prominent, but poorly understood, aspect of reproductive behaviour (Hart 1983). The behaviour is observed more frequently in males than females during encounters. A flehmen response occurs when an animal curls back its upper lip, exposing its teeth and usually inhales with closed nostrils.

This facilitates the transfer of scent particles (pheromones) and other scents to the Jacobsen's or vomeronasal organ in the roof of the mouth (Hart 1983). During a flehmen response it appears as if the animal is grinning or grimacing. It appears the core function of the flehmen response is intraspecific communication. For example, we have observed on camera trap video, male rhinos approach females in wallows (often coated in urine-soaked mud and water) and use flehmen to determine their reproductive status. Play behaviour was observed between females and calves during bouts of wallowing. Females with calves were noticeably vigilant when approaching wallows, particularly if a male were present, females would often not stay, both female and calf would often call and vocalise their nervousness in these situations.

5.5.2 Wallows characteristics and their importance to Javan rhino ecology and conservation

Based on our research wallows were not created randomly in the landscape. We recorded and observed some common wallow characteristics. For example, wallows are usually created at 30 m or greater elevation, in slightly sloping areas to allow water run-off. Rhinos create the wallow shape through digging and shaping the rear of the wallow from a from a bank or edge which enabled the wallow to be enlarged and expanded as necessary, horn marks in banks were often observed (Figure 5.17). Shade at the wallow site was important as it influenced the temperature of water and mud, the percentage cover averaged 75%. These factors contribute to thermoregulation benefits, the persistence of mud and water allowing urine and other scents to remain in situ for longer periods as well as the long-term maintenance of the wallow itself, extended its use and value as a key habitat feature. As well as wallowing Javan rhino would make behavioural adjustments to avoid heat stress. These would include, nocturnal foraging, resting in shade, and resting near coastal areas with cooling sea breezes. The implications of this wallow data are obvious. The baseline dataset of 35 wallows and their characteristics are valuable. Translocation of Javan rhino into new or former historic ranges needs to include the important criterion in site selection, that sites are selected that enable the long-term maintenance of wallows is critical. A greater understanding and knowledge of a threatened species' behaviour and the threats facing the species can help inform conservation efforts to increase their likelihood of success (Tuft et al. 2011; Dutta et al. 2015). This wallow data is important for future conservation efforts, and crucially, the development and identification of suitable rhino habitat areas and future translocation plans of animals to new sites.

5.5.3 Does interaction and vocalisation increase at wallowing sites?

The data showed that rhino calling increased in both diversity of calls (3 to 1) and number of calls (2 to 1) at wallows when compared to forest situations. As a mostly solitary species, Javan rhino communicates its presence via spray urination, dung deposition and pedal scent gland secretions. Wallows as an often-shared habitat resource, calling has been shown to increase due to increased opportunity to meet other rhino either wanting to thermoregulate or interact in some way. A comprehensive study on the behaviour of the greater one-horned rhino categorised behaviour into two types; breeding and non-breeding (Hazarika & Saikia 2010). For the related Javan rhino, we did not observe in camera trap videos any distinct breeding behaviour at wallows in relation to the calls recorded. However, one seven video sequence observation of an adult male calling a repeated ‘short pant’ (Figure 5.11) and displaying a flehmen response whilst approaching a female and calf in a wallow included an open mouth, upper lip curl and tongue movement. Presumably, the male was assessing this female for its reproductive state. The ‘snort’ (Figure 5.15) and ‘lip vibration’ (Figure 5.14) calls, according to Hoogerwerf (1970), and Hazewinkel (1933) were agonistic in context.

Earlier studies by Ammann (1985) suggested that the ‘lip vibration’ in Javan rhino was possibly a comfort behaviour, made, for example, by a feeding animal. Our data supports the description given by Ammann (1985) of the ‘lip vibration’ as a comfort behaviour. A ‘snort’ call made by an adult male after wallowing and rubbing its scent on a tree stump, was strong and implied a vocal dominance. Similar behaviour was observed for greater one-horned rhino by Hazarika & Saikia (2010) suggesting it may be related to hierarchy around wallow use. Javan rhinos are known to share wallows (Hariyadi 2009) perhaps this loud announcement or vocally dominant ‘snort’ indicates a dominant animal’s presence to others waiting for their turn at the wallow. The calf ‘bleat’ call was noted by Schenkel & Schenkel-Hulliger (1969a, 1969b), who suggested it was a contact vocal between female and young and my video recordings confirm this. The vigilance behaviour at wallow sites of greater one-horned rhinos was found to be more prevalent in females with calves than other age-sex classes (Hazarika & Saikia 2010), presumably due to predation threat. Similar vigilance behaviour was observed of Javan rhino on camera trap video, most notably calves calling a repeated ‘bleat’ call to remain in contact with females, and, to express what appeared to be ‘nervousness’ in the presence of adult males. Vigilance behaviour was characterised by Hockings (2016) as being at a heightened sense of awareness and alertness. The 157 individual call recordings, whilst low in number, have provided important new insights into the call repertoire of Javan rhino.

Camera trapping cannot replace direct observation, however it can provide valuable insight into Javan rhino communication behaviour in a rainforest environment and a shy species, such as the Javan rhino that is rarely observed in nature. Interestingly, 80% of the 196 (157 at wallows, 39 in forest) individual Javan rhino call recordings were captured upon entering or while *in-situ* in wallows. Given that Javan rhinos wallow regularly throughout the year, the role wallows play as communication and socialisation hubs appears underestimated. For example, as an often-shared habitat feature wallows offer the opportunity for dominant males to monitor other males and determine the reproductive status of visiting females. This appeared to be the case in the sequence of seven videos, where an adult male used ‘short pant’ and mothering female used ‘long hiss’ (Figure 5.12) calls to communicate to each other at a wallowing site. The pant calls of southern white rhino provide conspecific information about the caller’s sex, age class and social context (Cinková & Policht 2016). Our data suggests the ‘short pant’ calls of Javan rhino may be conveying similar information, however further research is needed on this specific call.

The greater one-horned rhino is known to live in small home ranges, with males forming dominance hierarchies (Dinerstein 2003, 2011). It remains unclear if Javan rhino males form dominance hierarchies. Camera trap vision of two adult Javan rhino males sharing a wallow (Hariyadi 2009) in Ujung Kulon, and video observations of two males moving through the forest together, indicate that may be the case, and at minimum warrants further exploration. A study by Ammann (1985) considered it likely that there are dominant and subordinate Javan males, as in greater one-horned rhino (Laurie et al. 1983; Dinerstein 2003), and that dominant male’s occupied territories and spray urinated to mark them much more than did subordinate males. Behaviour records from video camera monitoring (Hariyadi et al. 2010) showed that Javan rhinos are not aggressive towards one another except during mating seasons when males compete to mate (Hariyadi et al. 2016).

The data supports socially positive behaviour amongst males, confirming Hariyadi et al. (2010) video monitoring. The remaining population of Javan rhino is distributed across approximately 30,000 hectares of rainforest habitat, with persistent wallows regularly being used by more than one animal. Olfactory communication in Javan rhino through spray urination, defecation and scent is poorly understood. In this work, we detected adult males approaching a wallow and spraying urine on vegetation at least three metres behind itself. However, it remains unknown whether only dominant adult males spray urinate.

Whilst yet to be proven conclusively as their primary place of vocal and olfactory communication, wallow sites were found in this work to be important, possibly primary centres of communication in the rainforest environment. The results tested and supported the hypothesis that Javan rhinos utilise wallows not only for thermoregulatory function, but also as sites of interaction and communication.

5.5.4 Wallowing behaviour of other rhino species

All five-rhino species will utilise waterbodies, muddy depressions, rivers, and sandy areas for wallowing activity (see Table D.3 Comparison of all five-rhino species wallowing behaviour and type of wallow used, Appendix D) (Dinerstein 2011). During the seven-day period 21/09/2018 - 27/09/2018, SW directly observed 17 greater one-horned rhinos *R. unicornis* in both Chitwan National Park (27° 30′ 0″ N, 84° 20′ 0″ E) and the adjacent Andrauli Community Forest, near Megauli, Nepal (27.58° 30′ 0″ N, 84.21° 20′ 0″ E). During this late monsoon period, rhino was spending significant amounts of time either in rivers and both water and mud wallows. SW observed animals regularly sitting in the current of the nearby Rapti River almost submerged for periods averaging five hours per day (Figure 5.25).

Ox-bow lakes up to a depth of three metres were also used regularly as well as mud wallows, with wallowing duration again averaging five hours. The congeneric greater one-horned rhino like Javan rhino is solitary but would readily share a wallow with another rhino without incident. SW observed up to three rhinos, including females with calves sharing a mud wallow approximately 20 m^2 without any agonistic behaviour being shown (Figure 5.26). This communal type wallowing activity has also been reported by Laurie (1978, 82), Ghosh (1991), Dinerstein (2003) and Hazarika & Saikia (2010). In most cases animals would remain almost completely submerged in either water or mud, often with only the ridge of their backs exposed. The average high daytime temperature during my visit was 34°C (mean 33.57; SD ± 0.534), with an average low of 19°C. Humidity during this period averaged 78% (mean 78; SD ± 2.160).

Figure 5.25: Two adult greater one-horned rhino resting in the current of the Rapti River, Chitwan National Park, Nepal during the hot monsoonal period, September 2018.

Figure 5.26: Two adult female and sub-adult calf greater one-horned rhino resting in mud wallow in riverine forest in Chitwan National Park, Nepal during late monsoon, September 2018.

Assuming wallowing behaviour's primary function is restriction or reduction of heat. During the long hot humid periods, particularly during monsoon (June-September), rhinos spend most of the daylight hours in wallows or rivers, presumably to reduce heat stress. During this monsoon period solar radiation is greater due to the longer day lengths. Additionally, wind speeds are often less during the monsoon. For example, wind speed averaged only 5 km/h during my visit, which meant heat reduction via evaporative cooling of the skin is much reduced (Dinerstein 2011). In Van Strien's (1986) formative study of Sumatran rhino in Gunung Leuser National Park, Sumatra, Indonesia found rhinos living in the high ambient heat and humidity of tropical forests utilised mud wallows on a daily basis throughout their home ranges. Similar to the other Asian rhino species, although solitary Sumatran rhino would share wallows with other rhino (Van Strien 1986). Sumatran rhinos live in closed canopy forest areas and utilise mud wallows up to 5-6 hours daily (Ng et al. 2001).

Wild caught animals captured between 1984 to present for captive breeding efforts suffered greatly from exposure to sunlight and limited to no access to mud wallows, often exacerbating other chronic health issues (Kretzschmar et al. 2009; Ahmad et al. 2013). Both African rhino species the black and white rhino are active wallowers, however both species also manage heat stress by resting in shade, and where suitable increasing their elevation in the landscape to gain access to cooling breezes, and both species can go without water for several days, including wallowing (Dinerstein 2011). White rhino in Kruger National Park, South Africa would regularly use waterholes for wallowing, often laying in water for several hours, as well as using available mud wallows to coat themselves in cooling mud (Pienaar 1994). One suggested reason for the wallowing behaviour of black rhino is to help dislodge ticks (Joubert & Eloff 1971). Animals will roll and coat themselves in mud, which eventually bakes dry, cracks, and falls off, or is rubbed off along with the ticks. A study by Goddard (1967) of black rhino in south-west Africa recorded ninety percent of his wallowing observations between 1600-1800 hours, suggesting the excess heat accumulated in the body during the day would be dissipated through wallowing behaviour in the cooler evening period.

5.5.5 Value of camera trapping in studying Javan rhino vocalisations

The very small size, currently 74 animals (Gokkon 2020) and isolation of the only extant Javan rhino population makes it a difficult species to study (Dinerstein 2011). Camera trapping is an emerging remote sensing tool used to study wildlife, especially for species that are endangered or difficult to observe (Bernard et al. 2013; Mohd-Azlan & Engkamat 2013). There are several advantages to camera trapping. Firstly, it is a cost-effective (Mohd-Azlan & Engkamat 2013), non-invasive method of sampling which eliminates observer bias (O'Brien & Kinnaird 2011). Furthermore, the cameras can also run for extended periods of time in remote locations that are difficult for people to access and they provide unambiguous records of the species present and the date and time of detection (O'Brien & Kinnaird 2011).

The advent of camera trap technology improves individual recognition, and captures behaviour, using Griffith’s (1993) identification criteria, (mark-recapture) which has been verified as an effective ID criterion, and the addition of date and time capture provided by camera imagery. This technology will assist in identifying the individual animals, activity patterns (date/time of day), visitation frequency (day/month) and behaviour in wallows and in other landscape contexts. This photo identification technique has been found to be a reliable censusing methodology (Hiby & Lovell 1993; Haryono et al. 2015).

5.5.6 Strengths and weaknesses of camera trapping for recording behaviour

The strengths of using camera traps to study a species such as Javan rhino is its non-invasive. Animals are not exposed to unnecessary stress and reduces any impact on behaviours displayed. The terrain in Ujung Kulon National Park is difficult with limited opportunities for direct observation, the use of cameras is practical. Additionally, cameras also capture the movement and behaviour of other species, data which can be valuable to gain understanding of broader species ecology, behaviour, and habitat use. From a translocation perspective, cameras would be valuable tool to monitor moved populations. For example, translocated animals could be checked for their movements i.e. spatial distribution, assess health, and record any behaviour, identify potential predators or competitors, the activity patterns and use of key habitat features such as wallows.

Weaknesses of camera trapping are the placement of cameras, which are usually placed on tracks and trails and key visitation sites such as wallows. However, for the study of rhino behaviour, this often results in a bias of certain behaviours recorded such as wallowing or walking along tracks and trails. The implications of this wallow data are obvious. The baseline dataset of 35 wallows and their characteristics are a useful translocation tool. Translocation of Javan rhino into new or former historic ranges needs to include the important criterion in site selection, that sites are selected that enable the long-term maintenance of wallows is critical. This wallow data is important for future conservation efforts, and crucially, the development and identification of suitable rhino habitat areas and future translocation plans of animals to new sites.

The recorded calls highlight the importance of filling the gap of knowledge regarding Javan rhino communication and presents fertile ground to build further understanding of Javan rhino ecology and social dynamics. Because there are very few direct observations of Javan rhinos this makes comparisons difficult. Recognition and understanding of the information that can be obtained by recordings of Javan rhino calls and videos showing a range of other behaviours is critical and is amplified when the population is so low. As demonstrated by Linklater et al. (2013) and Cinková & Policht (2016), the manipulation of chemical signals in dung and urine, and calls can be useful conservation tools. For example, translocated Javan rhino could be stimulated to reduce stress and modify behaviour by using urine-impregnated water and mud at wallows, and playback call recordings. Future research in this area should focus on expanding the database of recordings and increase our understanding of the function of described vocals and any vocals yet to be described.

Chapter 6 Understanding an icon: Social behaviour and communication in the Javan rhino

Figure 6.1 Camera trap image of adult female Javan rhino and calf in Ujung Kulon National Park, West Java, Indonesia. (Image: Courtesy Ujung Kulon National Park Authority).

6.1 Abstract

The Javan rhino *Rhinoceros sondaicus* is the rarest of five extant rhino species. The only remaining population of Javan rhino on the planet is located in Ujung Kulon National Park (UKNP) in West Java, Indonesia. With only 74 animals remaining, it is important to better understand the species social behaviour to plan and assess management actions, including relocation options. The primary aim of this study was to examine the social behaviour of the Javan rhino, the forms of communication used by the species and the value of using camera trap data for conservation. I analysed 137 remote camera trap videos (2011-2015) from the peninsula area and 255 videos (2016) from the eastern Gunung Honje region of Ujung Kulon in this study and confirmed wallows as important communication hubs for the Javan rhino. Altogether 11 behavioural patterns were categorised, and these were related to their daily activities. This work has expanded our knowledge of Javan rhino vocalisation, identifying eight vocalisation descriptors with the first ever sonograms via 55 recordings comprising 196 individual vocalisations. The information collected can help monitor the species and enhance its persistence. Knowledge of a species' behaviour can be pivotal in deciding how and where to apply conservation strategies such as translocation

6.2 Introduction

Global biodiversity is declining at an alarming rate, with around 60% of the world's largest carnivores and largest mega-herbivores now threatened with extinction (Ripple et al. 2016). It is vital that the world's largest threatened carnivores and herbivores are protected. This is particularly imminent in species that are now restricted to a single location (Alliance for Zero Extinction 2016). Globally, The Alliance for Zero Extinction (2016) has identified 588 sites globally, which represent the most important places for conserving threatened biodiversity (Butchart et al. 2012; Conde et al. 2015). There is a lack of ecological and behavioural knowledge for most of the world's threatened mega-herbivores (Ripple et al. 2015). (Sutherland 1998; Robertson et al. 2006; Schwartz & Martin 2013; Caro & Riggio 2014; Plein et al. 2016). The application of such behavioural knowledge can increase the likelihood of program success (Tuft et al. 2011; Dutta et al. 2015), as shown, for example, where knowledge of social structure and behaviour has informed conservation actions for elephants and rhinos (e.g., Pinter-Wollman 2009; Shannon et al. 2013; Dutta et al. 2015).

6.2.1 Social behaviour in mammals

The class Mammalia represents a highly variable range of social systems, coupled with diversity of social complexity, behavioural flexibility, brain size and cognitive ability (Silk 2007; Clutton-Brock 2009; Isler & van Schaik 2009; Ricklefs 2010). The variation of social organisation can broadly be defined via three basic types, adult individuals can either lead a solitary existence, form a bond or relationship with the opposite sex by forming pairs, or they associate with two or more partners forming groups (Kappeler et al. 2013). One of the most threatened mammalian families is the *Rhinocerotidae* (Ripple et al. 2015). All five species of rhino have experienced major population declines since the 1800’s due to hunting and habitat destruction, and in modern times the escalation in poaching of rhino horn (Martin & Martin 1982; Thapa et al. 2013; Biggs et al. 2013; Havmøller et al. 2015; TRAFFIC 2016; Setiawan et al. 2017). Despite ongoing threats, as genuine megafauna, the large size of modern rhino has two significant advantages: a strong defence from predators (as adults) and ability to survive on coarse vegetation (Dinerstein 2011).

6.2.2 Social behaviour in rhinos

For the family Rhinocerotidae the most stable and social bond amongst extant rhino species is between a female and calf (Owen-Smith 2004; Dinerstein 2011). Males are usually solitary, separating themselves spatially and temporally through olfactory communication using dung and urine to convey scent signals (Black rhino *Diceros bicornis*, Schenkel & Schenkel-Hulliger 1969a; Javan rhino *Rhinoceros sondaicus* (Figure 6.1), Schenkel & Schenkel-Hulliger 1969b; White rhino *Ceratotherium simum*, Owen-Smith 1975; Greater one-horned rhino *Rhinoceros unicornis*, Laurie 1982; Sumatran rhino *Dicerorhinus sumatrensis*, Van Strien 1986). All five living rhino species are polygamous and polyandrous, with both males and females seeking multiple mates (Owen-Smith 2004; Dinerstein 2011). Intraspecific courtship and mating behaviour (e.g., male combat) are known to be aggressive, intense, and often violent in all five species (Hutchins & Kreger 2006; Dinerstein 2011).

6.2.3 Communication in mammals

Mammals communicate primarily in three main forms, using visual, vocal (calls) and/or olfactory signals (dung, urine, scent gland secretions) (Marneweck 2013). Communication, the method by which animals convey information to each other, is the bond that holds animal societies together, facilitating reproduction, conveying information on identity, status, mood, and intentions (Bradbury & Vehrencamp 1998; McGregor & Peake 2000). Communication behaviour includes a significant proportion of the behavioural repertoire across animal taxa and is a major driver of species biology, affecting the evolution of life histories and genes

(Laiolo 2010). In most mammal species, olfaction is the primary form of communication, with information passed via urine (e.g., spray or stream) (Kimura 2001; Archuman & Rajagopal 2013), dung (e.g., faeces or droppings) (Karthikeyan et al. 2013; Marneweck 2013; Marneweck et al. 2017a, 2018) or specialised scent glands (e.g., pre-orbital and pedal scent glands) (Cross et al. 2014; Vaglio et al. 2016). Olfactory communication provides many advantages. Chemical scent signals allow a clear indicator of the depositors' characteristics. For example, female house mice *Mus musculus* have the detection ability to determine the health status of males from urinary scents and show preference for non-parasitised males (Cavalieres & Colwell 1995). Male ring-tailed lemur *Lemur catta* use scent gland secretions to promote their genetic qualities (Charpentier et al. 2008) allowing females to make suitable mate choices. A major advantage is that olfactory communication ensures that information remains available long after the sender has moved away (Mitro et al. 2012). For example, Linklater et al. (2013) discovered that black rhino dung were still effective in stimulating investigatory behaviour 32 days after deposition.

Olfactory signals can also provide spatial information, for example, territory ownership and dominance or movements of a significant individual such as a dominant male. For example, klipspringers *Oreotragus oreotragus* use pre-orbital scent glands to mark and define their territory boundaries (Roberts & Lowen 1997). A study by Bhattacharya & Chakraborty (2016) suggested greater one-horned rhino *R. unicornis* dung and dung piles (middens or heaps) not only scent mark territories, but they also communicate the reproductive state of individuals.

6.2.4 Mammalian vocalisation

Intra-specific communication through vocalisation is important to understanding animal behaviour, yet little is known about the vocalisation of cryptic and solitary species, such as the Javan rhino (Allen et al. 2014) especially about species in small numbers and/or in remote and inaccessible areas. Vocal communication is used by many solitary species across taxa, including other threatened species. For example, tiger *Panthera tigris* (Sunquist & Sunquist 2009), okapi *Okapia johnstoni* (Skinner & Mitchell 2011), Sumatran orangutan *Pongo abelii* and Bornean orangutan *P. pygmaeus* (Williamson et al. 2013), Muntjac (or barking) deer *Muntiacus sp.* (Mattioli 2011) and Sumatran rhino (Dinerstein 2011) have been shown to vocalise among individuals of their species.

Depending on habitat type, acoustic communication has advantages for carrying information over longer distances than can be achieved by visual or chemical cues (Morton 1975; Brown & Handford 2000; Kondo & Watanabe 2009; Ey & Fischer 2009). For example, the solitary giant panda *Ailuropoda melanoleuca* communicates by communal scent marking (sign posting) with conspecifics for most of the year (Swaisgood et al. 2004; Charlton et al. 2010). However, for a brief period during the annual breeding season, the unique ‘chirp’ vocal of oestrus females seeks to attract male attention and interest (Schaller et al. 1985; Kleiman & Peters 1990). Understanding a species vocal behaviour is of critical importance to the reproductive and spatial management of the species (Charlton et al. 2010), and especially for threatened species.

6.2.5 Vocalisation (calls) in rhinos

While there have been studies on vocalisation and communication in many large mammal species, such as elephants (e.g., Wood et al. 2005; Venter & Hanekon 2010), much less is known about vocalisations for the family Rhinocerotidae (Cinková & Policht 2014), and almost no information has been collected to systematically record and learn about vocalisation in Javan rhino. For the family Rhinocerotidae communication via vocal and olfactory signals (e.g., dung, urine, pedal scent glands) are prominent as they have an acute sense of hearing and scent detection, but relatively poor eyesight (Penny 1987). All five rhino species vocalise (hereafter called ‘call’) in various categories including puffing, snorting, growling and harmonic calls (Owen-Smith 1973; Laurie 1982; Budde & Klump 2003; Policht et al. 2008; Cinková 2013).

Based on limited research Javan rhinos are considered the least vocal rhino species (Hazewinkel1933; Schenkel & Schenkel-Hulliger 1969a, 1969b; Hoogerwerf 1970; Ammann 1985). This suggests that the conception that the Javan rhinos have a very limited repertoire of calls could be due to its geographical remoteness, small numbers, and very limited research on the species. In contrast the Sumatran rhino is considered the most vocal (Muggenthaler et al. 1993, 2003; Dinerstein 2011; Groves & Leslie Jr. 2011), producing more call signals over time than any other species of rhino. Field studies of the greater one-horned rhino have identified a range of 10 calls including snorts, honks, bleats, squeak-pant, and a moo-grunt commonly used by mothers and calves (Hazarika & Saikia 2010; Dinerstein 2011). At least five different types of call have been recorded in black rhino (Spellmire 1981; Budde & Klump 2003).

White rhino considered the most social rhino species (Cinková & Policht 2015) are known to have the broadest vocal repertoire out of all rhino species whose calls have been studied bio acoustically (Muggenthaler et al. 1993, 2003; Budde & Klump 2003; Policht et al. 2008). Currently, our knowledge of Javan rhino social structure, behaviour and communication has been restricted to a few historic accounts mostly from the 1900's (e.g., Hazewinkel 1933; Schenkel & Schenkel-Hulliger 1969a, 1969b; Hoogerwerf 1970; Ammann 1985). For example, Schenkel & Schenkel-Hulliger (1969a, 1969b), suggested Javan rhino were mostly solitary, independent, or were "loosely associated nomads". Initial work by Ammann (1985) described five distinct Javan rhino calls, including 'neigh,' the 'loud blowing whistle' of Schenkel & Schenkel-Hulliger (1969a, 1969b); 'bleat,' a contact call between mother and young; 'snort,' made separately or in a series; 'shriek,' a possible response to a threat; and 'lip vibration', similar in sound to that made by horses. Individual white rhino is known to use subsonic or advanced ultrasonic communication like elephants (Dinerstein 2011).

Other species of rhino are known to produce infrasounds (greater than 20 Hz, inaudible to humans) (Dinerstein 2011). Vocal and olfactory signals are considered important for communication amongst rhinos; however, their vocal communication has only been investigated to a limited extent to date (Cinková & Policht 2014). A goal of this study is to systematically document the range of calls in the only remaining population of the Javan rhino for the first time. By relating this information to the social and spatial dynamics of the Javan rhino, I hope to help inform management actions to assist conservation of the species.

6.2.6 Using camera trapping in the study of behaviour and conservation

The advent and use of camera trap technology has improved the opportunity to record more animal behaviours. Camera trapping can be a cost-effective (Bernard et al. 2013, Mohd-Azlan & Engkamat 2013), non-invasive method of studying rare and elusive species. Camera traps have been used in Ujung Kulon since 2010 to estimate the population size and structure of the Javan rhino; the most cryptic of all rhino species (Ramono et al. 2009). The camera traps reduce observer bias (O'Brien & Kinnaird 2011) and can operate for extended periods in remote locations and during seasons where access to field sites is limited. They also provide time and location specific records of multiple species presence (O'Brien & Kinnaird 2011). Camera trapping is particularly useful when studying medium to large terrestrial mammals, as well as critically endangered species that have a very small population size and are therefore difficult to locate in the field (O'Brien & Kinnaird 2011).

6.3 Methods

6.3.1 Camera trap recording

Direct observation of Javan rhino is extremely difficult due to its rarity and remote rainforest habitat. Therefore, camera traps are a valuable remote sensing tool for studying Javan rhino behaviour in the wild. All rhino calls were recorded using Bushnell 8-megapixel Trophy CAM HD™ cameras as part of an ongoing monitoring program used by UKNP managers to monitor Javan rhino populations and other endangered species. Across the Ujung Kulon peninsula (Figure 6.2) 120 cameras have been permanently strategically placed in 1000 m^2 quadrats to best capture rhino activity, and each quadrat has been given a coded number and letter, for example, 34AQ (Figure 6.3). Each camera was set at a height of 1.7 metres, then angled 10 degrees to cover a field of view out to 5 metres. To reduce disturbance to the rhinos and other animals, the cameras were placed high above rhino eye level with a downward angle that enables capture of details of rhino behaviour. The video camera footage has been provided to the author by the UKNP Authority and Indonesian Rhino Foundation were provided due to their clarity of imagery. No camera trap video data was collected by authorities during the 2012 period. Due to the low, dispersed population, access to clear imagery and reliance of animals to move in front of cameras is quite difficult.

The calls and behaviours were captured after reviewing 137 camera trap videos recorded between 2011-2015 (see Table D.1 Camera locations, Appendix D) examining rhinos occupying the peninsula area of Ujung Kulon and 255 camera trap videos recorded during 2016 from the eastern Gunung Honje area of the park (Figure 6.2). The cameras were programmed to record sound and imagery both day and night when an animal is in the field of view. The camera video records in 30 second intervals whilst an animal remains in camera vision. UKNP rangers and rhino protection unit staff collect and download camera memory cards each month (while on routine patrol), except for December and January when the whole park area becomes inaccessible due to monsoonal conditions. In this study, all rhinos were identified only to determine their sex due to individual identification limitations of the video clips. The UKNP Authority monitors the rhino population across the national park using its network of permanent video cameras and has built up a considerable database of each individual rhino and its identification characteristics.

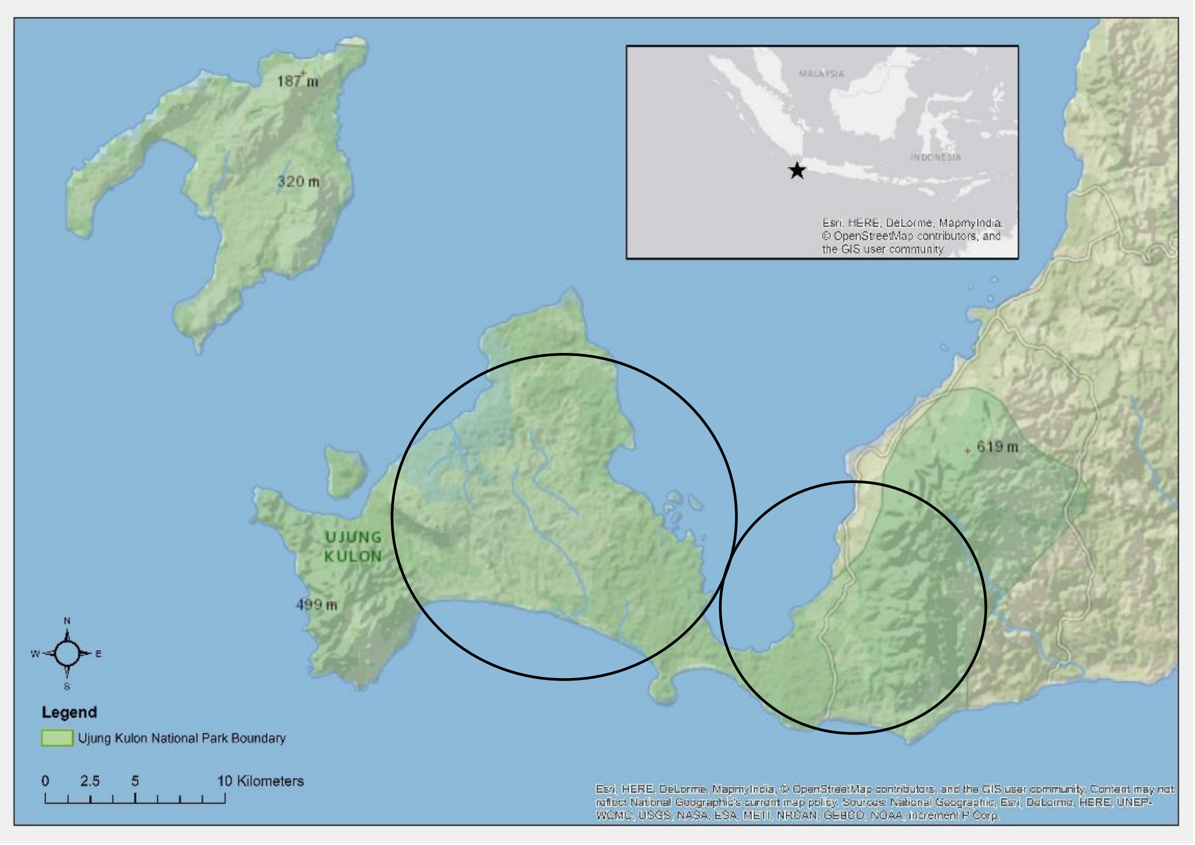

Figure 6.2: Map of Ujung Kulon National Park (shaded green), dark circles indicate peninsula (left) and eastern Gunung Honje area (right), West Java, Indonesia. Map: ESRI, HERE, DeLorme, MapIndia © OpenStreetMap contributors and GIS user community.

6.3.2 *Sound and visual recording*

I converted each video into a sound file using Adobe Audition CC 2015 to create a sonogram of each identified call (e.g., Figures 6.5, 6.6, 6.7 & 6.8). The video file was opened in Adobe Audition, sample type was then converted, and a sample rate of 32,000 Hz was used with, Channel to Mono and Bit Depth of 16 bits. The files were originally recorded in stereo at a sample rate of 48,000 Hz with a 32-bit depth. The file was converted to a mono sample at 32,000 Hz with a 16-bit depth to show the vocal characteristics more clearly. Calls were then sampled by using the cursor to measure length and frequency of the rhino's vocal. Headphones with a noise cancelling function are used to listen to calls to ensure good quality sound. A video of the sound recording was made using Microsoft Office PowerPoint and then the video of the rhino was attached to this using Adobe Premier. The sample rate indicates the number of digital snapshots taken of an audio signal each second and determines the frequency range of an audio file.

The higher the sample rate, the closer the shape of the sound wave is that to the original waveform. The bit depth determines the dynamic range of the sound wave. Amplitude is shown as intensity of either grey scale or colour. I acknowledge the recorded frequency bandwidth may vary due to the bandwidth range being a function of the recording volume (which could vary based on the rhino distance to the camera trap microphone). Sonograms of each different call were identified using Adobe Audition CC 2018.

Calls were compared to the video vision to ensure they were correct, isolated, and saved as wav. files into a new window within Adobe Audition. Individual calls were then opened in Raven Lite 2.0.0™ showing the time (sec) and frequency (kHz) scales. These calls were then converted to a colour scale for clarity and snipped using the snipping tool in Microsoft Office 2016. Images were saved as jpeg files. Collected data from each video included gender of rhino, age, date, time of day, location, call type, duration of call (sec), frequency of call and behavioural activity (see Table D.2 Recorded characteristics, Appendix D). Animals can be identified through several criteria (Griffith 1993), which has been verified and best for use. For example, presence of horns (males only) or absence of horns (females). Horn length in Javan rhino male's averages 25 cm (Dinerstein 2011).

6.3.3 Social interaction and behaviour recording

I used and modified Hazarika & Saikia's (2010) ethogram model developed for the congeneric greater one-horned rhino to identify and present the range of behaviours seen on the camera trap videos. It will be presented as a description of all behaviours seen (e.g., Stevenson & Poole 1976), as well as a flowchart (behavioural catalogue) adapted from Hazarika & Saikia (2010) and Cinková & Bičík (2013) and Hockings (2016).

6.3.4 Data analysis

I used chi-squared (χ^2) tests to determine whether there were temporal and seasonal differences in the frequency at which Javan rhino were captured on the camera trap videos. To test whether there was temporal variation, the categories Early Morning (EM, 24:00 - 06:00), Morning (M, 06:00 - 12:00), Afternoon (A, 12:00 - 18:00), and Evening (E, 18:00 - 24:00) were used. To test for seasonal variation, I used wet season (November - May), and dry season (June - October) observations. I also examined the frequency of sightings in four vegetation types, open broadleaf, dense broadleaf, open broadleaf/arenga palm and dense broadleaf/arenga palm forest. I considered test statistics as significant with P values < 0.05.

Additionally, chi-squared (χ^2) analysis was used to determine whether there was any significant statistical variation in the number and frequency of use of vocal descriptors (calls) used. This was undertaken for each year of camera trap video recordings e.g. 2011. A total of 196 individual calls (2011-2016) were examined (Table 1).

6.4 Results

In the peninsula area of Ujung Kulon, I identified several behaviours from 137 videos taken during (2011-2015) (Figure 6.3). Temporal (time of day) observations (χ^2 tests > 23.90, P = 2.61, df = 3), seasonal (wet/dry) observations (χ^2 tests > 0.59, P = 0.74, df = 1) and vegetation type observations (χ^2 tests > 39.78, P = 1.18, df = 3) (Figure 6.3). Fifty-five video recordings comprising 196 individual calls, identifying eight individual call descriptors with accompanying sonograms (a first for the species), were developed after reviewing 392 camera trap videos (2011-2016), 137 from the peninsula area (Figure 6.3) and 255 from the eastern Gunung Honje section of the park (Figure. 6.2) (Table 1).

Chi-squared (χ^2) analysis for the number and frequency of calls used by year showed a significant result for 2015, n=25 (χ^2 tests > 9.08, P = 0.028, df = 3). Results for the years 2011, n=53 (χ^2 tests > 29.35, P = 1.884, df = 2), 2013, n=65 (χ^2 tests > 22.95, P = 1.035, df = 5), 2014, n=29 (χ^2 tests > 1.320, P = 0.724, df = 2) and 2016, n=24 (χ^2 tests > 31.75, P = 5.908, df = 2) showed no significant statistical variation. The videos contained 196 individual calls identified from eight call descriptors, included the development of sonograms of the 'bleat' (Figure 6.6), 'sniff-huff' (Figure 6.5), 'short pant' (Figure 6.8), 'long hiss' (Figure 6.9), 'lip vibration' (Figure 6.12), 'sigh' (Figure 6.11), 'snort' (Figure 6.7) and 'moo-bray' (Figure 6.10), (Table 2).

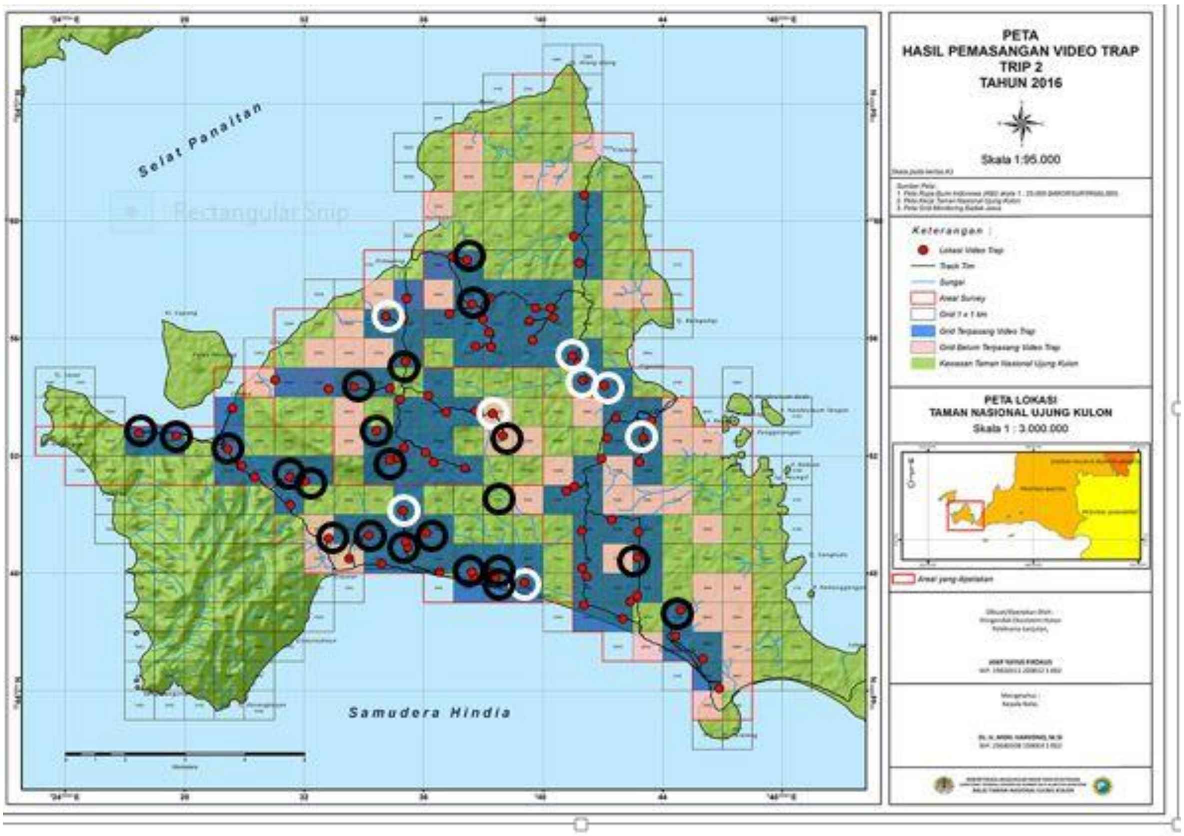

Figure 6.3: Map of Ujung Kulon NP (peninsula) West Java, Indonesia, with grid system overlaid, and locations of camera traps (red dots). White circles = wallow locations of camera recordings, black circles = forest locations of camera recordings. Map: Courtesy Ujung Kulon National Park Authority.

Table 1 Summary table of Javan rhino camera trap video data (2011-2016)

Total no video clips	Year video recorded	Clip duration (min)	No clips with calls	Call clip duration (min)
6	2011	3.0	5	2.5
45	2013	22.5	13	6.5
32	2014	16.0	8	4.0
54	2015	27.0	15	7.5
255	2016	127.5	14	7.0
Total 392		183.5	55	27.5

Note: no camera trap data was collected by authorities during the 2012 period.

Table 2 Summary table of camera trap video Javan rhino call descriptor data (2011-2016).

Call descriptor	No. individual calls	Call frequency band width (Hz - kHz)
Short pant	65	100 Hz - 12 kHz
Sigh	32	100 Hz - 12 kHz
Snort	2	100 Hz - 12 kHz
Sniff-huff	48	100 Hz - 14.5 kHz
Long hiss	6	100 Hz - 11.5 kHz
Lip vibration	5	100 Hz - 5 kHz
Bleat	34	100 Hz - 4.5 kHz
Moo-bray	4	100 Hz - 12 kHz
Total 8	196 (157 at wallows, 39 in forest)	

Note: no camera trap data was collected by authorities during the 2012 period.

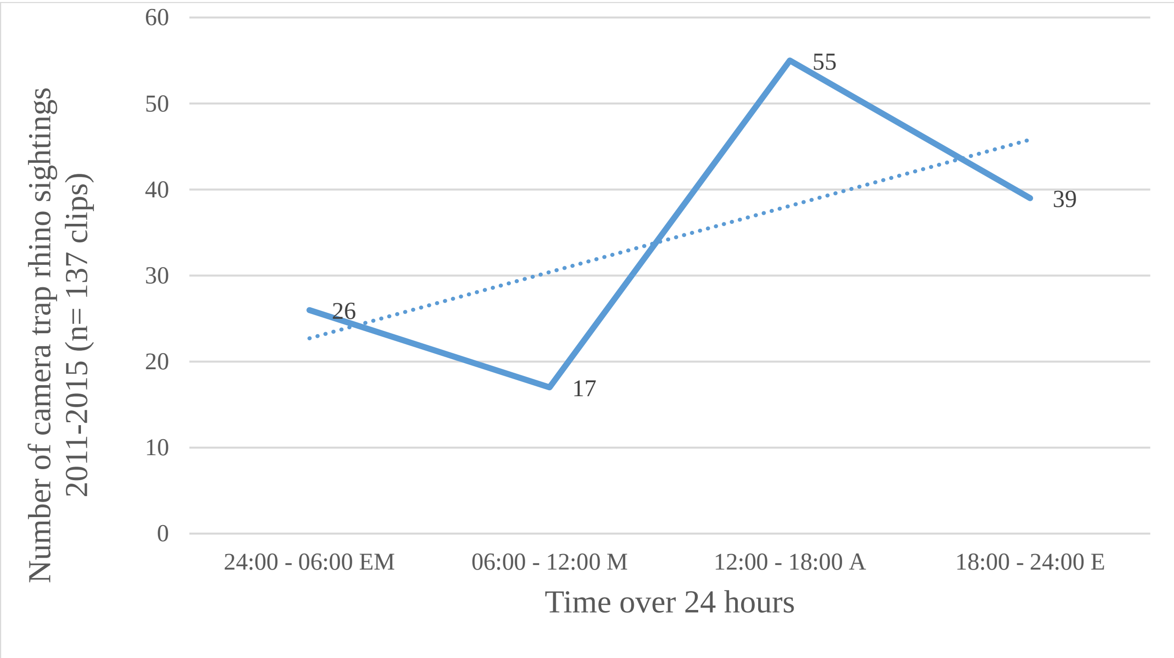

Figure 6.4: Line graph of Javan rhino activity patterns (time over 24 hrs) EM (early morning); M (morning); A (afternoon); E (evening) of animals from the peninsula area of Ujung Kulon NP.

6.4.1 Sonograms of described calls

I identified eight call types from the audio video data and categorised these in a manner consistent with terms used by previous researchers (e.g., Schenkel & Schenkel-Hulliger 1969a, 1969b; Ammann 1985). The following eight sonograms identify and describe the characteristics of these new calls.

Sniff-huff. The sniff is a short nasal inhalation, followed by an exhaled huff. Used by both sexes, often used when investigating the environment i.e. sniffing vegetation, or possible scent trails left by conspecifics. Frequency band width range is shorter than the snort or sigh, and ranges between 100 Hz - 14.5 kHz, with most calls lasting less than half a second (e.g., 0.2 - 0.5 sec). Average based on dataset = 0.379 seconds, n=48, mean 0.322; SD ± 0.104 (Figure 6.5).

Bleat. Low intensity contact call made by calves to females. The bleat call is short, clear, and often repeated. Repeated bleats appear to imply urgency or uneasiness i.e. calf wanting to suckle, vocalising vulnerability, or seeking a contact or acknowledgement response from the mother (e.g., sigh or lip vibration). Frequency band width range = 100 Hz - 4.5 kHz, n=34, mean 0.293; SD ± 0.091 (Figure 6.6).

Snort. A strong exhaled loud call may infer vocal dominance from adult male or female. The frequency band width range varies between 100 Hz - 12 kHz, with a single vocal lasting more than one second (e.g., 1.148 sec), n=2, mean 1.148 (Figure 6.7).

Short pant. A short, often repeated air sounding call. Circle (brown) indicates soft whistle sound at start of call. May be a contact/acknowledgement call, possibly infers sexual or dominance status. Recorded only in males to date. The frequency band width range varies between 100 Hz - 12 kHz, with most repeated calls lasting less than half a second (e.g., 0.1 - 0.3 sec). Average based on dataset = 0.260 seconds, n=65, mean 0.278; SD ± 0.122, (Figure 6.8).

Long hiss. An extended single, strong, air sounding, almost ear-piercing call. May infer a warning/message i.e. I'm with calf or I'm non-reproductive. Only recorded in adult females near approaching males to date. The frequency range varies between 100 Hz - 11.5 kHz, with the single call lasting more than half a second (e.g., 0.7 - 0.8 sec). Average based on dataset = 0.754 seconds, n=6, mean 0.754; SD ± 0.114 (Figure 6.9).

Moo-bray. A repeated single ‘bleat-like’ call exhibited by the female during courtship. Frequency band width range varies between 100 Hz - 12 kHz, with repeated calls lasting on average based on dataset = 0.596 seconds, n=4, mean 0.596; SD ± 0.041 (Figure 6.10).

Sigh. An exhalation call, longer in duration to lip vibration, slow and softer in emphasis, comfort-like and may be used as an acknowledgement i.e. female response to calf bleat or infers comfort i.e. resting in a wallow. Lip vibrations occasionally follow the sigh call. Sighs appear to be used mostly as single calls. The frequency range varies between 100 Hz - 12 kHz, with most calls lasting less than one second (e.g., 0.2 - 1.056 sec). Average based on dataset = 0.610 seconds, n= 2, mean 0.685; SD ± 0.285 (Figure 6.11).

Lip vibration. Softer than snort, may be a contact response i.e. from female to calf, or indicate comfort i.e. when feeding. Lip vibrations appear to be mostly single calls, rarely repeated and may be called after a snort or sigh call. The frequency range varies between 100 Hz - 5 kHz, with calls lasting less than one second (e.g., 0.7 - 0.8 sec). Average based on dataset = 0.810 seconds, n=5, mean 0.987; SD ± 0.166 (Figure 6.12).

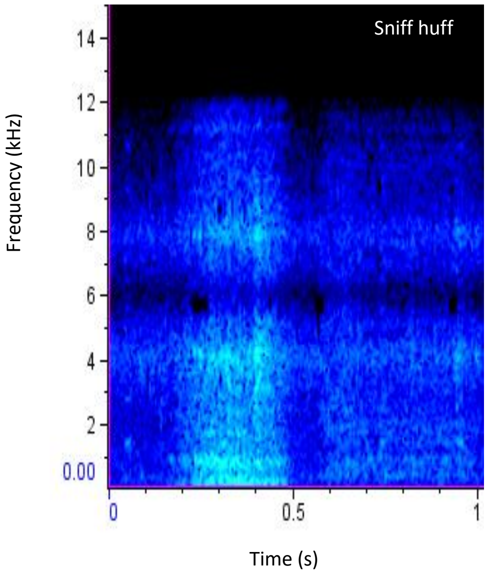

Figure 6.5: *Sniff-huff.* The sniff is a short nasal inhalation, followed by an exhaled huff.

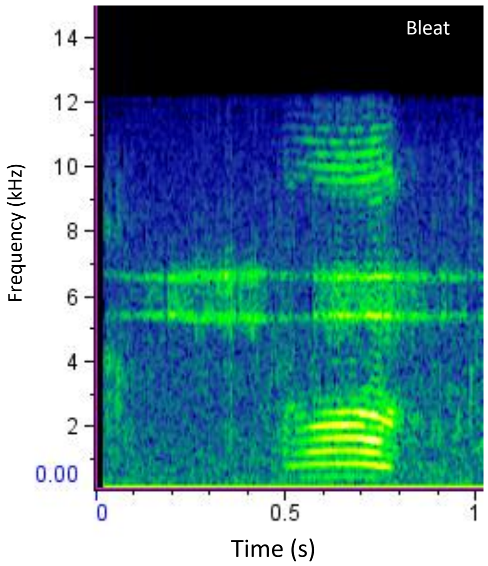

Figure 6.6 *Bleat*. Low intensity contact call made by calves to females.

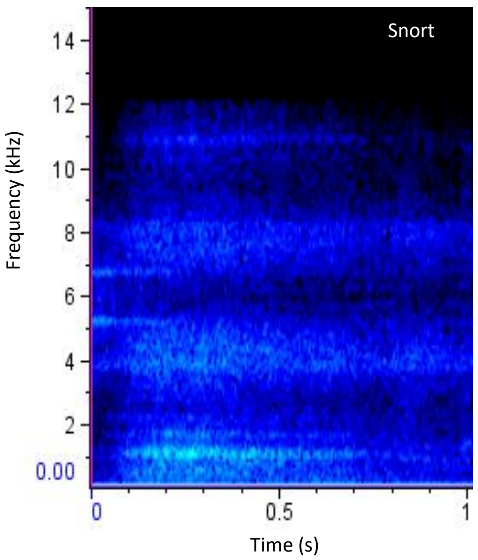

Figure 6.7: *Snort.* A strong exhaled loud call may infer vocal dominance from adult male or female.

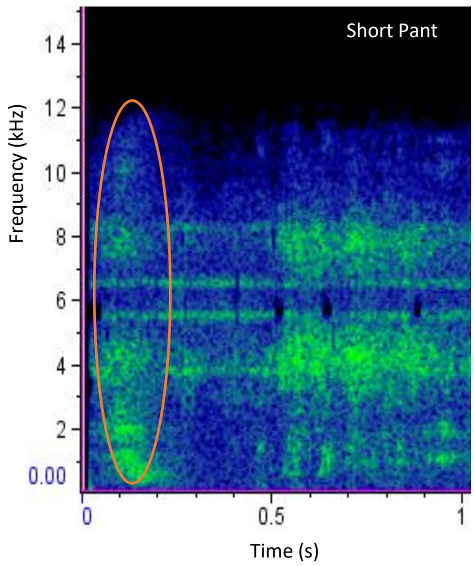

Figure 6.8: *Short pant.* A short, often repeated air sounding call.

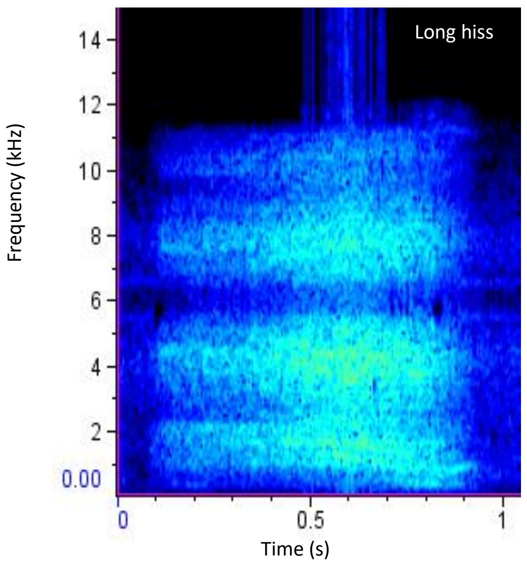

Figure 6.9: *Long hiss.* An extended single, strong, air sounding, almost ear-piercing call.

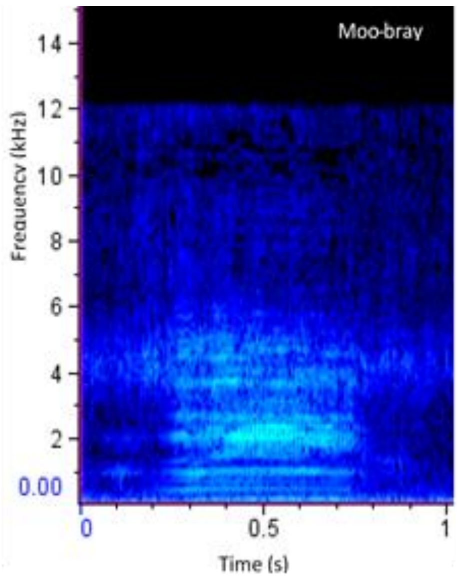

Figure 6.10: *Moo-bray.* A repeated single 'bleat-like' call exhibited by the female during courtship.

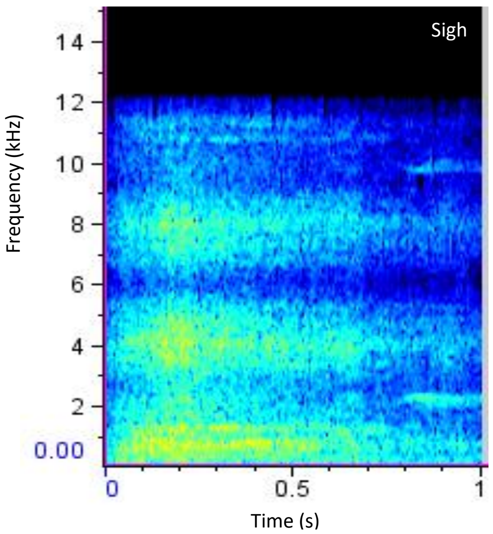

Figure 6.11: *Sigh.* An exhalation call, longer in duration to lip vibration, slow and softer in emphasis, comfort-like and may be used as an acknowledgement i.e. female response to calf bleat or infers comfort e.g. resting in a wallow.

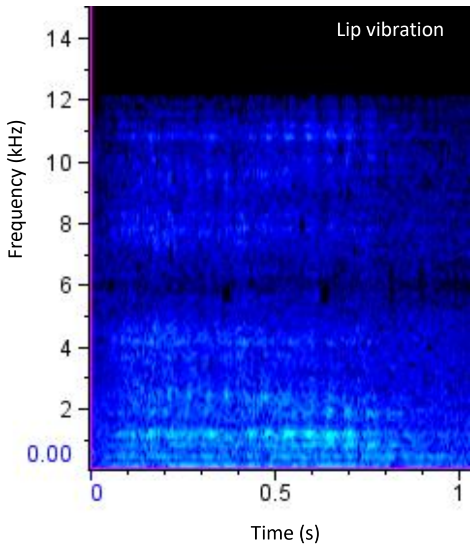

Figure 6.12: *Lip vibration.* Softer than snort, may be a contact response i.e. from female to calf, or indicate comfort e.g. when feeding.

6.4.2 Social interaction and behaviour recordings

Altogether 11 behavioural patterns were categorised, and these were related to their daily activities (Table 3). Additionally, within each behavioural pattern, 11 sub-categories of behaviour were identified (Table 3). A flow chart behavioural catalogue of both non-breeding and breeding behaviours was developed (Figure 6.13). The 137 (2011-2015) peninsula area videos (30 sec) = 68.50 minutes of footage. Forty-three videos contained social behaviour with more than one animal = 31.38%, 55 videos contained calls = 40.1% and 100 videos contained only one animal = 73.0% (Table 4).

The 255 (2016) eastern Gunung Honje region videos (30 sec) = 127.50 minutes in total. Videos taken between (12/11/2016 - 16/12/2016) recorded the following behaviours, 14 calls, 5.49%, nine (n=9) walking, 3.5%, drinking (n=1), 0.03%, standing (n=2), 0.07%, feeding (n=1), 0.03%, rubbing (on structure), 1.5% and wallowing (n=244), 95.6%. Table 5 lists the social interactions recorded during the 2011-2015 period.

Table D.1, Appendix D lists the 32-peninsula camera trap video quadrat locations and the total 137 videos of recorded rhino activity at both wallow and forest areas. Eight wallow sites captured 68 videos, 49.6%, and 23 forest sites captured 69 videos, 50.4%. The wallow sites recorded increased calling and greater diversity by rhinos, including 157 individual calls compared to 39 calls by rhino in forest. Presumably, this is due to increased opportunities to interact with conspecifics at wallow sites, an often-shared habitat feature.

For example, at wallows the number of different call recordings, dataset = 16, averaged, mean 3.2; SD ± 1.643. In forest the number of different call recordings, dataset = 5 averaged, mean 1.25; SD ± 0.5. In forest individual calls recorded included ‘sniff-huff’ 26, ‘short pant’ 9 and ‘moo-bray’ 4. In wallow individual calls recorded included, ‘short pant’ 58, ‘bleat’ 23, ‘sniff-huff’ 15, ‘sigh’ 30, ‘lip vibration’ 5, ‘snort’ 2 and ‘long hiss’ 6. The statistically significant χ^2 result for the number and frequency of vocalisation (calls) recorded in 2015, may have been due to the uneven observed total data set (n=25) comprising four call descriptors, the largest being ‘sniff-huff’ (n=12), ‘short-pant’ (n=7), ‘lip vibration’ (n=2) and ‘moo-bray’ (n=4). The expected or average figure was 6.25.

Table 3 Description of behavioural patterns adapted from (Hazarika & Saikia 2010) exhibited by Javan rhino recorded on 137 camera trap videos (2011-2015) in the peninsula area of Ujung Kulon NP.

Behaviour category	Description
Non-breeding	
1) Feeding	Behaviour associated with consumption of vegetation or water and the method for intake of different vegetation types
Browsing	Involved the consumption of leaves and small twigs from understorey vegetation. Used prehensile upper lip to either bring leaves from short standing vegetation directly into their mouth or to pull a branch down and strip leaves along the length of the branch
Geophagy	Soil tasting or ingestion of soil by rhino in habitat. For example, was observed on two occasions in wallows. In both cases the animal licked and appeared to eat soil from the edge of a wallow. Followed by a flehmen response
Drinking	Often drink water when first entering a wallow, may be for thirst, however some animals display a flehmen response. Known to urinate in wallows to impregnate their scent, any new animal entering a wallow could be stimulated to use a flehmen response
2) Locomotion	Included any behaviour that resulted in the rhino moving from one place to another. The most commonly seen locomotion sub-category was walking
Walking	Slow movement from one place to another, using the alternate fore and hind limbs simultaneously
Galloping	Rapid movement from one place to another, where at a point both fore and hind limbs are not touching the ground.
Entering/wading through water/mud	Entering or wading through water or mud by the movement from dry land into a body of water or mud
3) Comfort	Behaviour that showed relaxation or relief to the rhino, whether related to energy levels or relief from ectoparasites and/ or the sun. Comfort behaviour patterns were sometimes characterised by a lack of motion within the body
Resting	Resting was characterised by the lack of physical movement and the rhino was either sitting down or standing motionless
Rubbing (on structure)	Vigorous rubbing of a section of the rhino’s body against a tree stump or tree trunk. May be a form of scent marking, for example, after leaving a wallow impregnated with scent-laden mud and water (Fig. 6.16).
Mud/water wallowing	Rhino lying or standing in the wallow. Animals were either motionless while in the wallow or when lying down often moved and rolled about to cover themselves in mud or water. Rhinos periodically shake their heads allowing mud and water to penetrate the skins folds on the neck.

4) Vigilance	Behaviours which suggested a heightened sense of ‘alertness’. Including raised head, scanning with eyes and head, erect ears and moving of ears, likely to determine the source of sound heard.
5) Investigating environment	Scanning of the surrounding environment and sniffing of the ground, either while stationary or while walking along. Sniffing ground could possibly be related to searching for food as suggested by Hazarika & Saikia (2010), with their inclusion of foraging behaviour in their description of feeding behaviour.
6) Defecation	Defecation is rapid and was not on a heap of previous defecation (midden) as has been recorded for other species. Animal gives a single quick back leg kick of the dung post defecation, presumably impregnating dung on the feet and spreading dung odours (Fig. 6.13, 6.14).
7) Spray urination	Recorded on two occasions by adult males. May infer male dominance? Unclear if females spray urinates? Involves urine being sprayed backwards across the ground and on vegetation up to and across a three-metre arc (Fig. 6.15).
8) Flehmen response	Recorded on three occasions, twice by adult males and once by an adult female. A flehmen response was displayed after drinking water from a wallow and tasting mud. Rhinos periodically urinate in wallows and impregnate their scent on their bodies.
9) Play behaviour	Only recorded between mothers and young or sub-adult calves. Characterised by play sparring between mother and calf (on both dry land and while in a wallow), young calves running around while the mother fed or displayed vigilant behaviour and mothers and calves running and spinning around to come back together.
10) Non-breeding vocalisation	Several different calls were recorded including a ‘bleat’ call produced by calves to their mothers, a ‘sigh’ response by the mothers, a ‘sniff-huff’, ‘short-pant’, ‘long hiss’ and ‘snort’, ‘lip vibration’ call made by both sexes.
Breeding	
11) Courtship	Courtship behaviour was seen between males and females and is related to seeking/choosing a mate.
Touching	Male used his head to touch a female on her head and used his horn to rub a female under the neck. Female responded with open mouth displays and rubbing back against the male. Touching was gentle and non-agonistic and presumed to be a prelude to mating.
Breeding vocalisation	Males approach females with repeated ‘short-pant’ calls. Female responds with a repeated ‘moo-bray’ calls.

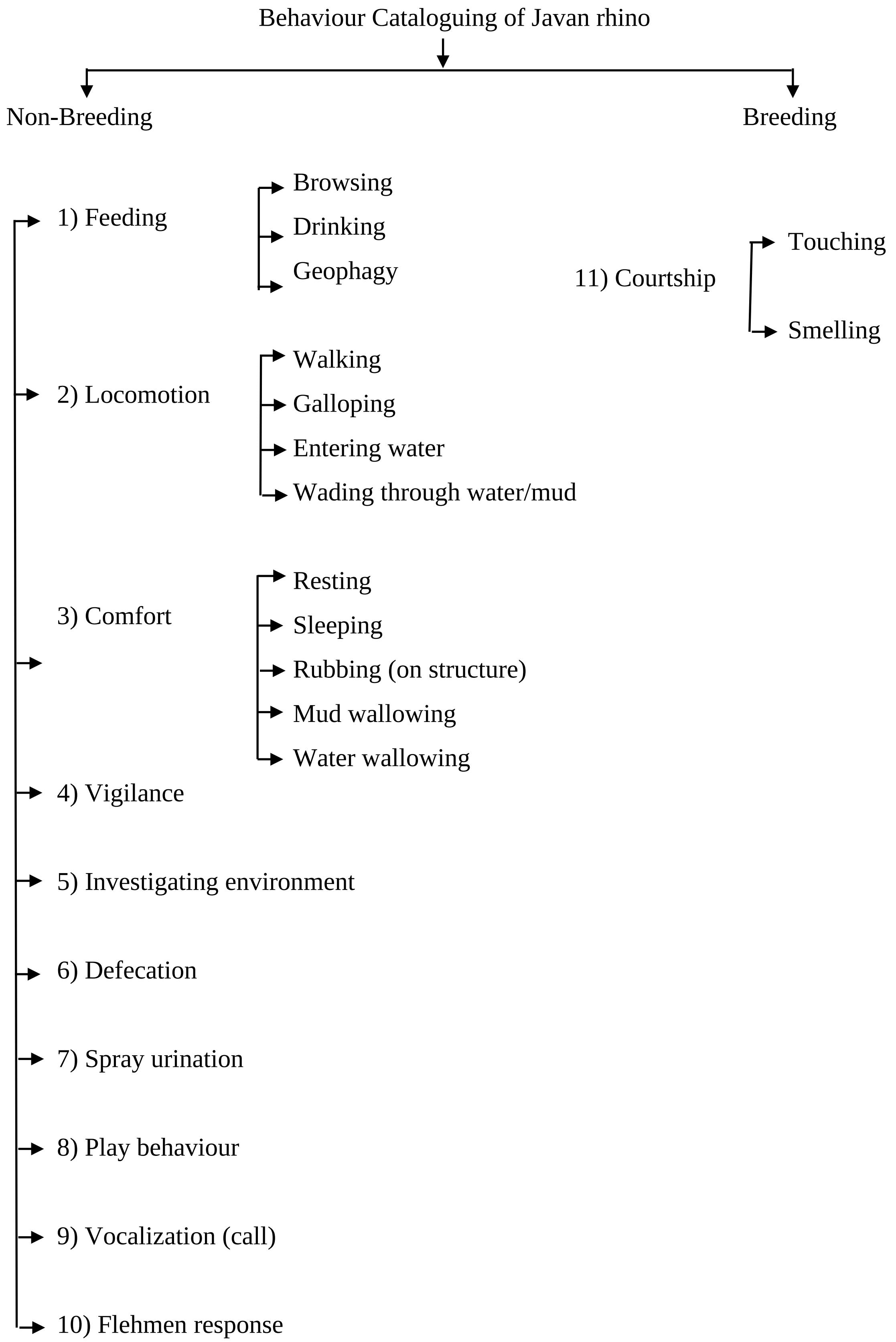

Figure 6.13: Flowchart of behavioural categories for the Javan rhino. Adapted from Hazarika & Saikia (2010), Cinková & Bicik (2013) and Hockings (2016).

Table 4 Summary of peninsula rhino population video behaviour observation results 2011-2015 (n = 137 videos).

Variable	Result		% of no. video clips
Season (Wet = Nov - May), (Dry = June - Oct)	Wet season (n=73)		53.28%
	Dry season (n=64)		46.72%
Habitat where observation occurred	Wallows (n=68)		49.6%
	Forest (n=69)		50.4%
Vegetation type where observation occurred	Open broadleaf evergreen (n=23)		16.78%
	Dense broadleaf evergreen (n=49)		35.76%
	Open broadleaf evergreen/arenga palm (n=55)		40.14%
	Dense broadleaf evergreen/arenga palm (n=10)		7.29%
Number of individual (vocalisation) calls recorded	Calls from 55 (n=55) videos, comprising 182 (n=182) individual calls (peninsula), 14 (n=14) from eastern Gunung Honje area. Total 196 (n=196)		
Behaviour category, no and percentage of behaviours recorded on camera traps (2011-2015), n=137 clips	Non-breeding		
	Feeding	Browsing (n=3)	2.18%
		Drinking (n=8)	5.83%
		Geophagy (n=2)	1.45%
	Locomotion	Walking (n=64)	46.71%
		Galloping (n=1)	0.72%
		Entering/wading through water/mud (n=15)	10.94%
	Comfort	Resting/standing/sitting (n=9)	6.56%
		Rubbing (on structure) (n=7)	5.10%
		Wallowing (mud/water) (n=67)	48.9%
	Vigilance (n=16)		11.6%
	Investigating environment (n=20)		14.5%
	Defecation (n=1)		0.72%
	Spray urination (n=2)		1.45%
	Flehmen response (n=3)		2.18%
	Non-breeding play (n=4)		2.91%
	Non-breeding calls (n=51)		37.2%
	Breeding		
	Courtship	Touching (neck, chin and head rubbing) (n=1), 0.72%	
		Call (short pant, moo-bray (n=4), 2.91%	
No. of observations (n=138), social context and sex of rhinos	Solitary male (n=72)		52.55%
	Solitary female (n=28)		20.43%
	Female & calf (n=26)		18.97%

	Unknown sex (n=2) Male & Male (n=1) Male & female (n=4) Male, female & calf (n=5)	1.45% 0.72% 2.91% 3.64%
Distance from coast where observation occurred (km)	Mean 1.71; SD ± 1.11	
Distance from nearest waterway from where observation occurred (km)	Mean 0.31; SD ± 0.30	

Table 5 Observations (n = 42) of social behaviour of Javan rhino recorded on camera trap videos 2011-2015 in the peninsula area of Ujung Kulon NP.

Clip # Date Time of day	Location	Gender	Behaviour
MVIV 04,5,8,9,36 03/01/2011 10:02 - 10:58	Water wallow	Adult female, male calf < two yrs, adult male	Female with calf in wallow, calf bleats, female calls a ‘long hiss’, male approaches wallow calling a repeated ‘short pant’, male approaches female produces a flehmen response, all settle together in wallow
MVIV 08,11,12,68 31/03/2013 19:08 - 20:50	Water wallow	Adult female with male calf < two yrs	Female calls a repeated ‘sniff-huff’, enters wallow, drinks water, and produces a flehmen response, calf at edge of wallow repeats a ‘bleat’ call, both animals settle and rest in wallow with eyes closed
MVIV 10,11,12,13,14,15,41 01/04/2013 02:21 - 02:24	Water wallow	Adult female with male calf < two yrs, adult male	Female and calf enter a wallow, female calls a repeated ‘sniff-huff’, calf ‘bleats’, female and calf head rub each other and begin wallowing. Male approaches wallow calling a repeated ‘short pant’, all animals settle together in wallow
MVIV 05, 6 14/04/2013 22:06 - 22:07	Water wallow	Adult female and sub-adult male calf and adult male	Female and calf approach wallow with adult male present. Female calls repeated ‘sniff-huffs’, adult male responds with ‘short pants’. Female and calf leave, adult male remains then emerges from wallow
MVIV 39,40,47 23/05/2013 16:27 - 16:34	Mud wallow	Adult female with male calf < two yrs, adult male	Female enters wallow, drinks, produces a flehmen response and call a ‘lip vibration’. Male calf enters behind female, both lay down and rest, then wallow and head rub each other
MVIV 12 19/07/2013 17:51	Forest	Two sub-adult males	Two sub-adult males walking in forest together, no agonistic behaviour was observed
MVIV 4,5,6 25/11/2013 18:56 - 18:58	Mud wallow	Adult female and sub-adult male calf	Female and sub-adult male calf wallowing together, with occasional head rubbing behaviour

MVIV 20 03/04/2014 23:54	Forest	Adult female with female calf < one yrs	Female with young calf sits down, calf calls a repeated 'bleat', tries to suckle, female sighs in response
MVIV 61 12/10/2014 08:25	Forest	Adult female and sub-adult female calf	Female with sub-adult female calf enter forest clearing, demonstrate vigilance behaviour, then walk off
MVIV 89 27/11/2014 11:00	Mud wallow	Adult female and sub-adult female calf	Female with sub-adult female calf leave wallow, calf calls repeated 'bleats', female 'sighs' in response, both show vigilance behaviour
MVIV 007 09/03/2015 17:27	Forest	Adult male and adult female	Adult male and female in courtship display. Male neck rubs and rubs horn under the chin of female. Male calls a repeated short pant, female play bites male, has open mouth and repeats a 'moo-bray' call. Courtship was gentle and non-agonistic
MVIV 023,25 05/06/2015 03:33 - 03:34	Forest	Adult female and sub-adult unknown calf	Female with calf stands in forest, showing vigilance behaviour, then both walk off
MVIV 10,11,12,13 24/06/2015 16:26 - 16: 29	Mud wallow	Adult female with female calf < two yrs, adult male	Female and calf leave wallow, female calls a repeated 'sniff-huff', both animals stand and show vigilance behaviour, calf calls a repeated 'bleat'
MVIV 08 27/07/2015 15: 17	Forest	Adult female and sub-adult female calf	Female with calf walking in forest
MVIV 4,3,5,7,8,9 07/08/2015 13:15 - 13:26	Forest	Adult female with female calf < one yrs	Female with young female calf enter forest clearing, showing vigilance behaviour, then walk off

6.5 Discussion

6.5.1 Social behaviour of Javan rhino, what have we learnt?

Research, specifically on Javan rhino social behaviour and communication has been limited to date, due to their rarity, cryptic nature, and highly protected status. There remain significant data gaps especially in understanding the reproductive repertoire of Javan rhino due mostly to lack of direct observation (Groves & Leslie Jr. 2011). Limited insight was recorded during early accounts (e.g., Hoogerwerf 1970; Ammann 1985), and, the very small size, currently 74 animals (Gokkon 2020), and isolation of the only extant Javan rhino population makes it a difficult species to study (Dinerstein 2011). A study by Ammann (1985) considered it likely that there are dominant and subordinate Javan males, as in greater one-horned rhino (Laurie et al. 1983; Dinerstein 2003), and that dominant male's occupied territories and sprayed urine to mark them significantly more than did subordinate males. The greater one-horned rhino is known to form dominance hierarchies (Dinerstein 2003, 2011). Adult male black, white and greater one-horned rhino are mostly solitary, with sub-adult males often clustering together to avoid pressure from dominant males (Dinerstein 2011).

This study has shown both male and female Javan rhino to have a mostly solitary existence. Social behaviour increases at wallowing sites due to the increased chances of communicating, meeting, and interacting with other rhinos given wallows are often a shared habitat resource. Rhino calling was greater in and around wallows compared to in forest habitat. There was a noticeable increase in the frequency and diversity of calling at wallows compared to in forest habitat. For example, rhinos used three or more calls at wallows compared to one or more calls in forest. The most used call by rhinos in forest was the 'sniff-huff' (Figure 6.5). This call is used by animals when investigating the environment. Females in forests kept in contact with calves using the 'bleat' (Figure 6.6) call and females responding with a 'sigh' (Figure 6.11) call. In and around wallows the 'short pant' (Figure 6.8) was the most used vocal. Adult males used the 'short pant' (Figure 6.8) to announce their presence and communicate with females. The 'lip vibration' (Figure 6.12) and 'sigh' (Figure 6.11) were also used by both sexes in wallows. Both calls appear to indicate comfort or enjoyment. Adult males were observed to regularly visit wallows to determine female sexual receptivity. This was done either by approaching an *in-situ* female vocally or by flehmen response. A flehmen response was also used by both sexes after drinking wallow water or when tasting or ingesting soil or mud, presumably determining the sex, reproductive and possible dominance status of other wallow users.

Females with calves were noticeably more vigilant when approaching wallows, vigilance which heightened in the presence of males, often resulting in the female and calf leaving altogether. This same heightened vigilance behaviour was shown by females entering clearings, particularly with young calves, noting Javan calves follow behind the female when moving. Sumatran and black rhino calves also follow behind the female (Joubert & Eloff 1971; Van Strien 1986). White and greater one-horned rhino calves walk in front of the female (Owen-Smith 1973, 1975; Laurie 1978, 1982). The calf 'bleat' (Figure 6.6) contact call and female response 'sigh' (Figure 6.11) call are not vocally loud. This may be due to the risk of loud calls attracting the attention of predators (Tuttle & Ryan 1982) such as Javan leopard *Panthera pardus melas* or the pack-hunting Javan dhole *Cuon alpinus sumatrensis*. Historically, Javan tiger *Panthera tigris sondaica* may have predated on young Javan rhino. Predation of greater one-horned rhino calves by Bengal tiger *P. t. tigris* is a common occurrence in Rajiv Gandhi Orang National Park, Assam, India (Hazarika & Saikia 2010).

This predation effect on greater one-horned rhino calves by Bengal tiger was also reported by Talukdar (2002) in Kaziranga National Park, Assam, India. Rhino calves predated by tiger are usually less than eight months old (Talukdar 2002; Hazarika & Saikia 2010). It is worth noting Javan rhino may have lived in more social and group behaviour settings than the current low wild numbers indicate. Today's grouping behaviour is most likely marginalised relative to what it once was (Fernando et al. 2006). This is reflected in many early accounts which speak of a more social and gregarious nature and large aggregations (Horsfield 1824; Deuve & Deuve 1962, 1964; Schaller et al. 1990; Santiapillai et al. 1993a, 1993b).

Early recollections by Horsfield (1824) wrote 'the rhinoceros lives gregarious in many parts of Java, it is not limited to a particular region or climate, but its range extends from the level of the ocean to the summit of mountains of considerable elevation'. Historically, Javan rhino inhabited the productive lowland areas due to the availability and proximity of water and food resources, an attraction factor which would have made them easier to see and hunt (Santosa et al. 2013). It has been suggested at least in Java, Javan rhino may have existed in high local concentrations (Groves 1967) and was common enough in the 18th century to be considered a pest, and for government endorsement of its hunting (Ramono et al. 1993). Java, Indonesia was clearly viewed as a source country for rhino horn, records from the T'ang Dynasty, 618-906 AD, mention the export of rhinoceros horn from Java (Nardelli 1987). The congeneric greater one-horned rhino lives a mostly solitary existence however it lives in high densities in quality habitat (Dinerstein 2003, 2011).

Based on research greater one-horned rhino may have amongst the smallest annual and seasonal home ranges of any mega-herbivore (Dinerstein 2011) (see Table E.2 Home range comparison of the five-rhino species, Appendix E). The greater one-horned rhino is known to congregate in either temporary or semi-stable groupings (Laurie 1982). Historically, it is reasonable to assume in quality habitat the Javan rhino may have behaved and lived a similar existence to greater one-horned rhino and its current social behaviour is most likely an artefact of its confinement and adaptation to the conditions of Ujung Kulon.

6.5.2 How do Javan rhinos communicate?

The Javan rhino conveys information with conspecifics via vocal (call) and olfactory signals including using dung, spray urination and pedal scent gland secretions. It remains unclear if Javan rhino deposits dung in the same spot in piles or middens, early accounts suggested they did (Sody 1959; Ammann 1985). However, Schenkel & Schenkel - Hulliger (1969b) and Hoogerwerf (1970) found little evidence. Based on camera trap video observations I believe dung deposits communicate information on individual identity, and generates investigation from other rhino, including sniffing and periodic flehmen responses. However, all my *in-situ* forest observations to date have shown dung depositions in a variety of situations, in water, at feeding sites, occasionally on tracks and randomly in habitat, but never in the same spot or an actual midden situation. Based on my findings I support both Schenkel & Schenkel - Hulliger (1969b) and Hoogerwerf (1970) evidence.

My camera trap observations indicate a male Javan rhino delivers a single back-foot kick immediately after defecation, presumably to spread the scent and impregnate the foot. White rhino for example, defecate communally in dung piles or middens, where individuals leave olfactory signals and obtain information left by other individuals (Marneweck 2013). Territorial male white rhino is also known to kick dung with their back feet immediately after defecation (Owen-Smith 1973). During a seven-day visit during 21/092018 - 27/09/2018, to both Chitwan National Park (27° 30′ 0″ N, 84° 20′ 0″ E) and the adjacent Andrauli Community Forest, near Megauli, Nepal (27.58° 30′ 0″ N, 84.21° 20′ 0″ E), I observed and recorded the congeneric greater one-horned rhino *R. unicornis* dung middens in both riverine forest and *Saccharum spontaneum* (family Poaceae) grassland habitats. Most rhino dung middens I observed during my September 2018 visit had germinating seedlings of *Trewia nudiflora* coming through (Figures 6.17, 6.18, 6.19). The rhino fruit tree *Trewia nudiflora* (family Euphorbiaceae), local Nepali name '*bhellur*" is a common riverine forest tree and is also found in pockets of trees occupying *Saccharum* grassland areas established through germination in rhino dung middens.

Greater one-horned rhino regularly feed on the fallen fruit which ripens during the monsoon period June-September (Dinerstein 2003). *Trewia nudiflora* is not the only plant species to take advantage of dung middens as sites of germination and establishment. A study by Dinerstein (1991b) recorded 38 species including four trees, five grasses, sixteen shrubs, six herbaceous plants, and seven herbaceous climbers growing at greater one-horned rhino dung middens. Interestingly, after five years of (2014-2019) of examining Javan rhino dung in the field, including older depositions I never observed any plant or seed germination activity occurring.

A study of the defecation behaviour of the greater one-horned rhino by Bhattacharya & Chakraborty (2016) found 86% of dung middens were situated along major movement pathways. They also discovered single dung depositions were often placed near major pathways, eventually over 80% of these depositions would become dung middens. Greater one-horned rhino is stimulated to defecate by the sight (Ullrich 1964) and scent (Srivastava 2015; Bhattacharya & Chakraborty 2016) of previously deposited dung and dung middens. This indicates there are clear communication benefits to placing dung deposits in locations where rhinos will investigate. During my study I only periodically detected Javan rhino dung on movement pathways or tracks, in most cases it was random deposits found in a variety of locations (Figures 6.14, 6.15). Other rhino species including white rhino (Owen-Smith 1975) and black rhino (Schenkel & Schenkel-Hulliger 1969a) also tend to place dung middens in locations frequented by other rhino such as travel pathways, near waterholes and territorial boundaries.

This dung midden placement in prominent locations suggests territorial marking, most likely by dominant males, however both sexes and different age classes are known to use middens also (Marneweck et al. 2017a, 2018). I suspect dung middens are used not only as territorial markers by dominant males, but also as communication hubs. However, just how the different age and sex classes of rhino use middens is a worthy research investigation across all three species (white, black and greater-one horned) that utilise middens in their behavioural repertoire. Behavioural studies (e.g., Owen-Smith 1973; Rachlow et al. 1998; Kretzschmar et al. 2001; Marneweck et al. 2018) have suggested that sex is identifiable via odour. For example, a study by Linklater et al. (2013) discovered both sexes of black rhino examined male dung more frequently than female dung suggesting they were able to determine the sex of conspecifics from dung odour. Interestingly, animals may also be able to identify the actual age of the depositors via the signals of dung, urine, and scent marks (Marneweck 2013). For example, Linklater et al. (2013) suggested black rhino are able to identify the dung of adult animals greater than six years old and from sub-adults two to four years old from scent signals alone. Female white rhino can distinguish the different ages of males from urine deposits (Kolar et al. 2002). Common scent organs found across the Order Artiodactyla and shown to be confined to the genus *Rhinoceros* (Javan and greater one-horned rhino) among Perissodactyla are pedal scent glands (cutaneous) (Cave 1961). It has been suggested pedal scent gland secretions are used to mark territory, home range, and presence (Dinerstein 2011). Oestrus females may also be detected by males from scent deposited from pedal scent glands. I have observed Javan rhinos urinating in wallows which helps impregnate their bodies with distinctive odours and males investigating the ground closely near wallows and in rainforest.

6.5.3 What is the social structure of the Javan rhino?

Based on camera trap observations, an adult male Javan rhino is almost always solitary. Adult females with calves do not appear to form associations with other individuals regardless of sex and age. Adult females without calves are mostly solitary. Sub-adult males may form groups of two individuals, these pairings may occupy peripheral areas of dominant male home ranges. Presumably, subadult males form these groupings to increase their ability to detect and be protected from dominant males. Sub-adult greater one-horned rhino are known to form loose associations living around the edges of a dominant male’s territory (Laurie et al. 1983). The social structure of Javan rhino has similarities to other rhino species. For example, adult males of the other four species are usually solitary outside of breeding events (Dinerstein 2011). Female white, black, and greater one-horned rhino may congregate together in good habitat and foraging areas (Goddard 1967; Owen-Smith 1974, 1975; Laurie 1982). Male greater one-horned rhino form dominance hierarchies and will defend areas where females congregate (Dinerstein 2003, 2011). Sumatran rhinos are mostly solitary except for females with young (Groves & Kurt 1972; Van Strien 1986).

6.5.4 What are the intraspecific interactions that occur among Javan rhinos?

Female Javan rhinos with calves maintain the strongest social bond and social interaction. Adult male Javan rhinos regularly visit wallowing sites to monitor visiting females for sexual receptivity as well as for thermoregulatory purposes. Solitary Javan males and females would periodically drink and ‘taste’ soil or mud at wallows, often followed by a flehmen response. A flehmen response analyses the chemical (scent) signals of other rhino identities, including sex, reproductive and possible dominance status (Hart 1983). I have observed, on camera trap video, females with calves being cautious and vigilant around wallows, particularly with males present.

Wallowing females are noticeably vigilant and will respond vocally to unwanted male attention. If uninterested, females would vocalise a ‘long hiss’ warning call (Figure 6.9) to males either waiting in a wallow or approaching a resting female with or without a calf. Male rhinos are known to engage in mate guarding behaviour, following females until they come into oestrus and will tolerate close approach and physical contact with other males (Estes 1991; Owen-Smith 2004). For example, territorial male white rhinos are known to form attachments with females coming into oestrus approximately one to two weeks prior to mating. During this period, the male will pay close attention to the female and try and restrict her from leaving his territory (Owen-Smith 1973).

Based on this (Owen-Smith 1973) behavioural data it supports the fact that males are able to detect the onset of oestrus from dung or urine. A study by Grün (2006) on white rhino supports this, where males were recorded spending time investigating dung deposits of breeding females, suggesting the identification of female oestrus signals. It remains unproven, however plausible that Javan males would engage in mate guarding behaviour. Infanticide has been recorded in greater one-horned rhino. A radio-collared dominant male killed a young calf that it had not sired (Dinerstein 2011). The unexpected loss of a calf would stimulate the female’s oestrus cycle, an opportunity that the infanticidal dominant male could benefit from. It remains unproven if Javan rhino males engage in infanticide behaviour. Female greater one-horned rhino females in oestrus urinate frequently; and are often closely followed and monitored by males that test the female’s reproductive status by tasting her urine, which is then followed by a flehmen response (Goddard 1967; Laurie 1982). I have observed on camera video Javan rhino males using flehmen response at wallow sites to determine the sexual receptivity of in-situ females.

Until receptive, females may repeatedly drive males away with mock charges and other defensive behaviours (Hutchins and Kreger 2006). Both Laurie (1978) and Dinerstein (2003) confirmed in their studies that greater one-horned rhino engaged in aggressive combat, which is periodically fatal to establish dominance and gain access to oestrus females. In Dinerstein’s (2003) research work he found breeding activity in greater one-horned rhinos is socially delayed in young adult males due to older, and stronger males excluding them from grazing areas where breeding females often reside. Both Laurie (1978) and Dinerstein (2003) observed that the sharp lower incisors, rather than the horn inflicted injuries. Presumably, the Javan rhino who also possesses these sharp lower incisors can do similar injuries in dominance and courtship activities. I have observed on camera trap video, incisor slash injuries on the side, flanks, and heads of females, presumably because of courtship chases.

All three Asian species use their tusks (lower outer mandibular incisors) in combat between breeding males (Dinerstein 2011). Males use their tusks to control breeding females and females use them to defend their calves from males. Male rhino is considered amongst the most aggressive of hoofed mammals (Dinerstein, Shrestha & Mishra 1990).

6.5.5 What specific calls do adult male, adult female, sub-adult male, sub-adult female, and calves exhibit and in what contexts?

Adult male Javan rhinos specifically use ‘short pant’ (Figure 6.8) calls to approach females. Males and females ‘sigh’ (Figure 6.11) and ‘lip vibrate’ (Figure 6.12) when resting, which appears to indicate comfort or pleasure. For example, rhino entering and settling into a wallow induces the ‘sigh’ and ‘lip vibration’ call. Interestingly, females also ‘sigh’ in response to a calf’s ‘bleat’ call. When walking and travelling mobile adult males ‘sniff-huff’ when investigating the environment. Snorting appears to be the vocal response to a disturbance; it appears to infer dominance and is used by both sexes. The ‘moo-bray’ (Figure 6.10) call is used by adult females during courtship in response to an interested male’s ‘short pants’ (Figure 6.8) and is complimented by gentle horn rubbing on the head and under the chin of the female by the male. Females with calves respond to calf ‘bleats’ (Figure 6.6) with a ‘sigh’ (Figure 6.11). There appears to be no difference between the calls of sub-adult male and female animals and adult animals. Earlier studies by Ammann (1985) and Schenkel & Schenkel-Hulliger (1969a, 1969b) described several calls not recorded in this study, however both authors were unclear which sex produced the call. These calls including ‘neigh,’ a ‘loud blowing whistle’, and ‘shriek’, a possible response to a threat.

Therefore, it is reasonable to assume, the Javan rhino call vocabulary can be expanded with further research and investigation, particularly in the still understudied area of Javan rhino courtship and reproduction behaviour. Both sexes use flehmen response. The flehmen response or reaction is a mammalian behaviour mostly displayed by males of most hoofed ungulate (perissodactyls and artiodactyls) and felid (family Felidae e.g., tiger) species, is a prominent, but poorly understood aspect of reproductive behaviour (Hart 1983). I have observed on camera trap video this behaviour more frequently in males than females during encounters. A flehmen response occurs when an animal curls back its upper lip, exposing its teeth and usually inhales with closed nostrils. These mouth and facial movements facilitate the transfer of scent particles (pheromones) and other scents to the Jacobsen’s or vomeronasal organ in the roof of the mouth (Hart 1983).

During flehmen response it appears as if the animal is grinning or grimacing. Therefore, it appears the core function of flehmen is intraspecific communication. Male rhinos will use the ‘snort’ (Figure 6.7) vocal to infer annoyance or dominance. For example, I have observed on camera trap video two Javan dholes *Cuon alpinus sumatrensis* closely following a walking Javan male rhino, who repeatedly turned and chased both dogs and snorted its disapproval. A similar response was reported from a Javan rhino to an interaction with Javan wild pig *Sus scrofa vittatus* (Hariyadi et al. 2010).

6.5.6 Comparison of Javan rhino vocalisation (call) to other rhino species

All five-rhino species are known to vocalise through a range of calls and sounds (see Table E.1 Vocalisation comparison of the five-rhino species, Appendix E). White, black, greater one-horned and Sumatran rhinos are known to contain infrasonic properties (having frequencies below those of audible sounds i.e., < 16 Hz) (Spellmire 1981; Muggenthaler et al. 2003). All five species emit similar types of calls, for example, the ‘snort’ call, which may infer annoyance, possible dominance, and agonistic responses. In black rhino, the ‘snort’ call may have three contexts. Firstly, the ‘snort’ is used as a general call when disturbed, secondly a ‘hollow snort’ is used when listening, and thirdly an ‘aggressive snort’ is emitted in agonistic situations (Budde & Klump 2003). Calves of each species use similar contact calls to stay in contact with females. For example, black rhino females and calves stay connected using a ‘mew’ call (Budde & Klump 2003). Javan rhino calves emit a ‘bleat’ to which the female responds with a ‘sigh’. Calves of greater one-horned rhino stay in contact by emitting a ‘moo-grunt’ (Dinerstein 2003, 2011).

Just exactly when and in what context rhino resort to emitting infrasound signals remains to be determined, including if Javan rhino use infrasonic signalling at all. African elephants *Loxodonta africana* are known to use infrasound calling to maintain group cohesion and to find a mate (Poole et al. 1998). The landscape in which a rhino lives may influence the use of vocalisation as a form of communication. For example, white rhinos live in open woodland/grassland habitats (Owen-Smith 1973) are the most social rhino species and have a highly developed social system (Owen-Smith 1973, 1975; Penny 1987). It has been suggested (Policht et al. 2008) that white rhino may be using a repeated or pulsed contact call pant (unique to the species) for long distance communication in open environments that is able to compensate for issues such as wind disturbance. The features of habitat (e.g., forest) and landscape (e.g., mountains) creating some form of acoustic distortion (Wiley & Richards 1978) has been identified for some time.

Due to the humid rainforest environment, both Javan and Sumatran rhinos occupy wallows year round, unlike other rhino species, and therefore these sites are likely more important for interaction and communication for these species (Dinerstein 2011). Based on the examined camera trap video footage, my research has shown Javan rhino calling increases at and near wallowing sites, an often-shared habitat resource, hence the presumed need for closer vocal communication.

6.5.7 Future questions on the habitat soundscape of Ujung Kulon

The acoustic environment of Ujung Kulon in relation to Javan rhino communication poses several questions for future work. Are Javan rhinos calling more at wallows due to better acoustic properties at these sites? Or does calling increase because of the shared wallowing opportunity to interact, or monitor a visiting animal's reproductive or dominance status? In Ujung Kulon, wallows are often well concealed, typically have good canopy cover and the wallow itself is often situated in basin-like areas that hold and retain water. As these wallow sites are structurally different to adjacent rainforest areas, do they perform acoustically better? Every environment has its own acoustic characteristics for sound transmission (Linskens et al. 1976; Date & Lemon 1993), and a consequent daily distribution of ambient noise (Waser and Brown 1986; Schneider et al. 2008). It has been suggested by Morton (1975) and Brown & Handford (2000) that calls are expected to be more stereotyped in closed than in open habitats, since the availability of the visual channel is restricted, and vocal delivery conditions are relatively stable in closed habitats such as rainforest.

6.5.8 Javan rhino social interaction and communication conservation considerations

The recorded calls highlight the importance of the knowledge gap regarding Javan rhino communication and presents fertile ground to build further understanding of Javan rhino ecology and social dynamics. Because there are very few direct observations of Javan rhinos this makes comparisons difficult. Future research in this area should focus on expanding the database of recordings and increase our understanding of the function of described calls and any calls yet to be described. I acknowledge the importance of wallows as key habitat features and communication sites. Based on the dataset I recorded a greater individual number and increased diversity of calls at and near wallows. Wallows are important sites not only for communication but for thermoregulation also. I recorded animals utilising wallows for extended periods up to and greater than six hours per day. Any future planned translocations will need to factor in release sites that have good proximity to water and conditions that favour the maintenance of long-term wallows.

Recognition and understanding of the information that can be obtained by recordings of Javan rhino calls and videos showing a range of other behaviours is critical and is amplified when the population is so low. As demonstrated by Linklater et al. (2013) and Cinková & Policht (2016), the manipulation of chemical signals in dung and urine, and calls can be useful conservation tools. For example, translocated Javan rhinos could be stimulated to reduce stress and modify behaviour by using familiar/unfamiliar urine-impregnated water and mud at wallows, dung, and playback call recordings. A data gap remains regarding how important and what function pedal scent gland secretions present.

Both species of *Rhinoceros* (Javan and greater one-horned) possess pedal scent glands, how these species use pedal scent gland (cutaneous glands) secretions in their communication repertoire remains unclear (Dinerstein 2011; Groves & Leslie, Jr. 2011). At present, our most useful guide to understanding how Javan rhinos communicate is to compare calls and communication data from its more widely studied congener, the greater one-horned rhino. There are consequences for threatened species such as Javan rhino with long birth intervals that lower the reproductive rate (long gestation) and their recovery (Dinerstein 2003; 2011). The management issue of older, possibly infertile dominant males consorting with females to the detriment of younger more fertile males reducing the birth rate. For example, greater one-horned rhino produces calves at a rate of one every 2.5 years (Dinerstein 2003).

Presumably, this is due to females needing to be a certain body weight, so they can withstand the rigours of male interest in courtship or dominance related behaviour, whilst unproven, I suspect Javan rhinos reproduce and calve at a similar rate. Protected and natural areas rapidly decline as human populations and the occupation of habitat landscapes expand and impact on ecological processes (Theobald et al. 2000, 2005). This negative ecological impact trend is often seen in developing countries where urbanisation and human settlement growth occurs (Langpap & Wu 2008). Reducing human-induced adult mortality (e.g., hunting or habitat reduction) is a vital component to conservation and recovery. Due to their longevity, slow reproductive rate, many animals will suffer continued population decline if excessive hunting, poaching or other forms of impact are not brought under control (Dinerstein 2003; 2011). Home range size varies across rhino species and is dependent upon habitat quality and carrying capacity. For example, Namibian desert-dwelling black rhino may range 500 km^2 (Owen-Smith 2004) compared to the productive floodplains of Nepal's Royal Chitwan National Park where greater one-horned rhino ranges vary between 2.9 km^2 for females and 3.3 km^2 for males (Dinerstein 2011).

A recent study by Setiawan et al (2017) of Javan rhino home ranges using a large dataset of camera video clips discovered strong evidence that home range size varied between males and females and across seasons. Females maintained the smallest home ranges (14.20 km^2) during dry seasons, typically June - July. Male home ranges were largest (105.53 km^2) during the period from dry to wet season, usually September-October. Seasonal female home ranges were on average half the size of males (Setiawan et al. 2017). This valuable data highlights the species requirement for large sized habitat areas able to cater for the needs of both male and female home ranges and the climatic ranges within, key factors in any future proposed translocation efforts. Wherever possible male Javan rhinos should be monitored, particularly older males who may still hold dominance, however, may be past reproductive potency e.g. low sperm count. I suspect older, larger, and more experienced males may be dominating and guarding reproductive aged females and excluding younger potentially more sexually potent males from female access. This issue has been recorded in the congeneric greater one-horned rhino (Dinerstein 2003, 2011). Future translocations could be trialled using older past reproductive aged males.

There is a need for active management of Javan rhino to keep population densities lower and at more productive levels. For female rhino, the age at first reproduction can be an impediment given it takes time for a population to rebound and respond. A study by Dinerstein (2003) estimated the greater one-horned rhino female's age at first breeding in one population at 7 to 7.5 years, presumably Javan rhinos have similar age at first breeding results. With low numbers only a few Javan females may be reproductively active at any given time. Presumably, Javan rhino longevity as in other rhino species may compensate for the slower population recovery time, or at minimum reduce the disadvantage when compared to the rebounding ability of many small mammals. Under ideal conditions and in good habitat, Dinerstein (2003) suggests rhinos could produce a calf every 2.5 years.

The current lack of accurate knowledge of Javan rhino age at first breeding and interbirth interval is a significant data gap and worthy of investigation. The Sumatran rhino as evergreen forest dwellers use a system of trails through their habitat, that includes access to salt and mineral deposits (Van Strien 1986). My observations suggest Javan rhinos periodically uses trails, but often moves and forages well off trail. There are no obvious salt or mineral licks in Ujung Kulon, I suspect rhinos get their salt and minerals from salt-sprayed coastal vegetation, or possible periodic ingestion of sea water (Ammann 1985) and from mineral rich vegetation, for example, Wild Mango *Spondias pinnata* as the food plant with the highest calcium (4.70 g/100 g) and *Hibiscus tiliaceus* with the most phosphorus (0.3 g/100 g) (Haryono et al. 2016). Although unproven salt and mineral rich vegetation areas may be sites of communication given there is a biological need for rhino to visit these areas.

6.5.9 Value of camera trapping in recording social interaction and vocalisation

Camera trapping is an emerging remote sensing tool used to study wildlife, especially for species that are endangered or difficult to observe (Bernard et al. 2013; Mohd-Azlan & Engkamat 2013). There are several advantages to camera trapping. Firstly, it is a cost-effective (Mohd-Azlan & Engkamat 2013), non-invasive method of sampling which eliminates observer bias (O'Brien and Kinnaird 2011). Furthermore, the cameras can also run for extended periods of time in remote locations that are difficult for people to access and they provide unambiguous records of the species present and the date and time of detection (O'Brien & Kinnaird 2011). The advent of camera trap technology improves individual recognition, and captures behaviour, using Griffith’s (1993) identification criteria, (mark-recapture) which has been verified as an effective ID criterion, and the addition of date and time capture provided by camera imagery.

This technology will assist in identifying the individual animals, activity patterns (date/time of day), visitation frequency (day/month) and behaviour in wallows and in other landscape contexts. This photo identification technique has been found to be a reliable censusing methodology (Hiby & Lovell 1993; Haryono et al. 2015). In this study I have found that camera trap data can provide elements of the necessary information required to determine the suitability of potential translocation sites. The camera trap data highlighted coastal areas are frequently used by Javan rhino and that wallows are important sites for communication. While there has been planning to translocate Javan rhino since at least 2007 (Indonesian Ministry of Forestry 2007), continued challenges remain in identifying a suitable translocation site, among other issues, has delayed the process (Haryono et al. 2016).

In this study I have shown that camera trap video data can be used to increase understanding of the Javan rhino ecology and behaviour which can help inform conservation management decisions. While the current camera video recordings are valuable for rhino identification and for conducting regular population censuses, the provision of more cameras at wallow sites will likely increase to number of records of behaviours and interactions that are relevant to informing conservation decisions.

Figure 6.14: Fresh Javan rhino dung deposited in shallow creek near a feeding site.

Figure 6.15: Rhino protection staffer holding Javan rhino dung bolus next to large dung deposit in forest.

Figure 6.16: Fresh Javan rhino urine (spray) on vegetation. Javan rhinos can spray urinate up to several metres across vegetation.

Figure 6.17: Fresh and old greater one-horned rhino dung at midden in sandy area in *Saccharum spontaneum* grasslands in Chitwan National Park, Nepal.

Figure 6.18: Fresh and old greater one-horned rhino dung in midden in riverine forest in Chitwan National Park, Nepal.

Figure 6.19: Germinating fruit (*Trewia nudiflora)* and seeds in greater one-horned rhino dung midden in Chitwan National Park, Nepal.

Chapter 7 Thesis Discussion and Conclusion

Figure 7.1: Camera trap image of female Javan rhino with a newborn calf in Ujung Kulon National Park, West Java, Indonesia. (Image: Courtesy Ujung Kulon National Park Authority).

7.1 Overview

This PhD thesis undertook innovative research aimed at improving the long-term survival of the rare and highly threatened Javan rhino *Rhinoceros sondaicus*. A single small population of 74 Javan rhino currently remains globally (Gokkon 2020), all individuals are located on the western tip of Java, Indonesia, in Ujung Kulon National Park. Given that the Javan rhino persists only in one small stronghold in Java, one of the most populated islands on the Planet, its persistence depends on our understanding of its ecology, behaviour, the factors shaping its activity and the management actions taken by humans to enhance its persistence, and especially of the park rangers, the rhino protection units, and the large human community in the villages surrounding the park.

Given the importance of the rural communities living around the rhino’s remaining habitat **Chapter 2** examined the community awareness of local people living near Ujung Kulon National Park to Javan rhino conservation and determine the implications for future conservation of the rhinos. **Chapter 3** determined the approaches used and attitudes of rhino protection staff and national park staff to rhino management, and implications for future management. Understanding frontline staff insights into the outcomes of past conservation actions and required future actions are key in enhancing the outcomes of threatened species conservation actions. To study frontline staff perceptions to Javan rhino conservation, management actions and their outcomes, and operating environment, we surveyed 22 of 25 rhino protection staff and 14 of 16 National Park rangers.

Chapter 4 determined the implications for conservation and management of arenga palm on rhino, habitat, and food plants. Arenga palms have vastly expanded in the region since the explosion of the Krakatoa (Krakatau) Volcano in 1883 (Van Strien & Rookmaaker 2010) and now dominate the rainforest canopy in many areas of the park, substantially limiting the growth of native rhino food plants and available rhino foraging activity and threatening Javan rhino persistence. I found that arenga palm removal led to increased richness and abundance of native Javan rhino food plants and a rapid increase in rhino visitation to cleared sites that were previously avoided by rhinos. **Chapter 5** examined the wallow characteristics, spatial analysis of wallows in the study area, and their importance to Javan rhino ecology, social interaction and communication behaviour, and implications for conservation planning. In this study, we identified, mapped, and studied 35 wallows in eastern Ujung Kulon National Park, where rhinos were active. We discovered that Javan rhino utilise wallows not only for thermoregulatory function, but also as sites of interaction and communication.

Chapter 6 examined the rarely studied and data deficient area of Javan rhino social interaction and communication behaviour. This study categorised 11 behavioural patterns, and these were related to their daily activities. I also expanded our knowledge of Javan rhino vocalisation identifying eight vocalisation descriptors with accompanying sonograms (a first for the species), noting this is an extremely understudied aspect of Javan rhino ecology.

Collectively, this work improves current understanding of the factors shaping the conservation of Javan rhino by i) increasing awareness of effectiveness, data gaps and future risks to current conservation initiatives, ii) increase knowledge of Javan rhino ecology, social and communication behaviour, iii) and optimise the management of key threats, for example, the management of the invasive arenga palm.

In the final chapter of this thesis, I summarise the main findings from each chapter, and discuss the main contributions to Javan rhino conservation of this thesis as a whole. I then outline the major assumptions and limitations of my findings and suggest opportunities for future research.

7.2 Main findings

7.2.1 *Chapter 2 Implications of local community awareness to the conservation of the Javan rhino, one of Earth's rarest mammals*

The research identified that the local rural community maintained only a basic awareness of Ujung Kulon National Park's boundaries, rules, and regulations, and held only limited understanding of the rhino conservation efforts and management actions. All village communities were in agreement that more regular communication from the authorities will be important on the conservation and management programs in Ujung Kulon and its area. The data captured from this study will help inform national park managers and conservation planners of local community awareness and understanding of current conservation activity and assist in identifying future risks. This study also helped reveal what attitudes exist towards conservation activities, protected areas, or threatened species management, which may serve as a useful model to better explain community behaviour in other areas (Lepp and Holland, 2006; Triguero-Mas et al. 2010; Moreto et al. 2017).

Finally, studies that combine both field work and an examination of community approaches and involvement can help inform management authorities and even government policy makers which factors influence attitude, such as community involvement in threatened species and protected area management, which can benefit when prioritising areas of conservation action.

7.2.2 *Chapter 3 Protecting an icon: Javan rhino frontline management and conservation*

Frontline staff acknowledged the inception of rhino protection units and working partnership with the UKNP Authority, is meeting the needs of rhino protection. Staff attributed this success to regular patrol cycles and high awareness of such in local communities. Despite this success, staff noted challenges remain notably natural resource competition. This concern over natural resource competition and use is also documented at a higher strategic level by rhino range countries. For example, the Strategy and Action Plan for the Conservation of Rhino in Indonesia (Rhino Century Program 2007-2017), is the Indonesian Government's official conservation policy for the country's rhino populations (Indonesian Ministry of Forestry 2007). Anthropogenic pressure driven mainly by poverty (encroachment and need for more agricultural land) is putting pressure on rhino populations and habitat (Indonesian Ministry of Forestry 2007; Haryono et al. 2016).

The issue of balancing such objectives and the needs of local community is challenging (Karanth & Nepal 2012; Allendorf & Gurung 2016). Frontline staff residing in local villages can inform and educate local community through their presence. This study was valuable at several levels. Firstly, participants can provide frontline assessment of current approaches and threats. For example, frontline staff acknowledged the biggest threat to Javan rhino was disease risk to rhino from domestic stock. Secondly, this information can be used by authorities and conservation planners to improve and prioritise management actions. For example, authorities could respond by undertaking regular domestic stock vaccinations to reduce disease transfer to rhinos (Khairani et al. 2018). Thirdly, given that interviewed staff live in the local communities surrounding the park, by understanding local community impacts and insight may reveal opportunities to improve relationships and develop conservation-based programmes with local community input. This study has highlighted that whilst a conservation program can be viewed as effective (e.g., rhino poaching has ceased), the value of frontline staff input into conservation management is an asset, offering unique insight that may reduce future risk impacts and improve conservation objectives.

7.2.3 *Chapter 4 Understanding the implications of Arenga palm dominance in the conservation and management of Javan rhino*

Arenga palms have vastly expanded in the region since the explosion of the Krakatoa (Krakatau) Volcano in 1883 (Van Strien & Rookmaaker 2010) and now dominate the rainforest canopy in many areas of the park, substantially limiting the growth of native rhino food plants and available rhino foraging activity and threatening Javan rhino persistence. However, the impacts of arenga palm management on rhino activity and conservation prospects has not been studied.

To fill this gap, I monitored the impact of arenga palm removal on both native vegetation recruitment and post clearing visitation frequency of Javan rhinos. I found that arenga palm removal led to increased richness and abundance of native Javan rhino food plants and a rapid increase in rhino visitation to cleared sites that were previously avoided by rhinos. Within five months of clearing of the arenga palms, the experimental sites had 67 rhino food plant species belonging to 37 plant families comparable to native plant species in the control sites.

All 15 cleared arenga palm sites were visited by Javan rhinos over the two-year recording period following the arenga clearing compared with no visitation at all before clearing these sites. These findings suggest for the first time that rhino habitat manipulation and clearing of arenga palm in rainforest patches is an important management technique for increasing the remaining Javan rhino foraging habitat and for enhancing the persistence of the highly threatened Javan rhinos. The study demonstrated the benefits of habitat manipulation, and arguably is the strongest immediate conservation action needed to actively clear monoculture/dominant arenga palm areas to increase rhino foraging.

Historically, the eastern Gunung Honje area only had periodic visitation by rhino (Ramono et al. 2009). Today the area supports three resident males and occasional visits from other animals. Females with calves have been captured on camera trap videos but have not stayed in the area (Hariyadi et al. 2012). Camera trap videos demonstrate how females with calves are extremely vigilant and prefer to stay and travel in areas with good cover. Movement pathways from the western peninsula area of the park to the eastern Gunung Honje site need to be well-vegetated to assist this need. This rhino behavior has been recognized by park authorities and supplementary planting of rhino food plants is occurring along the corridor linking the peninsula to the eastern Gunung Honje area which may create the right conditions for single females to stay and ultimately breed with resident males (Hariyadi et al. 2016). The positive impact and involvement of local community who are employed to manually clear arenga palms (cutting palm trunks, clearing fronds, and collecting fruits) not only has an immediate effect on the landscape, but it also importantly engages community into the rhino conservation effort.

7.2.4 *Chapter 5 More than just mud: The importance of wallows to Javan rhino ecology and behaviour*

Wallows are critically important in the habitat and behavioural repertoire of all Asian rhinoceroses (Blyth 1862; Hoogerwerf 1970; Groves & Kurt 1972; Laurie et al. 1983; Ammann 1985).

The critically endangered Javan rhino *Rhinoceros sondaicus* use wallows in Ujung Kulon National Park, West Java, Indonesia that are often well concealed by jungle vegetation (Ramono et al. 2009). Javan rhinos need to wallow regularly throughout the year, yet the role wallows play in their behaviour and the importance to the species remains little understood. In this study, we identified, mapped, and studied 35 wallows in eastern Ujung Kulon National Park, where rhinos were active. We spatially mapped and recorded each wallow’s characteristics. We identified and categorised eight behavioural patterns at and near wallows related to rhino daily activities and found that wallows have several key features for the Javan rhinos. For example, our findings revealed that Javan rhinos who construct the wallows themselves, choose sites with 75% shade cover and often at an elevation.

Analysis of the rhino vocal calls from camera trap videos taken at and near wallows, identify seven vocalisation descriptors with accompanying sonograms, a first for this rare and shy rainforest species. We discovered that Javan rhino utilise wallows not only for thermoregulatory function, but also as sites of interaction and communication. We now have a good baseline database of 35 wallows as a useful guide for any future translocations into new or former historic ranges. Rhinos don’t just construct wallows anywhere, and certain landscape features are used. The recorded vocalisations (calls) highlight the importance of filling the knowledge gap regarding Javan rhino communication and presents fertile ground to build further understanding of Javan rhino ecology and social dynamics. Because there are so very few direct observations of Javan rhinos this makes comparisons difficult. As demonstrated by Linklater et al. (2013) and Cinková & Policht (2016), the manipulation of chemical signals in dung and urine, and calls can be useful conservation tools. For example, translocated Javan rhino could be stimulated to reduce stress and modify behaviour by using urine-impregnated water and mud at wallows, and playback call recordings.

Future research in this area should focus on expanding the database of recordings and increase our understanding of the function of described vocals and any vocals yet to be described. We acknowledge the importance of wallows as key habitat features and communication sites. Any future planned translocations will need to factor in release sites that have a viable proximity to water and conditions that supports the maintenance of long-term wallows (Ramono et al. 2009; Haryono et al. 2016).

7.2.5 *Chapter 6 Understanding an icon: Social behaviour and communication of Javan rhino*

Currently, our knowledge of Javan rhino social structure, behaviour and communication has been restricted to a few historic accounts mostly from the 1900’s (e.g., Hazewinkel 1933; Schenkel &

Schenkel-Hulliger 1969a, 1969b; Hoogerwerf 1970; Ammann 1985). A primary aim of this study was to increase our knowledge of the social behaviour of the Javan rhino, the forms of communication used by the species and the value of using camera trap data for conservation. This study has shown both male and female Javan rhino to have a mostly solitary existence. Social behaviour increases at wallowing sites due to the increased chances of communicating, meeting, and interacting with other rhinos given wallows are often a shared habitat resource. Rhino calling was greater in and around wallows compared to in forest habitat. There was a noticeable increase in the frequency and diversity of calling at wallows compared to in forest habitat. Female Javan rhinos with calves maintain the strongest social bond and social interaction. Adult male Javan rhinos regularly visit wallowing sites to monitor visiting females for sexual receptivity as well as for thermoregulatory purposes.

Altogether, 11 behavioural patterns were categorised, and these were related to their daily activities. I also expanded our knowledge of Javan rhino vocalisation via 55 recordings comprising 196 individual vocalisations, identifying eight vocalisation descriptors with accompanying sonograms (a first for the species), noting this is an extremely understudied aspect of Javan rhinoceros ecology. Although data gaps remain, for example, understanding rhino reproductive ecology and behaviour, we have increased understanding of rhino communication. Recognition and understanding of the information that can be obtained by recordings of Javan rhino calls and videos showing a range of other behaviours is critical and amplified when the population is so low. A data gap remains regarding how important and what function pedal scent gland secretions present. Both species of *Rhinoceros* (Javan and greater one-horned) possess pedal scent glands, how these species use pedal scent gland (cutaneous glands) secretions in their communication repertoire remains unclear (Dinerstein 2003, 2011).

There are consequences for threatened species such as Javan rhino with long birth intervals that lower the reproductive rate (long gestation) and their recovery (Dinerstein 2003). Protected and remaining natural areas rapidly decline as human populations occupy habitat landscapes and impact on ecological processes (Theobald et al. 2000, 2005; Acharya 2018). This negative ecological impact trend is often seen in developing countries where urbanisation and human settlement growth occurs (Langpap & Wu 2008; Acharya et al. 2016; Allendorf & Gunung 2016; Pálinkás 2018). Reducing human-induced adult mortality (e.g., hunting or habitat reduction) is a critical component to conservation and recovery (Distefano 2015; Pálinkás 2018).

Due to their longevity, slow reproductive rate, many animals will suffer continued population decline if excessive hunting, poaching or other forms of impact are not brought under control (Dinerstein 2003, 2011). Wherever possible male Javan rhinos should be monitored, particularly older males who may still hold dominance, however, may be past reproductive potency (e.g., low sperm count). I suspect older, larger, and more experienced males may be dominating and guarding reproductive age females and excluding younger potentially more sexually potent males from female access. Male guarding has been recorded in the congeneric greater one-horned rhino (Dinerstein 2003, 2011). Future translocations could be trialled using older, past their reproductive prime males.

There is a need for active management of Javan rhino to keep population densities lower and at more productive levels. For female rhino, the age at first reproduction can be an impediment given it takes time for a population to rebound and respond. For example, it is estimated the congeneric greater one-horned rhino female's age at first breeding is 7 to 7.5 years, presumably Javan's have similar age at first breeding results (Dinerstein 2003). With low numbers only a few Javan females may be reproductively active at any given time. I suspect, Javan rhino longevity as in other rhino species may compensate for the slower population recovery time, or at minimum reduce the disadvantage when compared to the rebounding ability of many small mammals. The current lack of accurate knowledge of Javan rhino age at first breeding and interbirth interval is a significant data gap worthy of investigation.

7.3 Contributions of this thesis to the conservation of Javan rhino

This thesis identified local community maintained only a basic awareness of Ujung Kulon National Park's boundaries, rules, and regulations, and held only limited understanding of the conservation effort in relation to Javan rhino and its threats. Authorities have responded to this issue and now have community liaison staff working with and informing local community. This work has already enabled national park managers and conservation planners of local community awareness and understanding of current conservation activity and assisted in identifying future risks e.g. human population growth and to include community considerations regarding possible reintroductions of rhinos into former historic ranges (Andrade & Rhodes 2012; Aryal et al 2017; Acharya 2018). The study on understanding frontline staff insights into the outcomes of past conservation actions and required future actions identified frontline field staff can provide real assessment of current conservation approaches and threats. For example, frontline staff acknowledged the ongoing threat of disease transfer from domestic stock to rhino.

I provide recommendations to reduce this risk, including instigation of an annual domestic stock vaccination program across all 19 villages in the Ujung Kulon precinct. Supporting this action, undertake regular soil and faecal analyses to identify the presence, location, and type of pathogenic agents both within local villages and the National Park and develop an emergency plan in the event of a disease outbreak. Additionally, an education and awareness program be instigated to highlight the risks and benefits to both domestic animals and local wildlife of such an initiative. As a biosecurity measure, a stock fence be built with gates across the narrow isthmus area (1.5 km wide) separating the peninsula from the eastern Gunung Honje area of the park which can be closed off in the event of a disease outbreak.

This fence would at least contain any disease outbreak from infiltrating the main peninsula rhino population. Outside of a disease outbreak the fence would remain open to allow natural movement of animals. By surveying frontline staff, I identified multiple challenges remain for conservation inherent to the survival of the small persisting rhino population. These included ongoing anthropogenic threats and risks, ranging from habitat encroachment from human population growth, local development pressure to disease impacts on rhino from domestic stock. This work has highlighted that whilst a conservation program can be viewed as effective, the value of frontline staff input into conservation management is an asset, offering insight that may reduce future risk impacts and improve conservation objectives.

The clearance of arenga palm is enhancing rhino habitat and has value for rhino management as a tool and option to increase access and probability of connecting isolated rhinos to breeding opportunities and importantly, improving the quality of habitat in rhino home ranges. The involvement of local community who are employed to manually clear arenga palm not only has an immediate effect on the landscape, but it also importantly engages community into the rhino conservation effort.

My research has determined the key characteristics of water and mud wallows through the development of a baseline database of 35 wallows, which will be a valuable guide for any future translocations into new or former historic ranges. I have expanded our knowledge and acknowledge the importance of wallows as key habitat features not only for thermoregulation function, but also as sites of interaction and communication. I have identified and categorised eight Javan rhino behavioural patterns and 11 sub-behavioural pattern categories that occur at wallow sites significantly increasing our knowledge of the species behavioural repertoire.

In the little-known area of Javan rhino social interaction and behaviour I have increased our knowledge by identifying and categorising 11 behavioural patterns, and these were related to their daily activities. Additionally, within each behavioural pattern, 11 sub-categories of behaviour were identified. This includes identifying a new vocal descriptor, taking our total number of identified vocalisations to eight. We now know the Javan rhino vocal frequency band width range varies between 100 Hz - 12 kHz. My research has shown that camera trap video data can be used to increase understanding of Javan rhino ecology and behaviour that can help inform conservation management decisions.

7.4 Limitations, and future research

The isolation of the only extant Javan rhino population makes it a difficult species to study (Dinerstein 2011). Camera trapping is an emerging remote sensing tool used to study wildlife, especially for species that are endangered or difficult to observe (Bernard et al. 2013; Mohd-Azlan & Engkamat 2013). The advent of camera trap technology improves individual recognition, and captures behaviour, using Griffith's (1993) identification criteria, (mark-recapture) which has been verified as an effective ID criterion, and the addition of date and time capture provided by camera imagery. This technology will assist in identifying the individual animals, activity patterns (date/time of day), visitation frequency (day/month) and behaviour in wallows and in other landscape contexts. This photo identification technique has been found to be a reliable censusing methodology (Hiby & Lovell 1993; Haryono et al. 2015). Recognition and understanding of the information that can be obtained by recordings of Javan rhino calls and videos showing a range of other behaviours is critical and is amplified when the population is so low. Future research in this area should focus on expanding the database of recordings and increase our understanding of the function of described vocals and any vocals yet to be described. The recorded calls highlight the importance of the knowledge gap regarding Javan rhino communication and presents fertile ground to build further understanding of Javan rhino ecology and social dynamics. Early studies by Ammann (1985) and Schenkel & Schenkel-Hulliger (1969a, 1969b) described several calls not recorded in this study, however both authors were unclear which sex produced the call.

These calls including 'neigh,' a 'loud blowing whistle', and 'shriek', a possible response to a threat. Therefore, it is reasonable to assume, the Javan rhino call vocabulary can be expanded with further research and investigation, particularly in the still understudied area of Javan rhino courtship and reproduction behaviour. The ongoing management challenges associated with the protection and conservation of endangered wildlife in the modern world remains one of humanities greatest dilemmas (Andrade & Rhodes 2012; Aryal et al 2017).

The composite risks of natural disasters, human population growth, land encroachment, illegal poaching, and lack of or reductions in the amount and quality of habitat remain some of many challenges both conservation managers and endangered wildlife face (Ranjan 2018). The Javan rhino, despite significant conservation effort and intervention over the past 50 years, remains one of the world's rarest and most critically endangered species (IUCN 2016). The need for a second population of Javan rhino remains a critical requirement and the current population would benefit from active biological management to keep the population at a lower level, maximise growth, reduce the constraints of environmental factors and high densities (Jooste & Ferreira 2018). Translocation of a small group of Javan rhino to a safe and suitable site remains a concern (Gunawan et al. 2012). Although not without risk, I believe Sumatra's Way Kambas and Bukit Barisan Selatan National Parks are prime sites for translocated animals, especially given rhino protection units are already in place and active in these areas to monitor and protect. The opportunity to radio-collar translocated animals is enticing given this has never been done before on this species. Reducing the impacts of arenga palm through control efforts has rapid and immediate habitat benefit and I have recorded how rapidly rhino respond to the disturbance regime and successional habitat response of a cleared arenga site.

An escalation of arenga palm clearing using local community labour particularly in the Ujung Kulon peninsula core habitat area would benefit rhinos through increased available habitat and foraging opportunity. The integration of landscape approaches to broaden the area and scope of Ujung Kulon through practical village planning to establish buffer zones, and where appropriate begin identifying habitat corridors where rhino can move or be attracted to. Core habitat areas remain critical and may need additional protection as roads, infrastructure and access to the Ujung Kulon peninsula becomes easier, and the human population grows along with associated risks. Ecotourism as an alternative livelihood should be encouraged particularly if buffer zones are created. Eco-lodges could be set up in these areas with strict controls on access to the park. There are many good examples of where local communities have benefited economically from ecotourism in buffer zone areas, creating greater awareness and respect for the core areas of national parks (e.g., Chitwan National Park, Nepal) (Dinerstein 2003; Aryal et al 2017). Supporting this approach would be an ongoing education and awareness program in local communities and to visitors of Javan rhino ecology and the broader conservation issues that affect its ongoing existence. I remain optimistic this remarkable animal can survive and continue to increase in numbers well into the future. The world deserves to see this animal, and hopefully animals will eventually be successfully relocated into suitable habitats in Sumatra and other parts of Eastern Asia and the species will once again thrive and persist.

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Appendix A - Chapter 2

Figure A.1 Local community questionnaire

RESEARCHER NAME: Steve Wilson PHD student - University of Queensland		
VILLAGE LEADER NAME:		
VILLAGE NAME:		
INTERVIEW DATE:	**TIME:**	**TIME FINISHED:**
INTERVIEWER:		
INTERVIEW LANGUAGE:		**INTERPRETER NAME:**

GENERAL			
Q1	G1	What is the current village population size?	
Q2	G2	What was the village population size 5 years ago?	
Q3	G3	How long have you lived in this village?	
Q4	G4	How long have you been village leader?	
NOTES:			

PEOPLE'S OPINION ON RHINO CONSERVATION			
Q5	P1	How important is protecting *Badak Jawa* to your community and local people?	1 / 2 / 3 / 4 / 5 Rank: 1. don't know, 2. not important, 3. some importance, 4. important, 5. very important
Q6	P2	If yes, why?	
Q7	P3	How important is protecting Ujung Kulon NP to your community and local people?	1 / 2 / 3 / 4 / 5 Rank: 1. don't know, 2. not important, 3. some importance, 4. important, 5. very important
Q8	P4	If yes, why?	
Q9	P5	Has your community or any local people been involved in *Badak Jawa* conservation efforts to date?	
Q10	P6	If yes, what activities?	
Q11	P7	If no, do you think they would like to?	
Q12	P8	How interested are your young people in *Badak Jawa* conservation?	1 / 2 / 3 / 4 / 5 Rank: 1. don't know, 2. not interested, 3. some interest, 4. interested, 5. very interested

Q13	P9	If yes, why?	
Q14	P10	How interested are your older people in *Badak Jawa* conservation?	1 | 2 | 3 | 4 | 5 Rank: 1. don't know, 2. not interested, 3. some interest, 4. interested, 5. very interested
Q15	P11	If yes, why?	
Q16	P12	Do you think community living close to the park have more interest in national park operations, including rhino conservation than those living away from the park?	1 | 2 | 3 | 4 | 5 Rank: 1. don't know, 2. not interested, 3. some interest, 4. interested, 5. very interested
Q17	P13	If yes, why?	
NOTES:			
		KNOWLEDGE	
Q18	K1	Do your community and local people have knowledge about *Badak Jawa* ecology and behaviour	1 | 2 | 3 | 4 | 5 Rank: 1. don't know, 2. no knowledge, 3. some knowledge, 4. good knowledge, 5. very good knowledge

Q19	K2	Do your community and local people know how many *Badak Jawa* there are?	
Q20	K3	How do local community find out what's happening re *Badak Jawa* and Ujung Kulon NP conservation activities?	I.e. newsprint media, social media, verbal (word of mouth), radio, meetings (NP info sessions), any others?
Q21	K4	Do you have a suggestion on how authorities could best inform community of *Badak Jawa* and Ujung Kulon NP conservation activities?	
Q22	K5	Do local community know and understand the Ujung Kulon NP regulations?	1 | 2 | 3 | 4 | 5 Rank: 1. don't know, 2. no knowledge, 3. some knowledge, 4. good knowledge, to 5. very good knowledge
Q23	K6	Do local community know and understand where the Ujung Kulon NP boundaries are?	1 | 2 | 3 | 4 | 5 Rank: 1. no knowledge, 2. don't know, 3. some knowledge, 4. good knowledge, 5. very good knowledge
Q24	K7	Are you aware the fact that the authorities have set up a new *Badak Jawa* conservation area in the eastern section of Gunung Honje, including building the new fence?	1 | 2 | 3 | 4 | 5 Rank: 1. don't know, 2. no knowledge, 3. some knowledge, 4. good knowledge, 5. very good knowledge

Q25	K8	Are you aware of the invasive Arenga palm or Langkap?	1 / 2 / 3 / 4 / 5 Rank: 1. don't know, 2. no knowledge, 3. some knowledge, 4. good knowledge, 5. very good knowledge
Q26	K9	If yes, what do you know about it?	
NOTES:			
ETHICS			
Q27	E1	How culturally important is *Badak Jawa* to local people?	1 / 2 / 3 / 4 / 5 Rank: 1. don't know, 2. not important, 3. some importance, 4. important, 5. very important
Q28	E2	How culturally important is Ujung Kulon NP to local people?	1 / 2 / 3 / 4 / 5 Rank: 1. don't know, 2. not important, 3. some importance, 4. important, 5. very important
Q29	E3	*Badak Jawa* is threatened with extinction, how much do community and local people want to protect or think it's important to protect *Badak Jawa*?	1 / 2 / 3 / 4 / 5 Rank: 1. don't know, 2. not important, 3. some importance, 4. important, 5. very important

Q30	E4	How important is having *Badak Jawa* around so your grandchildren can learn about them?	1 | 2 | 3 | 4 | 5 Rank: 1. don't know, 2. not important, 3. some importance, 4. important, 5. very important
NOTES:			
RISKS			
Q31	R1	Is the growing human population around Gunung Honje and West Java a risk to Ujung Kulon NP, its landscape, and wildlife, including *Badak Jawa*?	1 | 2 | 3 | 4 | 5 Rank: 1. don't know, 2. no risk, 3. some risk, 4. high risk, 5. very high risk
Q32	R2	If roads, infrastructure, and transport options to Ujung Kulon NP were improved do you see this as a risk to the national park and its wildlife?	1 | 2 | 3 | 4 | 5 Rank: 1. don't know, 2. no risk, 3. some risk, 4. high risk, 5. very high risk
Q33	R3	If yes, what do you think the risks are to the national park and wildlife, including *Badak Jawa*?	
NOTES:			
SPATIAL, TEMPORAL, AND SOCIAL CONTEXT			

Q34	S1	Do you think the local community benefits something from having *Badak Jawa* nearby?	1 | 2 | 3 | 4 | 5 Rank: 1. don't know, 2. no benefit, 3. some benefit, 4. good benefit, 5. high benefit
Q35	S2	If yes, what benefit?	
Q36	S3	Are there any commercial opportunities for communities and local people from having the national park and *Badak Jawa* so close?	1 | 2 | 3 | 4 | 5 Rank: 1. don't know, 2. no opportunity, 3. possible opportunity, 4. good opportunity, 5. very good opportunity
Q37	S4	If there are opportunities what are they?	
NOTES:			
TRUST			
Q38	T1	How important is the relationship between local community and the Ujung Kulon National Park Authority?	1 | 2 | 3 | 4 | 5 Rank: 1. don't know, 2. not important, 3. some importance, 4. important, 5 very important
Q39	T2	How good is the relationship?	1 | 2 | 3 | 4 | 5

			Rank: 1. don’t know, 2. not good, 3. seems good, 4. good, 5. very good
Q40	T3	Would you like the community to contribute or be involved in conservation management planning in relation to the national park and *Badak Jawa* management?	
Q41	T4	If yes, why?	
Q42	T5	Would it help if the Ujung Kulon NP authorities communicated more often with local community on a regular basis?	
NOTES:			
Terima kasih banyak for your participation and contribution before we finish is there anything else you would like to add regarding these questions?			

Note:

"*This study adheres to the Guidelines of the ethical review process of The University of Queensland and the National Statement on Ethical Conduct in Human Research. Whilst you are free to discuss your participation in this study with project staff (contactable on 0438 394 353), if you would like to speak to an officer of the University not involved in the study, you may contact the Ethics Coordinator on 61 7 3365 3924.”*

Table A.3 Responses and results (Mean/SD to Likert scale) and χ^2 tests of independence to People's opinion on rhino conservation (n=76).

Variable	Mean	SD	Min	Max	Yes	No*	χ^2	*P*- value
How important is protecting Javan rhino to your community and local people? (L)	4.171	1.508	2	5	68	8	47.368	5.882 > 0.05
If yes, why?	_	_	_	_	68	8	47.368	5.882 > 0.05
How important is protecting UKNP to your community and local people? (L)	4.381	0.923	2	5	74	2	68.210	1.469 > 0.05
If yes, why?	_	_	_	_	74	2	68.210	1.469 > 0.05
Has your community or any local people been involved in Javan rhino conservation efforts to date?	_	_	_	_	53	23	11.842	0.000 < 0.05
If yes, what activities?	_	_	_	_	56	20	17.052	3.635 > 0.05
How interested are young people in Javan rhino conservation? (L)	2.776	2.114	2	5	51	25	8.894	0.002 < 0.05
If yes, why?	_	_	_	_	46	30	3.368	0.066 > 0.05
How interested are your older people in Javan rhino conservation? (L)	2.921	2.177	2	5	50	26	7.578	0.005 < 0.05
If yes, why?	_	_	_	_	49	27	6.368	0.116 > 0.05
Do you think community living close to the park have more interest in NP operations, including rhino conservation than those living away from the park? (L)	3.684	1.682	2	5	65	11	38.368	5.857 > 0.05
If yes, why?					65	11	38.368	5.857 > 0.05

L = Likert scale responses (2-5). Ranked from 1 = 0 (no or don't know) 2 = (not important), 3 = (some importance), 4 = (important) to 5 = (very important), *Includes "don't know", *df* = 1 for χ^2 test. Results were considered significant with *P* values < 0.05.

Table A.4 Responses and results (Mean/SD to Likert scale) and χ^2 tests of independence to Stankey and Schindler's (2005) theme of knowledge (n=76).

Variable	Mean	SD	Min	Max	Yes	No*	χ^2	*P* - value
Do your community and local people have knowledge about Javan rhino ecology and behaviour? (L)	0.486	1.205	2	5	11	65	38.368	5.857 > 0.05
Do your community and local people know how many Javan rhino there are?	_	_	_	_	24	52	10.315	0.001 < 0.05
How do local people find out what's happening re Javan rhino and Ujung Kulon NP activities?	_	_	_	_	73	3	64.473	9.783 > 0.05
Do you have a suggestion on how authorities could best inform community of Javan rhino and Ujung Kulon NP activities?	_	_	_	_	29	47	4.263	0.038 < 0.05
Do local people know and understand the Ujung Kulon NP regulations? (L)	1.592	1.782	2	5	35	41	0.473	0.491 > 0.05
Do local people know and understand where the Ujung Kulon NP boundaries are? (L)	1.539	1.828	2	5	33	43	1.315	0.251 > 0.05
Are you aware the authorities have set up a new Javan rhino conservation area in the astern Gunung Honje, including building the new fence? (L)	1	1.704	2	5	21	55	15.210	9.616 > 0.05
Are you aware of the invasive Arenga palm or Langkap? (L)	0.789	1.257	2	5	14	62	30.315	3.671 > 0.05
If yes, what do you know about it?	_	_	_	_	9	67	44.263	2.870 > 0.05

L = Likert scale responses (2-5). Responses ranked from 1 = 0 (no or don't know) 2 = (not important), 3 = (some importance), 4 = (important) to 5 = (very important), *Includes "don't know", *df* = 1 for χ^2 test. Results were considered significant with *P* values < 0.05.

Table A.5 Responses and results (Mean/Standard deviation to Likert scale) and χ^2 tests of independence to Stankey and Schindler's (2005) theme of ethics (n=76).

Variable	Mean	SD	Min	Max	Yes	No*	χ^2	*P* - value
How culturally important is Javan rhino to local people? (L)	4.105	1.342	2	5	69	7	50.578	1.144 > 0.05
How culturally important is Ujung Kulon NP to local people? (L)	4.342	0.959	2	5	74	2	68.210	1.469 > 0.05
Javan rhino is threatened with extinction, how much do community and local people want to protect or think it's important to protect Javan rhino? (L)	4.434	1.074	2	5	73	3	64.478	9.783 > 0.05
How important is having Javan rhino around so your grandchildren can learn about them? (L)	4.631	0.727	2	5	75	1	72.052	2.095 > 0.05

L = Likert scale responses (2-5). Responses ranked from 1 = 0 (no or don't know) 2 = (not important), 3 = (some importance), 4 = (important) to 5 = (very important), *Includes "don't know", *df* = 1 for χ^2 test. Results were considered significant with *P* values < 0.05.

Table A.6 Reponses and results (Mean/Standard deviation to Likert scale) and χ^2 tests of independence to Stankey and Schindler's (2005) theme of risk (n=76).

Variable	Mean	SD	Min	Max	Yes	No*	χ^2	*P - value*
Is the growing human population around Gunung Honje and West Java a risk to Ujung Kulon NP, its landscape and wildlife, including Javan rhino? (L)	2.697	1.743	2	5	57	19	19	1.307 > 0.05
If roads, infrastructure, and transport options were improved do you see this as a risk to the NP and its wildlife? (L)	2.460	1.726	2	5	56	20	17.052	3.635 > 0.05
If yes, what do you think the risks are to the NP and wildlife, including Javan rhino?	_	_	_	_	45	31	2.578	0.108 > 0.05

L = Likert scale responses (2-5). Responses ranked from 1 = 0 (no or don't know) 2 = (not important), 3 = (some importance), 4 = (important) to 5 = (very important), *Includes "don't know", *df* = 1 for χ^2 test. Results were considered significant with *P* values < 0.05.

Table A.7 Responses and results (Mean/Standard deviation to Likert scale) and χ^2 tests of independence to Stankey and Schindler's (2005) theme of spatial, temporal, and social context (n=76).

Variable	Mean	SD	Min	Max	Yes	No*	χ^2	*P* - value
Do you think the local community benefits from having Javan rhino nearby? (L)	3.552	1.603	2	5	65	11	38.368	5.857 > 0.05
If yes, what benefit?	_	_	_	_	63	13	32.894	9.728 > 0.05
Are there any commercial opportunities for communities and local people from having the national park and Javan rhino so close? (L)	3.552	1.509	2	5	66	10	41.263	1.330 > 0.05
If there are opportunities what are they?	_	_	_	_	65	11	38.368	5.857 > 0.05

L = Likert scale responses (2-5). Responses ranked from 1 = 0 (no or don't know) 2 = (not important), 3 = (some importance), 4 = (important) to 5 = (very important), *Includes "don't know", *df* = 1 for χ^2 test. Results were considered significant with *P* values < 0.05.

Table A.8 Responses and results (Mean/Standard deviation to Likert scale) and χ^2 tests of independence to Stankey and Schindler's (2005) theme of trust (n=76).

Variable	Mean	SD	Min	Max	Yes	No*	χ^2	*P - value*
How important is the relationship between local community and the Ujung Kulon NP Authority? (L)	4.236	1.011	2	5	74	2	68.210	1.469 > 0.05
How good is the relationship? (L)	3.684	1.434	2	5	69	7	50.578	1.144 > 0.05
Would you like the community to contribute or be involved in conservation management planning in relation to the NP and Javan rhino management?	_	_	_	_	69	7	50.578	1.144 > 0.05
If yes, why?	_	_	_	_	69	7	50.578	1.144 > 0.05

L = Likert scale responses (2-5). Responses ranked from 1 = 0 (no or don’t know) 2 = (not important), 3 = (some importance), 4 = (important) to 5 = (very important), *Includes “don’t know”, *df* = 1 for χ^2 test. Results were considered significant with *P* values < 0.05.

Appendix B - Chapter 3

Figure B.1 Rhino protection unit and national park ranger questionnaire

RESEARCHER NAME: Steve Wilson PHD student - University of Queensland		
RHINO PROTECTION or RHINO MONITORING UNIT MEMBER:		
UJUNG KULON NP RANGER NAME:		
INTERVIEW DATE:	**START TIME:**	**TIME FINISHED:**
INTERVIEWER:		
INTERVIEW LANGUAGE: Bahasa		**INTERPRETER NAME:**

Q1	How long have you been a member of the RPU team?	
Q2	Do you come from a local village?	
Q3	If no where have you come from?	
Q4	If yes which village?	
Q5	If yes does this assist with your duties?	
Q6	What is your current RPU patrol cycle?	

Q7	How is the patrol destination determined?	
Q8	How many staff goes on patrol?	
Q9	How long do you go out for?	
Q10	What attracted you to becoming part of the UKNP/RPU team?	
Q11	How were you recruited?	
Q12	What RPU training you have completed?	
Q13	How has it helped you on the job?	
Q14	Do you get opportunities to learn new skills?	
Q15	What are the opportunities for promotion?	
Q16	What are the common issues you come across in your duties in UKNP?	

Q17	In terms of poaching activities what do you find is the most common issue you come across?	
Q18	Do you ever see *Badak Jawa?*	
Q19	If yes, in what situation?	
Q20	What was the animal doing?	
Q21	Do you ever come across other wildlife?	
Q22	If yes which species?	
Q23	How does local community feel about your RPU work?	1 | 2 | 3 | 4 | 5 Rank: 1. don't know, 2. not important, 3. some importance, 4. important, 5. very important
Q24	Do you think the local community understands how rare and threatened *Badak Jawa* is?	1 | 2 | 3 | 4 | 5 Rank: 1. don't know, 2. no knowledge, 3. some knowledge, 4. good knowledge, 5. very good knowledge

Q25	Do you think the local community have knowledge of *Badak Jawa* ecology and behaviour?	1 | 2 | 3 | 4 | 5 Rank: 1. don't know, 2. no knowledge, 3. some knowledge, 4. good knowledge, 5. very good knowledge
Q26	Does the community understand why the new fence in Gunung Honje has been erected and its importance to *Badak Jawa* conservation?	1 | 2 | 3 | 4 | 5 Rank: 1. don't know, 2. not important, 3. some importance, 4. important, 5. very important
Q27	Will the fence make a difference to *Badak Jawa* conservation?	1 | 2 | 3 | 4 | 5 Rank: 1. don't know, 2. no difference, 3. some difference, 4. good difference, 5. significant difference
Q28	If yes how?	
Q29	Given no rhinos have been poached since 1994, why do you think the RPU program has been successful?	Example: RPU Patrolling, rhino difficult to find, good community leadership and support
Q30	Is there anything you believe the RPU units could be doing they are not doing now?	

Q31	What do you see as the biggest threats to *Badak Jawa* moving forward?	
Q32	Local community has been engaged in *Badak Jawa* conservation work such as Langkap control, has this been a positive exercise?	1 | 2 | 3 | 4 | 5 Rank: 1. don't know, 2. not important, 3. some importance, 4. important, 5. very important
Q33	If yes, why?	
Q34	Does community ever assist you with intelligence gathering re poaching or negative activity in the park?	
Q35	What are your thoughts on future opportunities for the local community in Badak Jawa conservation?	
Q36	Are local communities reliant on Ujung Kulon NP in any way for their livelihoods?	
Q37	If yes, in what way?	
Q38	Is there any local community in particular that uses or impacts on the park more than others?	

Q39	If yes, why?	
Q40	Is the growing human population around Gunung Honje and broader West Java a risk to Ujung Kulon NP, its wildlife, including *Badak Jawa?*	1 | 2 | 3 | 4 | 5 Rank: 1. don't know, 2. no risk, 3. some risk, 4. high risk, 5. very high risk
Q41	If roads, infrastructure, and transport options to Ujung Kulon NP were improved do you see this as a risk to the national park and its wildlife?	1 | 2 | 3 | 4 | 5 Rank: 1. don't know, 2. no risk, 3. some risk, 4. high risk, 5. very high risk
Q42	If yes, what do you think the risks are?	
NOTES		
Terima kasih banyak for your participation and contribution before we finish is there anything else you would like to add regarding these questions?		

Note: "*This study adheres to the Guidelines of the ethical review process of The University of Queensland and the National Statement on Ethical Conduct in Human Research. Whilst you are free to discuss your participation in this study with project staff (contactable on 61 0438 394 353), if you would like to speak to an officer of the University not involved in the study, you may contact the Ethics Coordinator on 61 7 3365 3924.*"

Table B.1 Responses to eight Likert (2-5) questions examining differences in their perceptions of local community views on conservation for all frontline (both rhino protection and national park rangers), individual rhino protection unity and NP staff. Chi-squared (χ^2) tests for independence (n = 36) is shown comparing the groups.

Q23 How does local community feel about your work?

- Frontline staff (mean 4.194; SD ± 0.88, χ^2 tests > 5.16, P = 0.075 > 0.05, df =2)
- Rhino Protection Unit staff (mean 4.63; SD ± 0.65, χ^2 tests > 15.70, P = 0.000 < 0.05, df = 2)
- National Park staff (mean 3.5; SD ± 0.75, χ^2 tests > 6.23, P = 0.044 < 0.05, df = 2)

Q24 Do you think the local community understands how rare and threatened Javan rhino are?

- Frontline staff (mean 4.027; SD ± 0.90, χ^2 tests > 10.44, P = 0.151 > 0.05, df = 3)
- Rhino Protection Unit staff (mean 4.27; SD ± 0.82, χ^2 tests > 2.83, P = 0.418 > 0.05, df = 2)
- NP (mean 3.71; SD ± 0.91, χ^2 tests > 3.14, P = 0.370 > 0.05, df = 3)

Q25 Do you think local community have knowledge of Javan rhino ecology and behaviour?

- Frontline staff (mean 2.97; SD ± 0.55, χ^2 tests > 21.16, P = 2.533 >0.05, df = 2)
- Rhino Protection Unit staff (mean 3.13; SD ± 0.46, χ^2 tests > 14.38, P = 0.000 < 0.05, df = 2)
- National Park staff (mean 2.71; SD ± 0.61, χ^2 tests > 5.33, P = 0.069 > 0.05, df = 2)

Q26 Does community understand why the new fence in Gunung Honje has been erected and its importance to Javan rhino conservation?

- Frontline staff (mean 3.111; SD ± 0.97, χ^2 tests > 21.55, P = 8.070 >0.05, df = 3)
- Rhino Protection Unit staff (mean 3.59; SD ± 1.00, χ^2 tests > 11.59, P = 0.008 < 0.05, df = 2)
- National Park staff (mean 2.57; SD ± 0.64, χ^2 tests > 4.49, P = 0.212 > 0.05, df = 2)

Q27 Will the fence make a difference to Javan rhino conservation?

- Frontline staff (mean 4.222; SD ± 0.92, χ^2 tests > 18.66, *P* = 0.000 >0.05, *df* = 3)
- Rhino Protection Unit staff (mean 4.68; SD ± 0.56, χ^2 tests > 16.53, *P* = 0.000 < 0.05, *df* = 2)
- National Park staff (mean 3.5; SD ± 0.94, χ^2 tests > 8.18, *P* = 0.042 < 0.05, *df* = 3).

Q32 Community has been engaged in Javan rhino conservation work, such as arenga palm control, has this been a positive exercise?

- Frontline staff (mean 2.97; SD ± 0.87, χ^2 tests > 10.88, *P* = 0.012 > 0.05, *df* = 3)
- Rhino Protection Unit staff (mean 3.36; SD ± 0.65, χ^2 tests > 18, *P* = 0.000 < 0.05,
- *df* = 3)
- National Park staff (mean 2.35; SD ± 0.84, χ^2 tests > 7.10, *P* = 0.068 > 0.05, *df* = 3)

Q40 Is the growing human population around Gunung Honje and broader west Java a risk to UKNP, its wildlife, including Javan rhino?

- Frontline staff (mean 4.19; SD ± 1.06, χ^2 tests > 31.77, *P* = 5.829 > 0.05, *df* = 3)
- Rhino Protection Unit staff (mean 4.09; SD ± 1.15, χ^2 tests > 4.46, *P* = 0.040 < 0.05, *df* = 2)
- National Park staff (mean 4.35; SD ± 0.92, χ^2 tests > 7.10, *P* = 0.068 > 0.05, *df* = 2)

Q41 If roads and infrastructure and transport options to UKNP were improved, do you see this as a risk to the NP and its wildlife?

- Frontline staff (mean 2.55; SD ± 0.77, χ^2 tests > 27.11, *P* = 5.579 > 0.05, *df* = 3)
- Rhino Protection Unit staff (mean 2.36; SD ± 0.49, χ^2 tests > 1.63, *P* = 0.651 > 0.05, *df* = 1)
- National Park staff (mean 2.85; SD ± 1.02, χ^2 tests > 2.32, *P* = 0.508 > 0.05, *df* = 2)

Note: Statistical results were considered significant with *P* values < 0.05.

Appendix C - Chapter 4

Table C.1

Average annual climate data (temperature/rainfall) for Ujung Kulon National Park region

	January	February	March	April	May	June	July	August	September	October	November	December
Average temperature (°C)	26.5	26.1	26.4	26.8	26.9	26.8	26.4	26.1	26.2	26.6	27	26.9
Minimum temperature (°C)	22.4	22.3	22.2	22.5	22.4	22.2	21.7	21.4	21.5	21.9	22.2	22.4
Maximum Temperature (°C)	30.7	29.9	30.6	31.1	31.5	31.5	31.1	30.9	31	31.3	31.8	31.5
Rainfall (mm)	312	310	270	299	248	157	110	104	100	108	170	239

Note: data table is adapted from Climate Data (2018) http://e.climate-data.org/location/573872/

Table C.2

Records (n=32) of fresh rhino sign and visitation to cleared arenga palm sites 20/09/2016 - 19/09/2018

Rhino sign	Date	Latitude	Longitude	Notes
Prints and feeding sign	20/09/2016	S° 06' 49.555"	E° 105' 28.766"	tracks leading to forest and clear prints found, sapling *Dillenia obovata* with leaves stripped off
Prints, wallow and feeding sign	20/09/2016	S° 06' 49.301"	E° 105' 28.796"	tracks/prints and fresh mud on trees and vines (came from nearby wallow to feed), sapling *Dillenia aurea* knocked over and leaves stripped off
Prints and tracks	20/09/2016	S° 06' 50.4.54"	E° 105' 30.11.4"	tracks leading to forest and clear prints found
Prints, urine and feeding sign	20/09/2016	S° 06' 50.42.2"	E° 105' 30.12.7"	tracks leading to forest, clear prints and spray urination on vegetation, shrub *Amomum coccineum* with large leaves stripped off
Prints and feeding sig	21/09/2016	S° 06' 49.745"	E° 105' 28.409"	tracks and large sapling *Leea sambucina* knocked over and leaves stripped off
Dung and tracks	21/09/2016	S° 06' 49.707"	E° 105' 28.354"	dung pile found in centre of plot and tracks to forest
Prints and feeding sign	21/09/2016	S° 06' 50.42.2"	E° 105' 30.12.7"	tracks and sapling *Spondias pinnata* knocked over and leaves stripped off
Prints and wallow sign	22/04/2017	S° 06' 51.08.3"	E° 105' 29.54.5"	tracks/prints and fresh mud on trees and vines (came from nearby wallow)

Prints and tracks	22/04/2017	S° 06' 50.44.3"	E° 105' 30.13.6"	tracks leading to forest and clear prints found
Prints and feeding sign	22/04/2017	S° 06' 51.14.3"	E° 105' 29.34.8"	clear prints and saplings *Leea sambucina* and *Ficus montana* knocked over and leaves stripped
Prints and feeding sign	23/04/2017	S° 06' 50.42.2"	E° 105' 30.12.7"	Clear prints found leading to forest and shrub *Cladium bicolor* with large leaves stripped off
Prints, urine and feeding sign	23/04/2017	S° 06' 50.48.9"	E° 105' 29.41.8"	tracks leading to forest and clear prints found, and spray urination on vegetation, *Amomum coccineum* with large leaves stripped off
Prints and feeding sign	23/04/2017	S° 06' 50.53.4"	E° 105' 29.38.2"	tracks and large sapling *Leea sambucina* knocked over and leaves stripped off
Prints and feeding sign	24/04/2017	S° 06' 50.59.1"	E° 105' 29.46.3"	tracks and sapling *Dillenia aurea* knocked over and leaves stripped off and spray urination on vegetation
Prints and feeding sign	24/04/2017	S° 06' 50.56.2"	E° 105' 29.47.3"	tracks and large sapling *Baccaurea javanica* knocked over and leaves stripped off
Prints and feeding sign	18/09/2017	S° 06' 50.52.8"	E° 105' 29.47.0"	tracks and sapling *Spondias pinnata* knocked over and leaves stripped off
Prints and feeding sign	18/09/2017	S° 06' 50.52.4"	E° 105' 29.53.1"	tracks and shrub *Apama tomentosa* knocked over and leaves stripped off
Prints and feeding sign	18/09/2017	S° 06' 50.00.8"	E° 105' 29.47.4"	tracks and shrub *Oxymitra cunneformis* knocked over and leaves stripped off

Prints and feeding sign	18/09/2017	S° 06' 51.14.3"	E° 105' 29.34.8"	tracks and sapling *Sumbaviopsis albicans* knocked over and leaves stripped off
Prints and feeding sign	19/09/2017	S° 06' 51.06.0"	E° 105' 29.39.6"	tracks and sapling *Leea sambucina* knocked over and leaves stripped off
Prints and feeding sign	19/09/2017	S° 06' 50.55.6"	E° 105' 29.56.0"	tracks and sapling *Largerstroemia flos-regime* and shrub *Vitex pubescens* knocked over and leaves stripped off
Prints and feeding sign	19/04/2018	S° 06' 50.52.3"	E° 105' 29.55.6"	tracks and large sapling *Baccaurea javanica* knocked over and leaves stripped off
Prints, urine and feeding sign	19/04/2018	S° 06' 50.52.4"	E° 105' 29.53.1"	tracks and sapling *Dillenia aurea* knocked over and leaves stripped off and spray urination on vegetation
Prints, dung, and wallow sign	21/04/2018	S° 06' 51.10.6"	E° 105' 29.45.8"	tracks/prints and fresh mud on trees and vines (came from nearby wallow), small dung pile
Prints and feeding sign	21/04/2018	S° 06' 51.13.4"	E° 105' 29.52.5"	tracks and sapling *Largerstroemia flos-regime* and shrub *Barringtonia gagantostachua* knocked over and leaves stripped off
Prints and feeding sign	22/04/2018	S° 06' 51.16.8"	E° 105' 29.56.8"	tracks and shrub *Oxymitra cunneformis* knocked over and leaves stripped off
Prints and feeding sign	18/09/2018	S° 06' 50.42.8"	E° 105' 30.10.7"	tracks and large sapling *Baccaurea javanica* knocked over and leaves stripped off
Prints and feeding sign	18/09/2018	S° 06' 50.48.7"	E° 105' 29.39.2"	tracks and sapling *Diospyros javanica* and shrub *Vitex pubescens* knocked over and leaves stripped off

Prints and feeding sign	18/09/2018	S° 06' 50.51.3"	E° 105' 29.38.1"	tracks and shrub *Donnax cunnaeformis* knocked over and leaves stripped off
Prints and feeding sign	19/09/2018	S° 06' 50.56.8"	E° 105' 29.40.7"	tracks and shrub *Oxymitra cunneformis* knocked over and leaves stripped off
Prints and feeding sign	19/09/2018	S° 06' 50.53.4"	E° 105' 29.38.2"	tracks and sapling *Spondias pinnata* knocked over and leaves stripped off
Prints and feeding sign	19/09/2018	S° 06' 50.59.4"	E° 105' 29.44.1"	tracks and sapling *Leea sambucina* knocked over and leaves stripped off

Appendix D - Chapter 5

Table D.1 (Note this table is referred to in Chapter 6)

Camera site number (n=32) and no of videos (n=137) recorded at each site (UKNP peninsula)

Site no	Grid no	No videos	Habitat (forest/wallow)
1	31 AR	1	Forest
2	34AQ	18	Wallow
3	27AS	8	Wallow
4	34AP	11	Wallow
5	36AN	6	Forest
6	30AS	7	Forest
7	30AU	1	Forest
8	31AI	2	Forest
9	31AJ	2	Forest
10	31AL	1	Forest
11	36AJ	2	Forest
12	28AK	17	Wallow
13	31AO	2	Wallow
14	35AP	4	Wallow
15	24AM	2	Forest
16	26AO	1	Forest
17	27AK	6	Forest
18	27AN	1	Forest
19	28AJ	3	Forest
20	28AL	1	Forest
21	30AJ	7	Forest
22	25AM	11	Forest
23	32AI	4	Wallow
24	37AH	1	Forest
25	19AN	2	Forest
26	20AN	2	Forest
27	22AM	2	Forest
28	25AK	2	Forest
29	26AK	3	Forest

30	27AM	2	Forest
31	27AP	5	Forest
32	27AR	4	Wallow

Note: Refer Fig. 5.3 for map locations of these sites.

Table D.2 (Note this table is referred to in Chapter 6)

List of characteristics measured from camera trap videos and how they were measured, including categories/ distinctions made if appropriate.

Characteristic measured	How characteristic was measured
Date	Date and time stamp from camera trap video
Month	Date and time stamp from camera trap video
Year	Date and time stamp from camera trap video
Exact time of day	Date and time stamp from camera trap video
Time group	Early morning (EM) = 12:00 am - 6:00 am, Morning (M) = 6:00 am - 12:00 pm, Afternoon (A) = 12:00 pm - 6:00 pm, Evening (E) = 6:00 pm - 12:00 am
Gender (where possible)	External genitalia or presence or absence of a horn (females do not have a prominent horn) (Griffiths 1993)
Age group	Adult, sub-adult, calf - Body size and horn size are indicators of age (Griffiths 1993)
Social structure	Solitary Female and calf Adult male and female Two or more adults or sub-adults
Behaviour	Categories and descriptions of behaviours outlined by Hazarika & Saikia (2010) for the greater-one horned rhino, a closely related species (more extensive than those created by Hariyadi et al. (2010) in preliminary study on Javan rhino)
Site	Grid code, GPS coordinates and matching identifiable features
Location	Forest or Wallow
Habitat type *Estimated from vegetation map	Dense evergreen forest - 95% or more of habitat type in corresponding grid Open evergreen forest - 95% or more of habitat type in corresponding grid Dense to open evergreen forest - Mixture of habitat types with majority of dense forest in corresponding grid Open to dense evergreen forest - Mixture of habitat types with majority of open forest in corresponding grid

Table D3
Comparison of all five rhino species wallowing behaviour and type of wallow used.

Species	Wallow type used	Behaviour	References
Javan rhino *Rhinoceros sondaicus*	Mud and water wallows in forest, also rivers and riverbanks (dug out muddy banks) during dry periods when wallows may dry up	Daily use (up to 6 hrs), year-round wallowing (based on camera trap observations), often rests in shade near coastal areas, benefitting from onshore breezes and cooler temperatures	Schenkel & Schenkel-Hulliger (1969a, 1969b) Hoogerwerf (1970) Ammann (1985) Rahmat (2007) Hariyadi et al. (2010) Groves & Leslie Jr (2011) Dinerstein (2003, 2011) Santosa et al. (2013)
Greater one-horned rhino *Rhinoceros unicornis*	Rivers, also in riverine forest, mud and water wallows, also ox-bow lakes, large water bodies and smaller narrow creeks)	Daily wallowing peaks (up to 8 hrs) during monsoon period (June-September), less frequently during so in dryer hot periods (mid-Feb - mid-June), remains within 2km of water	Laurie (1978, 1982) Laurie et al. (1983) Dinerstein (2003, 2011) Hazarika & Saikia (2010)
Sumatran rhino *Dicerorhinus sumatrensis*	Needs clean mud wallows	Daily use (5-6 hrs) year-round wallowing activity will utilise number of wallows in home range	Groves & Kurt (1972) Van Strien (1985) Ng et al. (2001) Dinerstein (2011)
White rhino *Ceratotherium simum*	Waterholes, mud, and water wallows, will also use sandy areas and dust baths as well	Ability to go without wallowing for several days, also keeps cool by resting in shade or ridge crests utilising cool breezes, may wallow during heat of the day, more active in cloudy conditions	Groves (1972) Owen-Smith (1973, 1975, 1988) Pienaar (1994) Dinerstein (2003, 2011)

Black rhino *Diceros bicornis*	Muddy depressions, pools, will also use sandy areas and dust baths as well	Ability to go without wallowing for several days, also keeps cool by resting in shade or ridge crests utilising cool breezes	Goddard (1967) Joubert & Eloff (1971) Hillman-Smith & Groves (1994) Dinerstein (2003, 2011)

Appendix E - Chapter 6

Table E.1

Vocalisation (call) comparison reported in literature for the five living rhino species.

Species	Call description	References
Black rhino *Diceros bicornis*	mew, roar, snort, aggressive snort, growl, begging call, wonk, mmwonk	Goddard (1967) Frame & Goddard (1970) Hillman-Smith & Groves (1994) Budde & Klump (2003) Dinerstein (2003, 2011)
Greater one-horned rhino *Rhinoceros unicornis*	snort, honk, bleat, squeak-pant, moo-grunt, roar	Laurie (1978, 1982) Laurie et al (1983) Hazarika & Saikia (2010) Dinerstein (2003, 2011)
Javan rhino *Rhinoceros sondaicus*	neigh, bleat, loud blowing whistle, snort, lip vibration, roar	Schenkel & Schenkel-Hulliger (1969a,1969b) Hoogerwerf (1970) Ammann (1985) Groves & Leslie Jr (2011)
Sumatran rhino *Dicerorhinus sumatrensis*	humming, snort, whistle-bray, squeal, squeak, grunt, blow, eep, whale, whistle-blow	Groves & Kurt (1972) Van Strien (1986) Muggenthaler et al. (2003)
White rhino *Ceratotherium simum*	squeal, grunt, snort, pant, whine, threat, puff, snarl, grouch, groan, hoarse, hic, shriek, gruff squeal	Groves (1972) Owen-Smith (1975) Van Gyseghem (1984) Dinerstein (2003, 2011) Cinková (2013) Cinková & Policht (2014)

Table E.2

Home-range sizes reported in literature for the five living rhino species.

Species	Sex	Size	Reference
Black rhino *Diceros*	♀	2.59 - 90.6 km^2	Goddard (1967)
bicornis	♀	12.5 - 47.3 km^2	Kiwia (1989)
	♂	2.59 - 51.8 km^2	Goddard (1967)
	♂	69 km^2	Kiwia (1989)
Greater one-horned	♀	20 km^2	Laurie (1982)
rhino *Rhinoceros*	♂	(2 - 4 km^2 core)	
unicornis		3 - 4 km^2	
	♀	12 - 15 km^2	Groves (1972)
	♂	2 - 8 km^2	Laurie et al. (1983)
Javan rhino	♀ (no calf)	10 km^2	Schenkel & Schenkel-
Rhinoceros	♀ (with calf)	2 - 3 km^2	Hulliger (1969b)
sondaicus	♂	20 km^2	
	♀	2.61 - 8.4 km^2	Ammann (1985)
	♂	12.5 - 26.4 km^2	
	♀	14.20 km^2	Setiwan et al. (2017)
	♂	105.53 km^2	
Sumatran rhino	♀	10 - 15 km^2	Van Strien (1986)
Dicerorhinus	♂	30 km^2	
sumatrensis	♀	2 - 3.5 km^2	Groves & Kurt (1972)
White rhino	♀	9 - 20 km^2	Owen-Smith (1975)
Ceratotherium	♂	97 km^2	van Gyseghem (1984)
simum	♀	0.75 - 2.6 km^{2} *	Owen-Smith (1975)
	♂	30 km^2	Van Gyseghem (1984)
	♀	12 - 15 km^2	Groves (1972)

* Denotes breeding territories