GAJAH

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Journal of the Asian Elephant Specialist Group
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The journal is intended as a medium of communication on issues that concern the management and conservation of Asian elephants both in the wild and in captivity. It is a means by which everyone concerned with the Asian elephant (*Elephas maximus*), whether members of the Asian Elephant Specialist Group or not, can communicate their research results, experiences, ideas and perceptions freely, so that the conservation of Asian elephants can benefit. All articles published in *Gajah* reflect the individual views of the authors and not necessarily that of the editorial board or the Asian Elephant Specialist Group.

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Editorial Note

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Cover

Elephants at Yala National Park, Sri Lanka
Photo by Jennifer Pastorini
(Articles on Sri Lankan elephants on pages 22, 30, 40 and 50)

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Editorial

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Gajah 55 presents one peer-reviewed paper, three research articles and four short communications about Asian elephants. Three articles are from Sri Lanka, two from India and one each from Bangladesh and Cambodia. In News and Briefs you can read a story and learn about the Asian Elephant Range States Meeting.

The **Peer-reviewed Research Article** presents the results of an interview survey conducted by Megan English and G. Silva Collins in a village in Cambodia. It describes the problems people face due to increasing human-elephant conflict.

In **Research Articles** Shorf u A. Chowdhury *et al*. evaluate elephant habitat in south-eastern Bangladesh using satellite imagery. They found that 36% of elephant habitat was lost over the past 25 years. Rathnapala and co-authors report on the treatment of elephant dung to speed up its degradation and composting, which is of relevance to captive management. Prithiviraj Fernando *et al*. present a simple size-age class scale. The individuals to be evaluated are compared with an adult female, using certain anatomical points to assign them to classes.

In **Short Communications** Mihiran Medawala reports on the first twin birth at the Pinnawala Elephant Orphanage in Sri Lanka. The birth and care of the new-born twins in the first few months is described in detail. Biswajeet Panda and Bhaskar Behera followed elephants in northern Odisha, recording the plants they consumed. A table presents the 136 identified plant species. Tharindu Muthukumarana conducted a census of Sri Lanka's captive elephants held by temples or private owners. In 2021 there were 108 elephants kept at 72 different facilities. Madhvee Dhairykar and co-authors collected samples from 30 captive elephants to determine cortisol metabolite levels as well as haematological and biochemical values.

In **News and Briefs** Ivy F. Hussain tells us the heart-breaking story of how the calf 'Mainao' ended up in captivity when its mother became a victim of human-elephant conflict, being electrocuted with an illegal electric fence. Heidi S. Riddle summarises the outcome of the 'Third Asian Elephant Range States Meeting' for us. The meeting was held in Nepal and formulated the 'Katmandu Declaration', which is printed here in full for *Gajah*'s readership. The abstract section gives a glimpse of research findings from 59 studies published last year, all focusing on Asian elephants.

I am grateful to the authors who shared their work with the readers of *Gajah*. The editorial board has helped editing the papers and working with the authors to make them better, which is a time-consuming task. Financial support from Mandai Nature is greatly appreciated, making it possible to also print hard copies and mail them out to the readership all over the world.

2022 also brings some changes in the editorial board. Heidi S. Riddle is resigning after serving 16 years on the board. With this new term she has become the Vice-Chair for the Asian Elephant Specialist Group (AsESG), which means she will keep investing her time for the AsESG. Shermin de Silva also stepped down from the editorial board for the time being. She is starting a new position as an Assistant Professor at the University of British Columbia in Vancouver, from where she of course will continue to work on elephants. I want to sincerely thank both outgoing editorial board members for their services to keep *Gajah* going and wish them success in their new endeavours. I would also like to welcome two new editorial board members – Peter Leimgruber (Smithsonian Conservation Biology Institute, USA) and Christian Schiffmann (Tier-Erlebnispark Bell, Germany) – who have generously agreed to help with *Gajah*.

Notes from the Chair IUCN SSC Asian Elephant Specialist Group

Vivek Menon

Chair's e-mail: vivek@wti.org.in

Dear Members

I am happy that after the decline of the pandemic, most of us have regained normalcy and resumed our work, commitments and travels. In the second quadrennium of my continuation as Chair of the Asian Elephant Specialist Group (AsESG) a few changes have also taken place. As informed to you in my last communication, Dr. Sandeep Kr. Tiwari has taken over new leadership roles in his parent organisation Wildlife Trust of India (WTI) and left his Program Manager role from 1st April 2022. I am happy to inform that Dr. Prajna Paramita Panda (prajna@wti.org.in) has joined as Program Manager AsESG. She will be in touch with you all to take forward the activities of the group. I request you to extend her all support. On behalf of the group, I extend our sincere appreciation to Sandeep for his excellent work done during his tenure in the last quadrennium and for holding fort till we had Prajna in our team.

Today, the AsESG is a team of 101 members from 21 countries including all the 13 range states. This includes the addition of 8 new members as approved by the Chair on advice of the Membership Advisory Committee.

Early this year, in April 2022, the Government of Nepal in collaboration with IUCN SSC AsESG and with the support of the Asian Elephant Conservation Fund of the U.S. Fish and Wildlife Services hosted the Third Asian Elephant Range States Meeting in Kathmandu, Nepal from 27th -29th April 2022. Eight of the 13 countries were present physically (Nepal, Bangladesh, India, Myanmar, Laos, Malaysia (both peninsular and Borneo) and Sri Lanka) and the remaining five (Indonesia, China, Vietnam, Cambodia and Bhutan) attended virtually due to enhanced Covid regulations in their respective nations. As Chair of the AsESG, I had the unique privilege of co-chairing several sessions of this key meet with my range state colleagues. A key product of the meet was the Kathmandu Declaration which outlines the need to complete the nine key priority actions underlined and agreed upon by all range states to attempt and fulfil by 2025. The declaration forms

Third Asian Elephant Range States Meeting, Kathmandu, Nepal.

part of this issue of Gajah. I am happy to share that the AsESG will coordinate with the Asian elephant range states to complete national elephant conservation action plans, establish a pan Asian elephant database and that the Asian Elephant Conservation Fund will assist in financing conservation in range states.

In the last quadrennium 14 Working Groups were formed of which six of the documents have been finalised and two have submitted their documents for review. I profusely thank the entire team of the Working Group led by Dr. Raman Sukumar for finalising the "Guidelines for Creating Artificial Water Holes in Elephant Habitats", Dr. Sonja Luz and team that finalised the "Guidelines for Welfare and Use of Elephants in Tourism" and Dr. Janine Brown and team that finalised the report on the "Management and Care of Captive Elephants in Musth". I would also like to thank Mr. Sonam Wangdi and team for finalising and printing the Bhutan NECAP and Dr. Benoit Goossens and team for finalising the Sabah NECAP. Dr. Christy Williams and his team have been instrumental in completing the "Red List Assessment of Asian Elephants".

At present the "Guidelines for the Reintroduction of Captive Elephants in the Wild as Possible Restocking Option" and the report on "Emerging Diseases Affecting Asian Elephants" are being finalised and the final document will soon be shared. I urge the remaining Working Groups to work on their reports and I will be happy to hold meetings with each Working Group in the coming weeks to take stock of our progress and complete the task in hand. I would also like to thank the Asian Elephant Transport Working Group, formed jointly with members from IUCN SSC AsESG and IUCN WCPA Connectivity Conservation Specialist Group, for publishing the document "Protecting Asian Elephants from Linear Transport Infrastructure: The Asian Elephant Transport Working Group's Introduction to the Challenges and Solutions". The group is now working to develop a document on mitigation designs for linear infrastructures.

I am sure you have been waiting for the 11th meeting of IUCN SSC AsESG. The good news is that this will be held at the Corbett Tiger Reserve in India from 14th to 17th March 2023. I look forward to having you all for the upcoming AsESG members meeting, the first one in this quadrennium, and request you to block the dates. I am happy that we will be meeting in person after the long pandemic and the details of the upcoming meeting will be shared shortly by my office.

I would like to thank our partners and donors for financial support to the AsESG. Special thanks to the International Fund for Animal Welfare (IFAW), Asian Elephant Foundation and AZA Elephant SAFE Program (including Lion Safari) and Loro Parque Foundation for supporting the activities of the group.

Vivek Menon
Chair IUCN SSC AsESG

Elephants at the Corbett Tiger Reserve, location of the next AsESG meeting. Photo by Christy Williams.

Peer-Reviewed Research Article Gajah 55 (2022) 4-11

The Elephant in the Garden: Bunong Chamkars and Human-Elephant Conflict in Andoung Kraloeng, Cambodia

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Abstract. Bunong farms (chamkars) of Andoung Kraloeng village in Cambodia's Keo Seima Wildlife Sanctuary are increasingly being raided by elephants, leading to human-elephant conflict. We conducted twenty interviews in November 2017 to obtain information concerning this issue. Regression analysis found positive correlations between elephant group size and raided chamkar size, and between group size and distance of raided chamkars from permanent water sources. Results also suggested a decrease in effectiveness of deterrence methods and locals' tolerance toward elephants. This study highlights the need to implement effective mitigation actions before conflict escalates.

Introduction

Asian elephants (*Elephas maximus*) inhabit regions of South and Southeast Asia that are under extreme anthropogenic stress. China, India, and Indonesia alone support some three billion humans, and other nations with Asian elephants also have high human populations. It is not surprising that the greatest threats to *E. maximus*' long-term conservation are habitat loss and fragmentation, human-elephant conflict (HEC), and poaching (Calabrese *et al*. 2017; Menon & Tiwari 2019). Crop-raiding is one of the leading causes of HEC throughout Asia (LaDue *et al*. 2021; de la Torre *et al*. 2021). These threats have halved the number of wild Asian elephants between 1945–2020 (Williams *et al*. 2020), with the current population estimated to be 48,000–50,000 individuals (Menon & Tiwari 2019). However, these estimates may not accurately reflect real-world populations, and several authors have pointed out the need for more reliable population size assessments (Blake & Hedges 2004; Gray *et al*. 2014).

The difficulties and immediate necessities of Asian elephant conservation are especially clear in Southeast Asia, which hosts a series of fragmented populations. This area is characterised by extreme environmental pressure and a lack of reliable information (Hughes 2017) and it has some of the world's highest rates of land transformation for anthropogenic purposes (Tölle 2020). Between the late 1980s and 2000, elephant populations in Thailand, Laos, Vietnam, Cambodia, and Myanmar dropped from an estimated 14,400 individuals to 7,980 (Stiles 2004).

In Cambodia, elephant conservation issues match the wider Southeast Asian trends of habitat fragmentation and HEC. The country's 400–600 remaining elephants persist in scattered populations: namely, two core populations with approximately 175 elephants in the southern Cardamom Mountains Landscape and 223–335 in the Eastern Plains Landscapes of north-eastern Mondulkiri and Ratanakiri provinces (Fauna and Flora International 2020). Natural habitats in these areas were relatively little influenced by human activity until the post-Khmer Rouge era. Yet even as globalisation becomes more prevalent, local and smallholder communities continue to exist as important actors on the Cambodian environmental stage (Singh *et al*. 2018). Cambodia's surviving natural areas border small-holder communities, which sometimes are situated entirely within natural areas. Their impacts on the environment are closely linked to conservation successes or failures (Lonn *et al*. 2019; Riggs *et al*. 2020a).

Mondulkiri's Keo Seima Wildlife Sanctuary hosts one of Cambodia's larger remaining elephant populations, along with some twenty indigenous Bunong villages such as Andoung Kraloeng (Fig. 1). Keo Seima's 292, 690 ha are characterised by a mosaic of evergreen, semi-evergreen, and deciduous forests with a tropical monsoon climate that averages 2,200–2,800 mm of rain per year (Evans *et al*. 2012).

HEC in Andoung Kraloeng typically occurs in the traditional Bunong chamkars, or family farms. Chamkar damage affects both subsistence farming and the rapidly increasing cash-crop economy (Webber *et al*. 2011; Sochanny *et al*. 2018; Chou 2019). There were 57 recorded instances of crop raiding in Andoung Kraloeng between 18th May and 13th June of 2015 (WCS 2015). A previous survey by WCS (2015) found that cashews, jackfruit, and bananas were the most targeted crops with chamkar farmers reporting annually worsening raids, including damage caused to structures in addition to crop damage. At the time of this survey, Andoung Kraloeng villagers had been unable to find successful deterrence strategies (Tyson 2016). Additionally, Bunong communities relied on gathering non-timber forest products (Chou 2019), which also led to encounters between residents and wild elephants.

Given the reported increase of HEC in the village, the potential for reprisals against raiding elephants, an increasing occurrence in other parts of Southeast Asia, is a concern (Webber *et al*. 2011; Oelrichs *et al*. 2016). Yet such action may be locally moderated by traditional Bunong culture, which highly values elephants (Erickson 2017). Domesticated elephants played a significant role in Bunong livelihoods until Khmer Rouge disruptions, and the animals feature in many Bunong mythologies and rituals (Bunthy 2014). Bunong traditions also emphasise ancestral forest and nature spirits that de-

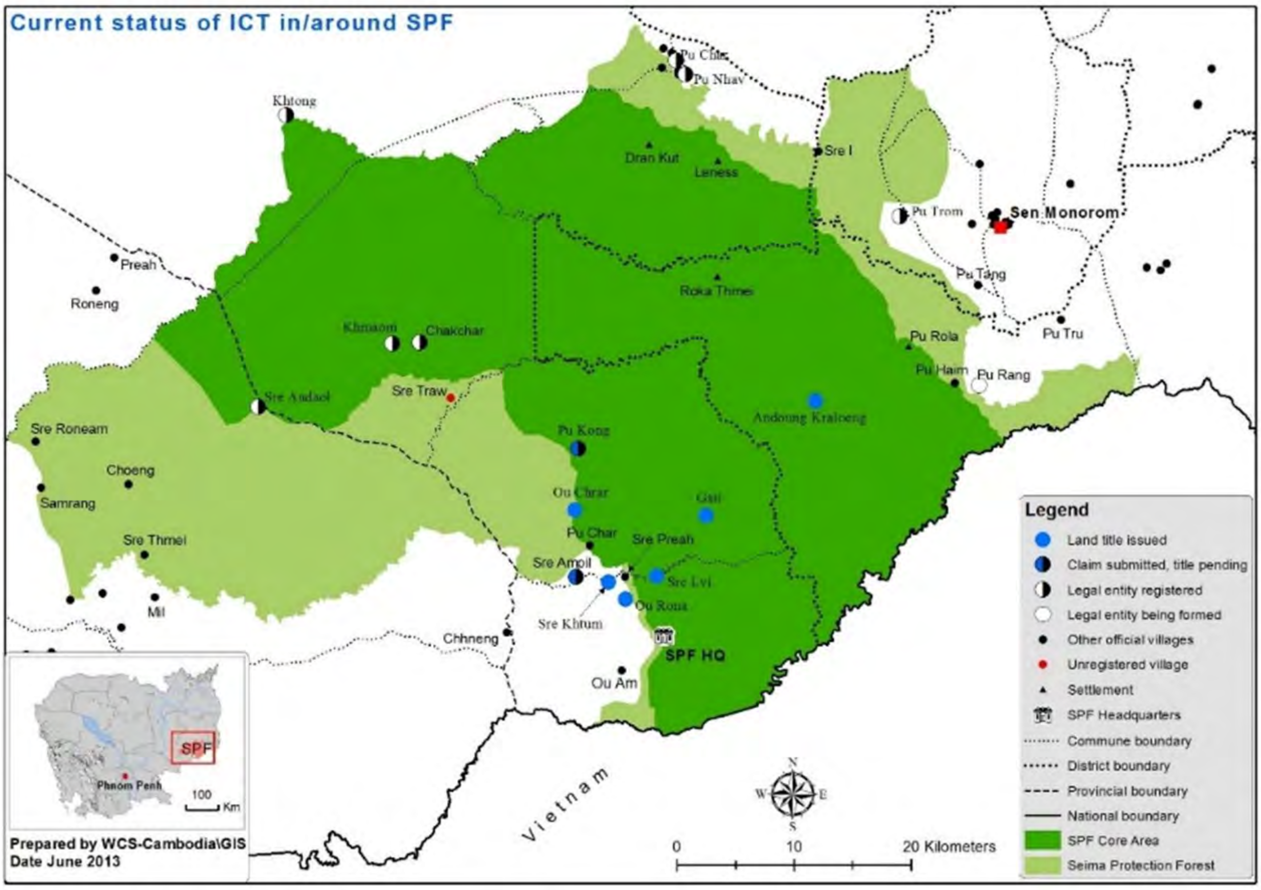

Figure 1. Andoung Kraloeng's position within Keo Seima Wildlife Sanctuary, Cambodia. This map also shows the other known communities within the wildlife sanctuary (WCS 2013).

serve protection (Leemann 2021). These beliefs mean that many villagers in Andoung Kraloeng actively search for non-lethal elephant deterrence strategies (WCS 2015). Populations of ethnic Khmer farmers also exist in and around Keo Seima, and these groups are also known to experience HEC. However only Bunong farmers were interviewed in this study.

Livelihoods in Cambodia are changing rapidly, and Mondulkiri is no exception. The environment has been modified by major road constructions, population growth, and shift towards cash crop farming (O'Kelly *et al.* 2018; Riggs *et al.* 2020b). These factors are not direct causes of HEC but can cause resource changes that may influence elephant movement. In Cambodia, environmental impacts of development and change have often been poorly managed (Hensengerth 2015). As a result, competition for space between humans and wildlife has increased.

Methods

Andoung Kraloeng village consists of 25 households and 101 individuals (pers. comm. Jahoo Gibbon Camp, 2021). The village's chamkars are usually separate from dwellings, although some farms have small huts for occasional use and storage of equipment. Most chamkars are unfenced and unirrigated. In chamkars that have fences, they are constructed using sticks and wood. Individual chamkars are clearly delineated from adjacent natural areas, but an irregular pattern of chamkar plots creates a ragged and unclear boundary between farms and wilderness.

The study was conducted in November 2017. Ethics approval for interviews was obtained from the School for Field Studies Institutional Review Board, Beverley, Massachusetts (IRB approval number CA-014-17). Semi-structured interviews were conducted with key informants using snowball sampling, whereby respondents recommended further individuals affected by human-elephant conflict to be interviewed. All respondents were chamkar owners from different households. Because most individuals in Andoung Kraloeng speak Bunong, discussions went through both, a Bunong-Khmer interpreter followed by a Khmer-English interpreter. Respondents were asked about what cash and subsistence crops they grow, the size and age of their chamkars, the location of their chamkar in relation to ongoing human disturbance, the average number of elephants entering a chamkar and timing of raids, the type of damage caused to their crops, and the distance from chamkars to water sources. Respondents were also asked about previous and current deterrence methods that they used to keep elephants away.

Inferences and resulting statements drawn from qualitative data were based on Wells' (1995) idea of grounded theory. Crops that had fewer than two mentions – soursop, avocado, and sugar cane – were excluded from analyses, as were cashews, which were grown in all respondents' chamkars except for one.

A Pearson Correlation analyses SPSS (version 23) was used to determine correlation between independent variables: chamkar size (ha), location (related to distance (m) to human disturbance such as permanent roads, homes, and farm huts), age (years since chamkar established), cash crops, and subsistence crops. Cash crops were made up of bananas, cashews, jackfruit, and cassava and were analysed separately, while subsistence crops included pineapple, rice, papaya, and multiple vegetables were combined into one variable for analysis due to their smaller individual sample sizes. A Linear Regression was then used to determine if there was a relationship between the dependent variable - elephant group size - and the remaining independent variables. Distance of chamkars to permanent water sources (m) was analysed separately as this variable had sample limitations. Elephant group size was selected as the dependent variable as farmers had expressed interest in understanding why some crops and chamkars attracted larger groups compared to others.

Results

Twenty interviews were conducted with respondents ranging from 26–70 years old, with a median age of 47. Information was obtained related to 24 chamkars (as some farmers owned more than one). The mean chamkar age was 10.13 years (SD = 7.46, SE = ±1.52) with a mean size of 2.03 ha (SD = 1.24, SE = ± 0.25). Elephants mainly raided chamkars from April to June, with raids occurring during both the day and the night. The mean number of elephants per raid was 8 individuals (SD = 4.56, SE ± 0.93). The number of elephants entering chamkars on average was significantly correlated with chamkar size (p = 0.00) (Fig. 2). Elephant group size was larger in chamkars located further away from a permanent water source (p = 0.005) (Fig. 3).

Correlation analyses between the seven variables found a significant positive correlation between chamkar age and chamkar size (p = 0.026), chamkar age and cassava crops (p = 0.014) and the presence of cassava and subsistence crops (p = 0.002). Therefore, chamkar age and cassava were removed from further analysis in order to maintain independence between variables. Regression analysis found a significant relationship between elephant group size and the size of the chamkar raided ($F(5,18) = 10.32$, $p = 0.00$) with an R^2 of 0.74. Larger chamkars were visited by larger elephant groups (Fig. 2). No correlation was found between elephant group size and the location or crop-type.

Distance of chamkars to permanent water sources was analysed separately due to having a smaller sample size of 15 respondents who could confidently report this distance (Fig. 3). A positive correlation was found, with larger groups visiting chamkars farther away from a permanent water source ($F(1,14) = 11.67$, $p = 0.005$) with an R^2 of 0.47.

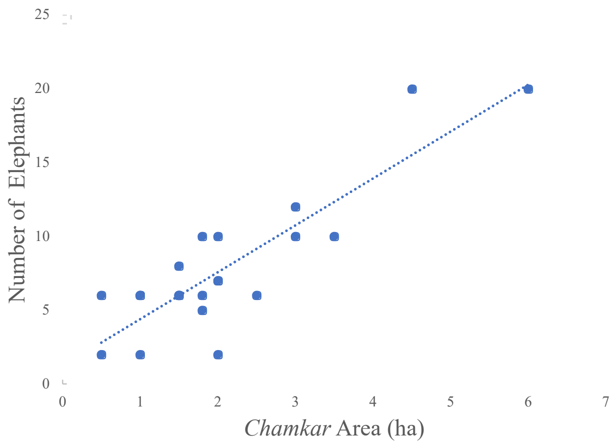

Figure 2. The number of elephants entering chamkars and chamkar size.

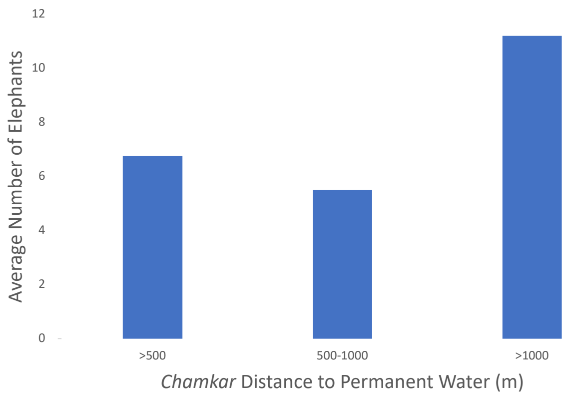

Figure 3. Elephant group size and distance of chamkars to a permanent water source. Distance >500 m (n = 8), 500–1000 m (n = 2) and >1000 m (n = 5).

Responses to the types of crops grown and frequency of damage was analysed from all 24 chamkars (Fig. 4). Respondents indicated that cash crops were generally affected more than subsistence crops, with cashews particularly targeted. For example, all respondents grew cashew and 90% said they were damaged by elephants. In comparison, rice was grown by 70% of farmers and listed as damaged by only 25%. Respondents listed six crops that elephants damaged, consisting of cashew, banana, cassava, jackfruit, pineapple and rice. Four of them (cashew, banana, cassava, and jackfruit) were cash crops, and the majority of crops not mentioned as damaged were grown for subsistence.

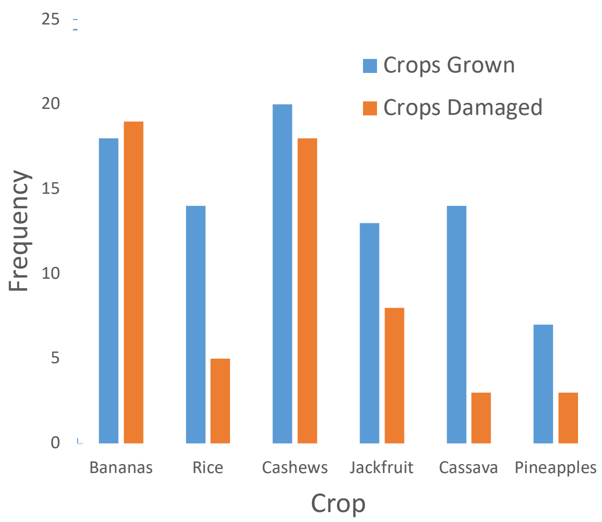

Figure 4. Frequency of crops cultivated by respondents and mentioned as damaged (n = 24).

Banana, cashew, and jackfruit trees were most commonly raided (in 19, 18 and 8 chamkars respectively). Two farmers had stopped growing banana owing to the elephants' preference for them. While cashew and jackfruit were not damaged as often as banana, farmers stated that their economic value was significantly decreased by elephant raids. Farmers stated that elephants only ate the young leaves and ripe fruits from cashew and jackfruit trees. Nevertheless, trees often had branches broken or were pushed over and uprooted. Elephants left rice, cassava, and pineapple relatively unharmed. Farmers said that the timing of crop damage was not random and claimed that the raids were noticeably concentrated at the end of dry season and onset of the wet season (between April and June). Eight respondents claimed that the raiding period overlapped with cashew and jackfruit fruiting times, which occurred at the end of the dry season (April or May).

Respondents mentioned nine deterrence methods. Four of them - blowing buffalo horns known as 'nong', using domestic elephants to keep raiding groups away, burning oil rags, and overnight stays where farmers slept in huts located on their chamkars, were used previously but no longer. Fifty-five percent of respondents indicated that they currently had no effective methods for discouraging elephant raids on their chamkars. Farmers who attempted to scare elephants away sometimes used multiple methods. Forty percent of farmers who tried to chase elephants away said that they attempted to scare the elephants away by individually making noise without fireworks, such as by shouting, banging pots and pans, and hitting sticks together, 25% said they used fireworks, and 5% used either fires or groups of fellow farmers and villagers who gathered to scare elephants away. Fifteen percent of respondents also mentioned that they had used offerings, such as pig carcasses, to appease the spirits who they believe will protect them and their crops from the elephants. Respondents agreed that all these strategies were more prevalent and successful in the past. The ineffective nature of current deterrence efforts may play a role in interviewees' frequent statements about having been more tolerant and fonder of elephants in the past.

Discussion

Elephant raids in Anduong Kraloeng come on the heels of growing stressors in surrounding elephant habitats. Namely, road construction and large cash crop plantations have contributed to the deforestation and fragmentation of Protected Areas near Keo Seima, as best exemplified by Snuol Wildlife Sanctuary becoming degazetted in 2019 (Clements *et al.* 2014; Schoenberger 2017). Negative pressures forcing elephants out of previous habitats are coupled with positive attractants bringing elephants toward Andoung Kraloeng, perhaps most importantly, the presence of cashews, jackfruits, and other nutritious cash crops.

The April/May dry season turning point coincides with the April – June time range that the villagers gave for the majority of elephant raids. Based on cashew and jackfruit fruiting times and ripeness, Keo Seima's elephants appear to be raiding at the height of productivity of those crops. This may be a strategy to offset foraging difficulties that are most pronounced at the end of the dry season, when wild plants may be suboptimal sources of food (Owen-Smith 2008).

Our results indicated that chamkar size and proximity to water were positively correlated with the number of elephants coming to farms. One explanation for higher elephant numbers at larger chamkars may stem from Asian elephants' preference for forest-grassland or forest-agriculture ecotones where food plants become more abundant and accessible (Fernando & Leimgruber 2011). Larger chamkars may have larger ecotone boundaries, along with more understory growth interspersed with crops, providing combined graze and browse opportunities that draw larger elephant groups. Additionally, groups with more individuals require more food, which could also explain why larger chamkars are visited more by larger groups. While it is also possible that larger chamkars border smaller ones, thus creating extra-large crop areas for groups to raid, our results found significance in elephant numbers in relation to individual chamkar size, which was also correlated with chamkar age. Elephants are known to respond to long-term patterns of productivity, more so than immediate forage conditions in familiar locations (Tsalyuk *et al*. 2019), which maybe reflected in the preference for raiding larger, older chamkars.

Along with larger chamkars, those more than 1000 m from water experienced the highest numbers of elephants. Larger elephant groups traveling to farms further from water may indicate elephant grouping strategies that mitigate perceived threats or discomfort in areas with more human influence. While streambeds provide natural and protected paths for elephants, reaching chamkars more distant from those routes, requires movement through more anthropogenically modified zones. By congregating in larger groups, elephants may feel safer to travel farther in order to reach larger chamkars i.e. higher risks leading to higher rewards (McArthur *et al*. 2014).

While there may be a correlation between distance to water and the size of the chamkar, due to sample size differences we were unable to assess it. More data across more locations is required to assess the relationship between the number of elephants visiting chamkars and their sizes or distances to water. Other variables also may play important roles that were not clear in this data set due to sample limitations. For example, larger chamkars may contain a greater quantity of cash crops compared to smaller plots. Elephants' disproportionate preference for cash crops, evident from the interview responses, may result in groups raiding larger chamkars not because of their size but because of what is grown there. Despite our results showing that crop type did not correlate with group size, there are likely other factors at play that were not within the scope of this short-term study. Additionally, while interviews suggest that larger chamkars are generally located farther from Andoung Kraloeng village, our data did show that the location of the chamkar (i.e. its distance from ongoing anthropogenic disturbance) was not correlated with group size of raiding elephants. Determining the chamkars' relative isolation from one another and the age of individual crops within the chamkar may provide further insights.

Respondents indicated that Andoung Kraloeng residents employed a decreasing range of strategies to discourage elephant raids. Prior to this study, most respondents indicated they had received little or no advice or aid with HEC issues, aside from information shared amongst locals. Those who did note outside organisations' aid were discouraged by the quality of that advice: some villagers were simply told to "chase the elephants away." Subsequent to this study, a dedicated human-wildlife conflict mitigation team was established by the Wildlife Conservation Society, and additional support provided to villages.

Along with their frequent explicit statements valuing elephants, Keo Seima residents' patience in withstanding raids without resorting to drastic retaliation suggests that they are averse to harming them. Analyses of integrated biological and ethnographic methodologies' effectiveness in studying human-animal conflict has concluded that combined approaches produce results which help promote sustainable interspecies coexistence (Setchell *et al*. 2017). These factors emphasise the need for a deeper understanding of Bunong spiritual beliefs and their impact on mitigation strategies. We recommend that farmers receive adequate training in mitigation from experts sensitive to these cultural influences and a program is put in place for monitoring the effectiveness of these strategies over the long-term. Immediate action to mitigate chamkar farmers' losses in Andoung Kraloeng is also suggested. Villagers are bearing the accumulated costs of reduced income from several years of damage by elephants. Although they are currently opposed to harming them, the situation is untenable and may change for the worse with time.

Acknowledgements

We thank Mr Chum Nith from The School for Field Studies and Mr Nach Norb from WCS for their guidance and translation between Bunong, Khmer, and English – without their help, this research would have been impossible. We are grateful to have had assistance from the late Mr Teurn Soknai, a Bunong ranger from the Department of Environment, who was killed while on-duty protecting the forests of Keo Seima. Ms Lisa Arensen also deserves thanks for her assistance with qualitative research and general knowledge about Andoung Kraloeng. Also, thanks to Mr Olly Griffin at WCS for his collaboration with the project. Finally, our thanks to the residents of Andoung Kraloeng, who were responsive interviewees and gracious hosts.

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Research Article Gajah 55 (2022) 12-21

Assessing Asian Elephant Habitat in South-Eastern Bangladesh

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Abstract. Small numbers of Asian elephants remain in pockets of forest within south-eastern Bangladesh. An analysis of Landsat images indicated ≈ 36% of elephant habitat loss from 1989–2015, and a 2015 ground inventory of 7 habitat patches, revealed decreasing canopy cover. Vegetation communities were dominated by non-native species, and dung surveys suggested elephants were favouring habitat patches with relatively more tree and bamboo species, and canopy cover. Given recent geo-political developments in Bangladesh, effective elephant conservation requires urgent habitat restoration that also addresses human requirements.

Introduction

Wildlife habitat continues to disappear at an alarming rate across the globe (FAO 2016). This is particularly evident in the case of large mammals that require extensive home ranges to meet life history requirements (Leimgruber *et al*. 2003). The fundamental driver of habitat alteration has been human population growth, resulting in a large proportion of the earth's natural habitats being converted into agricultural land, human settlements, roads, industrial areas and other anthropocentric uses. Further, as continuous habitat becomes fragmented, degraded and reduced in quality, wildlife may come to persist only in less suitable remnants or 'habitat islands' – leading to other factors taking a toll, such as edge effects and deleterious inbreeding. In Southeast Asia alone, 79 mammalian, 49 avian and 184 amphibian species are now threatened due to rapid loss of habitat, primarily deforestation (Li *et al*. 2016). The retention and restoration of natural habitat is thus a critical tool in stemming the loss of species. A critical first step is quantifying and assessing the status of remaining habitat, thus providing a foundation to devise realistic habitat restoration plans.

The natural habitat of the Asian elephant (*Elephas maximus*) is undergoing increasing reduction and fragmentation across all 13 Asian countries where it occurs. Nearly 20 years ago, Leimgruber *et al*. (2003) estimated that approximately half of the land inhabited by Asian elephants had become fragmented and unable to support large populations, and Sukumar (2003) calculated that the species was restricted to only 15% of its historical range. These figures likely are now very conservative, given approximately 20% of the earth's human population is also living in or near the current range of the Asian elephant (Stevenson & Walter 2006), leading to continuous habitat encroachment and conversion (Rood *et al*. 2010). Indeed, during 2000–2016, approximately 480,000 ha of natural forest was removed each year in southeast Asia (Li *et al*. 2016). A consequence of these trends likely is an increase in the frequency of encounters and conflicts between humans and elephants.

Nowhere is the loss of Asian elephant habitat more pronounced than in Bangladesh, where a rapidly growing (density 964 /km^2; BBS 2010) and predominantly poor human population has severely impacted the indigenous population of elephants (210–330 individuals remaining; Motaleb *et al*. 2016). Further, the forest cover of the country declined from nearly 20% to 9% during 1963–2003 (Brown & Durst 2003). The influx of Rohingya refugees from Myanmar and their encroachment on elephant habitat has ex-

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acerbated this situation (Rahman 2019). Consequently, any remaining elephant habitat has likely decreased significantly in quality, in terms of providing forage, cover, and other resources required to support healthy elephant populations. Traditional migration routes also may have become disrupted as the animals become dependent on small patches of forest.

Despite the obvious plight of the Bangladeshi elephant population, qualitative information on the status of remaining elephant habitat (e.g. vegetation cover and land-use) is scant. Moreover, a formal assessment of remaining elephant habitat is essential to begin stabilising (much less reducing) detrimental impacts on elephants, minimising human-elephant conflicts, and devising a comprehensive habitat restoration plan. Herein we present the first formal assessment of elephant habitat in the southeast region of the country, in order to (i) ascertain changes in elephant habitat during 1989–2015 and (ii) understand the current status of elephant habitat in terms of providing forage and cover.

Methods

Site description

The study was conducted in the Chittagong and Cox's Bazar districts (administrative units) of south-eastern Bangladesh. This region consists of hillocks, hills, valleys and forests ranging from 30–300 m elevation. The temperature ranges between 26–33ºC, and annual precipitation from 280–370 cm per year (Bangladesh Meteorological Department 2017). The forests in this area are tropical semi-evergreen, with moderate floristic and faunal diversity (Biswas & Choudhury 2007). The current annual deforestation rate in the country is less than 1%, with per capita forest land at approximately 0.022 ha (FAO 2016). Extensive agricultural areas and human settlements exist inside and surrounds remaining forest. Regional data are not available but the population growth rate for the country is 1.43%. Despite legal restrictions on entering forests, compliance is weak due to a lack of enforcement capacity. Almost all natural forests have been altered or converted into secondary forest or plantations with mostly non-native species, either intentionally or due to human disturbance.

Satellite image classification

Landsat imagery with 30 m resolution was acquired and used to identify forest loss that occurred within the study area during 1989–2015. Within each time period we selected imagery with minimum atmospheric haze, particularly those outside the monsoon season. Four sets of satellite imagery were selected: February 22, 1989 (acquired by Landsat 5 TM); November 7, 2001 (acquired by Landsat 7 ETM); January 23, 2010 (acquired by Landsat 5 TM) and November 21, 2015 (acquired by Landsat 8 OLI) (Source: USGS Explorer).

The different spectral bands (i.e. red, green, blue, near infrared and short-wave infrared 1 and 2) of the imageries were stacked. The images were first projected to UTM zone 47N to match the geographical projection of the reference data. The study area was delineated using the existing forest divisional maps prepared by the divisional offices of the Bangladesh Forest Department. On-screen digitalisation of the study area boundary was produced using both hard-copy maps and Google EarthTM. The boundary polygon was converted to a shape file format using ArcGIS Desktop 10.3.1 software.

ERDAS Imagine software (HEXAGON Geospatial, Version: 15.1) was used to carry out supervised classification based on six land cover classes, namely forest, degraded forest, agriculture, settlement, hill shade (where satellite ground cover was not achieved) and water bodies. At least ten training samples were defined for each land cover class. The land cover classifications assigned by the classifier were post processed using the clump-and-eliminate procedure to remove mixed classes and take care of salt-and-pepper error (Reddy *et al*. 2016). The thematic maps were then converted to shape files and imported into ArcGIS Desktop software to process layout and area calculation. Throughout the operation, historical satellite photos from Google EarthTM were used to corroborate logical class boundaries and the spatial distribution of classes.

Ground inventory of elephant habitat

In May – August 2015 we surveyed and sampled habitat patches of the study area where elephants reside (Fig. 1). Security issues constrained the area that could be worked. For sampling, we selected two districts of the area (Chittagong and Cox's Bazaar) where most of the resident elephants in Bangladesh were found (Motaleb *et al*. 2016). Within these districts, 15 candidate habitat patches were identified and from these, seven were selected randomly for ground sampling (Fig. 1, Table 1). The patches were largely encircled by villages and other development.

Within each of the patches, we established plots using a grid interval of 2.76 km x 1.86 km (1º30′ x 1º00′). Each plot coordinate was calculated prior to the start of fieldwork. A GPS instrument (Garmin 78) was used to locate each plot centre. The numbers of plots sampled in each habitat patch are summarised in Table 1. Additional details appear in Chowdhury (2018).

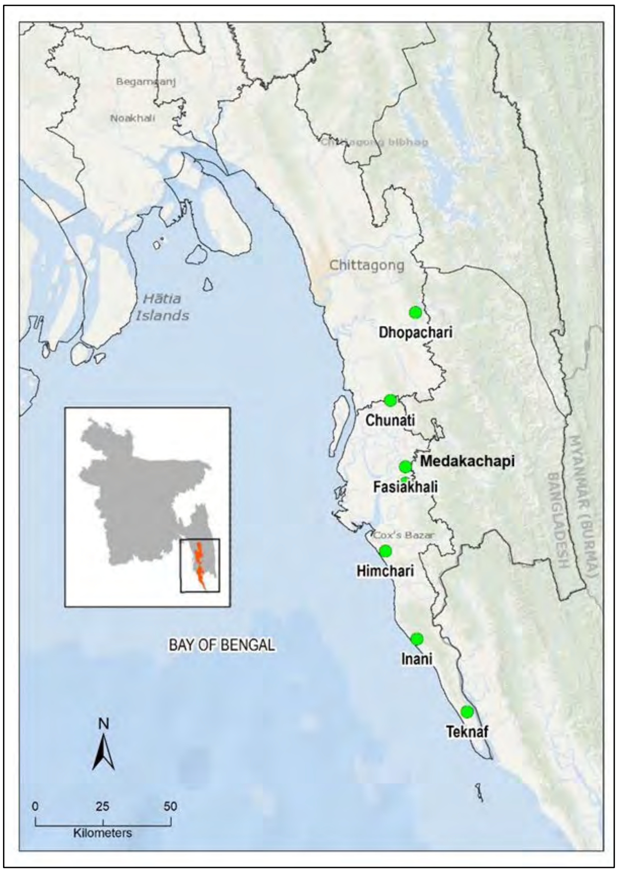

Figure 1. Map showing location of study's habitat patches in south-eastern Bangladesh.

Table 1. Number of sample plots surveyed in habitat patches arranged by patch size.

Patch	Latitude & Longitude	Area (km^2)	No. plots
Medakachhapia	21°41′16″N, 92°09′22″E	4.0	4
Fasiakhali	21°40′00″N, 92°08′00″E	13.0	6
Himchari	21°21′17″N, 92°02′50″E	17.3	5
Inani	21°08′24″N, 92°04′56″E	29.3	7
Dhopachari	22°13′36″N, 92°06′79″E	47.2	11
Chunati	21°54′00″N, 92°08′00″E	77.6	14
Teknaf	21°04′00″N, 92°09′00″E	116.2	10

Using the plot centre, we sampled habitat using three nested circular plots. Within the large plot (17.84 m radius, or 1000 m^2), we measured the height and diameter breast-height (DBH) of all trees >10 cm DBH and identified bamboo to species and counted stems (none exceeded 10 cm DBH). The tree and bamboo counts were combined into a single metric (average number trees+bamboo) as we felt this provided a single composite measurement of habitat quality for elephants. Also, at each plot centre we measured canopy cover using a densiometer.

Within mid-sized plots (10 m radius), DBH and height of trees 5–10 cm were measured and recorded. Inside small plots (2 m radius), we counted all live seedlings and saplings and visually estimated tall grass coverage (%).

Forest regeneration index

We used a forest regeneration index (FRI) that reflects the regeneration capacity of the habitat patches and, overall, the health of the patch ecosystem (Shirer & Zimmerman 2010).

We calculated FRI for each of the small plots as:

$$FRI = (20 \times SEEDLING\ COUNT) + (50 \times SAPLING\ COUNT)$$

FRI values were assigned into four categories based on their magnitude (Table 2).

Table 2. Forest regeneration categories adapted from Shirer & Zimmerman (2010).

Categories	Index Range	Stem density per ha	
		Seedlings	Saplings
Poor	0–200	<1899	<758
Fair	201–400	1900–3799	759–1519
Good	401–600	3800–5700	1520–2280
Very good	>600	>5700	>2280

Forage species categorisation

We compiled a list of forage plants eaten by elephants as reported by Joshi & Singh (2008) and Feeroz (2014). For each forage species, percent cover in the large plots was visually estimated. We used this as an indication of abundance within the study area. Species were categorised in each plot as 1 = very common (>60% of plot), 2 = common (40–60% of plot), 3 = fairly common (20–40% of plot) or 4 = infrequent (<20% of plot). The average for all plots in each habitat patch was taken to represent that patch.

Phytosociological attributes

We calculated the Importance Value Index (IVI) for all tree and bamboo species recorded across the large and mid-sized plots in each habitat patch (Curtice 1959; Joshi *et al*. 2019). Species diversity for each patch was calculated using the Shannon-Weaver (1963) index of diversity (Pielou 1975).

Dung counts

Within each large habitat plot we conducted dung pile counts as an indirect assessment of habitat use by elephants (Barnes 2008). Following Kumar *et al*. (2010) and Rood *et al*. (2010), we searched for and counted all dung piles other than those that were severely eroded, weathered and/or deformed to provide a crude assessment of elephant activity in the patches. Ahrestani *et al*. (2018) discusses the limitations of using dung counts to estimate densities. In this study logistical and safety considerations prevented more precise estimates through tracking dung pile decay rates and changes in appearance. The average number of dung piles per plot was calculated for each patch and used to represent elephant use.

Data analysis

All habitat data were entered into Microsoft Excel and analysed using statistical software Minitab 17 (Version: 17, Minitab Inc). We used simple linear regression to assess the relationship between elephant usage (dung piles) with the mean number of tree and bamboo species present, canopy cover and patch size.

Results

Land use/land cover (LULC) change

Figure 2 shows spatial changes of LULC, with corresponding class area statistics in Table 3. Our analysis indicated that ≈ 36% of forest area was converted to other land uses during 1989–2015 with approximately 21,183 ha of forest removed from 2010–2015 (Table 3). Over that time period, this equates to an annual deforestation rate of ≈ 1.7%.

Vegetation structure

The distribution of FRI categories varied by habitat patches (Fig. 3). Only two habitat patches (Dhopachari and Medakachapia) had the majority of plots falling in the Very Good or Good categories (73% and 100%, respectively). Average canopy cover for the 7 patches was ≈ 31% (SD = 17.81; Table 4). The highest percentage of tree species occurred in the lower DBH size classes and gradually decline up to the larger size classes (Fig. 4). The highest average tall grass cover measurements occurred in the Teknaf patch, followed by Himchari, Innani, Dhopachari, Chunati, Medakachapia, and Fasiakhali, yet these values ranged from only 2–17% (Table 4). Dhopachari and Chunati had the highest estimated clump and culm densities for bamboo, compared to the other patches (Table 4). We detected 40 different species of elephant

Table 3. Land Use/Land Cover (LULC) changes in south-eastern Bangladesh.

LULC class	Area (ha)				% Change
	1989	2001	2010	2015	1989–2015
Agriculture	59,492	69,999	69,019	96,249	+ 62
Settlement	17,565	32,075	36,335	42,011	+ 139
Forest	60,542	52,604	50,234	29,050	- 52
Degraded	76,363	74,954	67,361	58,634	- 23
Water body	18,705	4,343	10,103	7,284	NA
Hill shades	2,056	749	1,670	1,495	NA

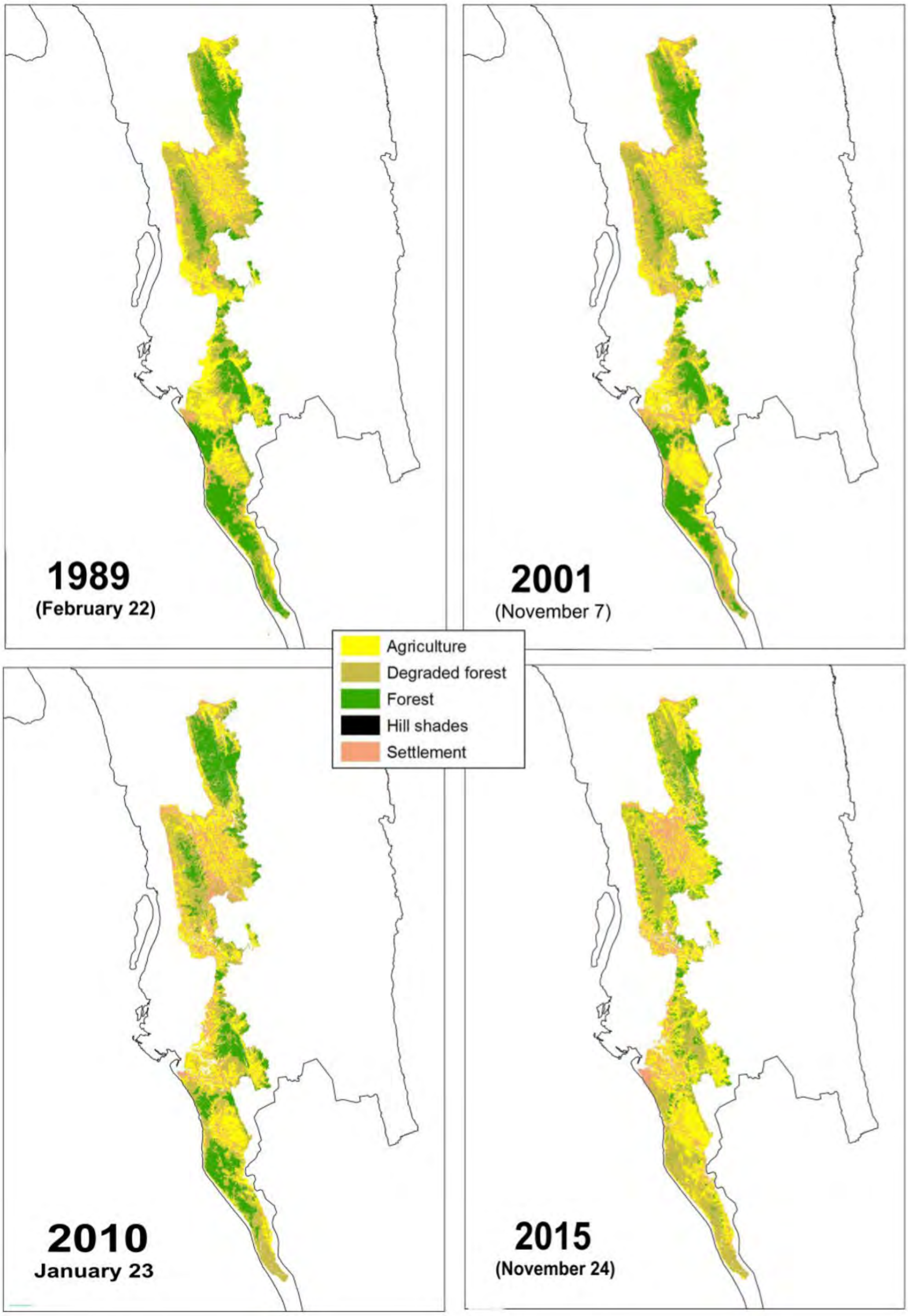

Figure 2. Satellite imagery showing land use changes in south-eastern Bangladesh.

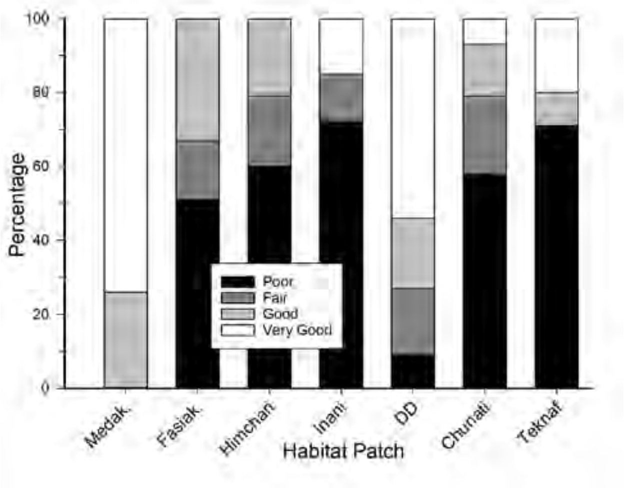

Figure 3. Forest regeneration index (poor, fair, good, very good) composition of 7 different habitat patches arranged from smallest to largest in area.

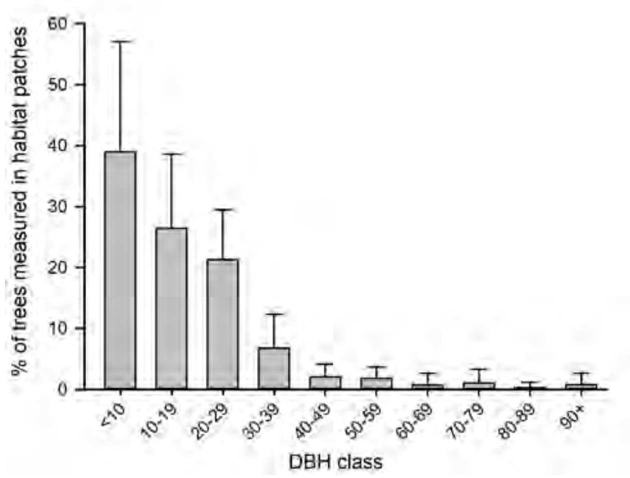

Figure 4. Distribution of tree diameters (DBH) in habitat patches (all patches pooled). Error bars = ± 1 standard deviation.

food plants across the seven habitat patches (see Appendix C in Chowdhury 2017). Their relative abundance ranged from rare to quite common. The Shannon-Wiener Index of patches ranged from 2.10–3.33 except for Himchari and Fasiakhali. Himchari displayed the greatest evenness followed by Fasiakhali (Table 4).

Phytosociological attributes

In 3 of the 7 habitat patches a non-native species occurred within the top three IVI values of detected plant species (Table 5). One non-native species, *Acacia auricularis*, held the highest IVI value in 3 sites (Inani, Teknaf and Chunati). One of the signature taxa for the study region (*Dipterocarpus* spp.) showed a dominant IVI value only in the Medakachhapia and Fasiakhali habitat patches; another historic key taxa, *Syzygium* spp. had the highest IVI value in Himchari and second highest in Fasiakhali, but failed to place in the top three IVI species in the other patches.

Elephant habitat use

We detected elephant dung piles in all seven habitat patches, and 61% (35/57) of all plots. A strong positive relationship existed between the average dung pile count and the average number of tree plus bamboo species in each patch ($F = 39.6$, $df = 1, 5$, $P < 0.001$, $R^2 = 0.86$, see Fig. 5). A similar strong relationship was found with canopy cover ($F = 8.1$ $df = 1,5$, $P < 0.04$, $R^2 = 0.62$). Dung pile counts were not related to the number of forage species ($F = 2.3$, $df = 1,5$, $P = 0.19$, $R^2 = 0.32$) nor patch size ($F = 0.01$, $df = 1,5$, $P = 0.91$, $R^2 = 0.03$).

Table 4. Vegetation measurements for 7 different habitat patches in south-eastern Bangladesh. Clump and Culm represent estimated bamboo density, SW = Shannon-Wiener diversity index, CC = canopy cover, and TG = tall grass cover.

Patch	Clumps/ha	Culms/ha	SW	Evenness	% CC	% TG
Teknaf	11	138	3.11	0.80	31	17.0
Inani	14	97	3.10	0.84	26	9.3
Himchari	4	44	1.04	0.95	9	12.4
Medakchhapia	12	240	2.10	0.74	55	4.2
Fasiakhali	7	22	1.89	0.71	40	2.3
Chunati	31	175	2.51	0.87	21	6.6
Dhopachari	162	1449	3.33	0.88	43	8.2

Table 5. Plant species (all elephant forage species) demonstrating the three highest Important Value Index (IVI) values within each of 7 surveyed patches of elephant habitat. The NN superscript indicates non-native species.

Patch	Species	IVI
Medakachhapia	*Dipterocarpus* spp.	131.9
	Mangifera indica	34.1
	Artocarpus heterophyllus	19.3
Fasiakhali	*Dipterocarpus* spp.	89.7
	Syzygium frimum	60.6
	Mangifera indica	40.1
Himchari	*Syzygium* spp.	140.0
	Albizia sp.	98.4
	Spondias mombin	61.6
Inani	*Acacia auriculiformis* NN	44.9
	Ficus bebghalensis	41.1
	Dipterocarpus spp.	14.2
Dhopachari	*Ficus hispida*	36.1
	Stereospermum coais	31.0
	Grewia nervosa	19.5
Chunati	*Acacia auriculiformis* NN	35.6
	Ficus hispida	34.5
	Callicarpa arborea	28.3
Teknaf	*Acacia auriculiformis* NN	73.1
	Erythrina fusca	29.5
	Gmelina arborea	19.5

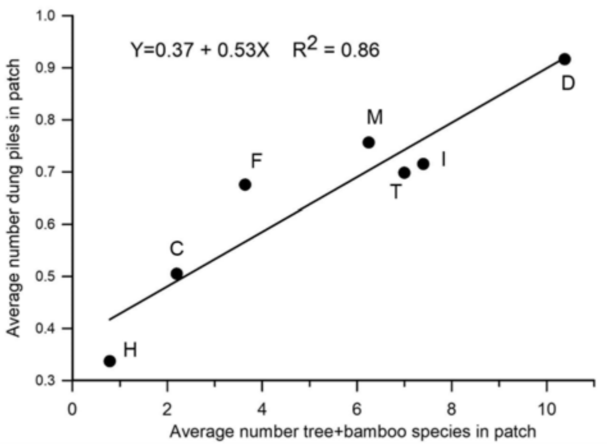

Figure 5. Relationship between average number of dung piles and average number of individual trees+bamboos across plots established within in each of 7 patches of habitat (number of plots vary depending on size of patch). Letters represent initials for the names of the patches (see Table 5 for full names).

Discussion

The overall annual deforestation rate we estimated for the study period (1989–2015) was higher than the national rate of 0.77% reported for 2006–2014 by Reddy *et al.* (2016). Nationally, this represented » 31% (36,275 ha) of elephant habitat being lost due to land conversion (unpublished data, Bangladesh Forest Department), similar to the 36% we detected in our region. The habitat loss in our study area is likely to continue. The LULC change also shows that forest and degraded forest are being fragmented, making the habitat discontinuous.

The consequences of LULC changes are multifold. Habitat loss may require elephants to seek forage, cover and other resources in new areas. As they extend their search, conflict with humans will rise (Chowdhury 2017). Blake *et al.* (2008) found the movement rate of African elephants (*Loxodonta africana*) in the Congo Basin increased 14-fold when they were crossing human-dominated landscapes, presumably to minimize risk of exposure. Our findings suggest that elephants in south-eastern Bangladesh may be forced to forage larger distances and to expend more energy. Elephant populations are unlikely to be sustainable over the long term, under such conditions.

Open patches in forest ecosystems often serve to increase biodiversity (Muscolo *et al.* 2014), but an unnaturally high predominance of young vegetation may suggest impediments to natural succession and forest maturation. The FRI values we observed, indicate poor forest regeneration in most habitat patches. Likely a number of factors suppress tree maturation in the region. Scarcity of firewood leads villagers to set fire to the existing vegetation in order to collect the resultant dead wood. Anthropogenic exploitation of these forests may hold patches in an early seral state, reducing shade for elephants. A preponderance of small diameter trees in the habitat plots indicates reduced maturation rates and potential long-term changes in species composition of the plant community. This may impact habitat quality for the elephants. However, lower basal area or fewer trees/ha also may produce more forage at ground level (Moore & Deiter 1992). The absolute loss of forest habitat may be more visible, but more subtle alterations of stand structure may also contribute to a decline of suitable elephant habitat.

The abundance of tall grasses and bamboo was low in our study patches. Elephant diets can contain 3–14% of grasses (Sukumar 1992; Joshi & Singh 2008). Tall forage grasses like sungrass (*Cypetus difformis*), and ful jharu (*Thysanolaena maxima*) are collected for roofing and makeshift brooms. Bamboo when present constitutes an important forage species for elephants. We detected a wide range of abundance of bamboo across the habitat patches, which likely reflects differences in local harvesting pressure. Excessive harvesting of bamboo and tall grasses by humans would add to the pressure on elephants to look for alternative food sources. Synchronous bamboo flowering which occurs once in 30–40 years, with all mature plants dying after fruiting, may partially explain the low levels of bamboo observed, as villagers stated that such an event occurred 3–4 years before.

Plant community domination by non-native species (*Acacia auriculiformis*, *Eucalyptus camaldulensis*) may have a profound impact on regeneration, growth and abundance of elephant forage species. The prevalence of non-native species may alter elephant habitat use (Prasad & Williams 2011). The historical multi-storied forests of Bangladesh are now converted to single-storied forests with minimal or zero ground cover (Hossain 2003). Non-native species like Eucalyptus and Acacia inhibit natural regeneration of some native forest species and influence the distribution, quantity and seasonality of natural forage, making habitats less favourable (Islam *et al.* 2003; Carnus *et al.* 2006). The domination of non-native species is not unexpected in an environment where exotic plants have been deliberately introduced since 1871, a notable example being teak (*Tectona grandis*). Other species (e.g. *Acacia auriculiformis*, *Eucalyptus camaldulensis*) were introduced in the 1980s for large scale afforestation, with the objective of replacing low yield heterogeneous forests with commercially-valuable species (Hossain 2003). The fact that most native species showed lower IVI values indicate their scarcity and need of high conservation priority. The domination of non-native species may result in the extinction of more palatable species (Hossain 2003), although the diversity of the habitat patches appeared relatively similar to that reported for other tropical forests.

The use of animal sign such as dung piles is a strong indicator of animal presence but is less reliable for assessing abundance or frequency of use (Williams *et al.* 2002). The positive relationships between dung counts and the tree/bamboo community observed by us suggests that this method provides a valuable assessment tool. Our results suggest that the animals had recently occupied the habitat patches, so presumably the patches provided some level of resources (including thermal refuge). Elephant use of high- canopy cover forest may be less, as medium and open canopy cover provide more forage (Sitompul *et al.* 2013). However, our results suggest that elephants respond positively to habitat patches with high canopy cover and a more diverse community of trees.

This study highlights the alarming rate at which elephant habitat in south-eastern Bangladesh is diminishing and degrading. A comprehensive habitat restoration program is urgently required to save this iconic and important species from extirpation. Although this study focused on remnant habitat patches, connectivity must also be maintained and has to be addressed in any habitat restoration program. Habitat restoration is not straight forward in a human-dominated landscape like Bangladesh. This study was conducted before the influx of well over three-quarters of a million Rohingya refugees into Bangladesh (UNHCR 2020). A large proportion of them have taken shelter in environmentally sensitive areas such as national parks, reserve forests, or agriculturally marginal areas including Teknaf and Ukhiya Upazila of Cox's Bazar (Imtiaz 2018). The settlements have led to increased demands on natural resources. For example, Hasan *et al.* (2018) suggest that the refugees required 750,000 kg of firewood every single day. Consequently, there has been an increase in conflicts between humans and elephants (Rahman 2019). Thus, habitat restoration needed to retain Bangladesh's elephants must not only safeguard elephant habitat but also address the root causes of human-elephant conflict.

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Research Article Gajah 55 (2022) 22-29

Rapid Composting: A Solution for Elephant Dung Management in Captive Centres

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Abstract. We investigated methods for rapid composting of elephant dung to support management of waste generated in establishments holding captive elephants. Elephant dung treated with effective microorganisms (EM) or urea alone, both EM and urea, and untreated dung were composted for 45 days. C:N ratios of treatments were estimated at 10-day intervals. Phytotoxicity and maturity of compost were evaluated after 45 days by a germination bioassay. Addition of urea decreased the C:N ratio more rapidly. EM and urea treatment resulted in an optimum C:N ratio of 22:1 after 20 days. Phytotoxicity was lowest in dung composted with EM and urea. Maturity of compost as indicated by seedling tolerance index was highest in EM and urea treatment. We conclude that EM and urea treatment results in the fastest composting and provides the best compost.

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Introduction

The daily food intake of an elephant is 200–270 kg and 100–130 kg is defecated per day (Sannigrahi 2015). In addition to leafy matter, they consume a considerable amount of bark and woody fragments (Steinheim *et al.* 2005). Therefore, elephant dung contains a significant amount of fibre and complex organic compounds.

The Pinnawala Elephant Orphanage (PEO) in Sri Lanka, where the study was conducted, was established in 1975 and held about 85 Asian elephants (*Elephas maximus*). As feed, elephants at the PEO were provided with leaves of coconut (*Coccus nucifera*), leaves and trunks of jaggery palm (*Careota urenus*), leaves and branches of jack (*Artocarpus heterophyllus*), sacred fig (*Ficus religeosa*), and weeping fig (*Ficus benjamina*). Daily, elephant dung is collected and dumped in an open field without any treatment.

As the decomposition of elephant dung takes a long time, waste management has emerged as a challenge at the PEO. Increasing the efficiency of composting of elephant dung at establishments like the PEO is useful for management. The slow decomposition of elephant dung is mainly due to the high amount of lignified constituents, and low cellulolytic activity (Meissner *et al.* 1988). Carbon mineralization from dung is extremely rapid during the first 48 h but microbial activity is progressively limited by moisture (Anderson & Coe 1974). Open field disposal of elephant dung leads to drying, decreasing microbial activity (Sannigrahi 2015), and consequently requires a considerable extent of land for dumping.

The decomposition rate of complex organic material can be enhanced by reducing the C:N ratio by adding material high in nitrogen such as urine or nitrogen fertiliser, as they increase the abundance of microbial flora involved in decomposition, leading to rapid composting (Adediran *et al.* 2014). Mixtures of effective microorganisms (EM) available in the market contain a special group of heterotrophic microorganisms commonly found in natural environments and could be used for many purposes (Mupondi *et al.* 2006). This concept was initially developed in Japan with 'nature farming'

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using mixed cultures of naturally existing beneficial microorganisms (Yamada & Xu 2000). EM require a carbon, nitrogen and an energy source. Hence, they can be used to convert organic waste into compost. Composting is the microbial aerobic degradation of organic waste through 'bio-oxidation' (Jimenez & Garcia 1989; Gautam *et al*. 2010) and time required for degradation varies with the type of substrate. EM can decompose organic substrates rapidly without any offensive odour (Sangakkara 1999). The objectives of this study were to determine whether elephant dung decomposition could be accelerated by treating with EM and urea and evaluating the applicability of elephant dung compost for improving plant growth.

Materials and methods

Composting of elephant dung

Elephant dung was collected within 48 h after defecation and brought to the Livestock Field Station of the Department of Animal Science, Faculty of Agriculture, University of Peradeniya. Composting bins 30 x 30 cm and 35 cm high were made with planks. The bottom and sides of the bins were covered with plastic-coated wire mesh (13 mm mesh size) and sides were insulated with white polythene sheets (gauge 1,000) to avoid excessive moisture and heat loss. Composting was done under of four treatments (Table 1) with four replicates each. Bins were randomly assigned to the four treatments. Dung boli were pulverised and mixed manually, 10 kg filled into each composting bin without pressing and treatments applied. A stock solution of EM was obtained from Sarvodaya Sustainable Economic Enterprises Limited. Both EM and urea treatments were applied on day 1. EM treatment was repeated for EM only and, EM and urea on day 16 to maintain microbiota throughout the composting period.

Turning of compost piles were carried out at 4-day intervals to facilitate aeration by dumping the contents of each bin onto a polythene sheet, mixing by hand and placing back in the bin. A hand-squeeze test was conducted to monitor moisture content of compost piles by taking a handful of sample and squeezing tightly. If water flowed out freely, it was considered too wet. A damp and sponge like consistency was considered as the ideal moisture content, assumed to correspond to about 50–60%. If it was dry and crumbly it was considered too dry. Piles considered too wet were allowed to dry and if too dry, they were watered. Composting was continued for 45 days.

A representative sample of about 50 g was taken from each bin, at 10-day intervals and stored in polythene bags. Samples were oven-dried at 60°C for up to 48 h and weighed at 1-hour intervals till constant in weight. Afterward, samples were ground using a laboratory-milling machine (ZM 200, Retsch, Germany) and passed through a 1 mm sieve.

Loss on ignition method was used to estimate the total organic matter percentage of samples. From the prepared samples, 2 g were oven-dried again at 100°C for 24 h and dried weight (DW) determined. Afterward, samples were transferred into a Muffle furnace (CSF 1200, Carbolite, UK) and completely burnt at 525°C for 4 h, and ash weight (AW) was determined. The equation below was used to estimate the total organic matter percentage (TOM%). A conversion factor (1.25) was used to estimate total carbon percentage from total organic matter percentage of treatments (Jimenez & Garcia 1989).

$$TOM\% = (DW - AW) / DW \times 100$$

The total nitrogen percentage was determined using the micro-Kjeldahl method (AOAC 2005).

Germination bioassay

A seed germination test was conducted to evaluate the phytotoxicity of compost. After 45 days

Table 1. Composition of compost treatments.

Treatment #	Composition
1	ED + Water (1:1000)
2	ED + Urea (1:1000)
3	ED + EM (1:1000)
4	ED + EM (1:1000) + Urea (1:1000)

the compost in each bin was mixed, a 500 g sample taken and combined to create a composite sample of 2 kg for each treatment, from which a sub-sample of 2.5 g was taken for testing. A compost-water extract was prepared by mixing 2.5 g of the compost with 25 ml of deionised water, mixed using a vortex mixer at 24,000 rpm for 2 min and filtered using Whatman no. 1 filter papers. Maize seeds (variety: Thai-Hybrid) were rinsed three times in de-ionised water and five seeds were placed on a petri dish lined with Whatman no.1 filter paper. Two replicates were set up per sample and 5 ml of compost extracts were added to each test sample and 5 ml of de-ionised water to the control. The petri dishes were incubated at a room temperature of 30 ± 2°C for 4 days in the dark.

At the end of the incubation period, radicle length, coleoptile length, and root length of each germinated seed were measured. If both radicle and coleoptile length was above 5 mm, a seed was considered to have germinated. Following equations (Asmare 2013) were applied to calculate the germination percentage (G%), relative seed germination (RSG), relative radicle growth (RRG), and germination index (GI). The method proposed by Chou & Lin (1976) was used for measuring root length of seedlings for calculating the seedling tolerance index (STI).

G% = # germinated seeds / # total seeds × 100

RSG = # germinated seeds (sample) / # germinated seeds (control) × 100

RRG = total radicle length of germinated seeds (sample) / total radicle length of germinated seeds (control) × 100

GI = RSG × RRG × 100

STI =mean root length in compost extract / mean root length in deionised water × 100

Plant growth bioassay

A plant growth bioassay was conducted to evaluate the effect of compost on plant growth using composite samples of each treatment. Compost and river sand were mixed in a ratio of 1:1 by volume and river sand alone was used as a control. Five grams of controlled-release fertiliser OSMOCOTE (14-14-14; N: P: K) were added to each treatment at 1:800 ratio, and placed in 4 L black plastic pots. Each treatment including the control was duplicated. All of the pots were kept under uniform conditions with day/night temperatures of 28±3°C and 12 h light per day. The pots were kept moist by regular watering. Maize seeds (variety: Thai-Hybrid) were soaked in de-ionised water overnight, and 5 seeds placed in each pot. After 7 days, 3 seedlings were removed to facilitate the growth of the remaining two seedlings. Stem height from the base to the junction of the two full upper leaves of plants was measured at 10-day intervals for 40 days, and a single maize plant was considered as a unit.

Statistical analyses

The C:N ratio data were subjected to analysis of variance (ANOVA) for each time point and throughout the time series. Germination bioassay and plant growth bioassay were subjected to ANOVA under CRD experimental design using SAS 9.0, and means were separated by Tukey's test at $P<0.05$.

Results

Total nitrogen percentage

Treatments with urea (2 and 4) had a higher total nitrogen percentage than those without urea (1 and 3) at the start, which declined by the 10th day (Fig. 1). Treatments 1 and 3 did not differ except on 30th day. Treatment 4 had the highest total nitrogen percentage among treatments, on 40th day.

Total carbon percentage

All treatments had similar total carbon percentages at the start (Fig. 2). Subsequently, treatment 4 had a lower total carbon percentage except on 30th day.

C:N ratio

At the start of the experiment the C:N ratios of treatments 2 and 4 were 13:1 and in treatments 1 and 3, 50:1 (Fig. 3). The C:N ratio of treat-

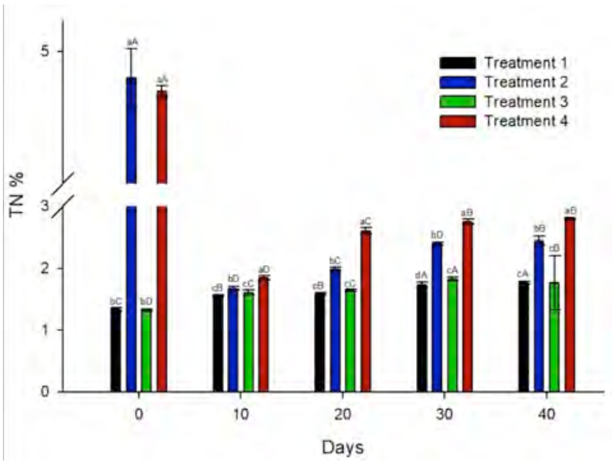


Figure 1. Changes in total nitrogen percentage (TN%). Lowercase letters on top of bars denote comparison of different treatments within days and uppercase letters the same treatment between days, with the same letter signifying no difference in means (Tukey's test at P<0.05).

ments 2 and 4 increased to 39:1 and 35:1 respectively on day 10 then decreased gradually to 34:1 and 22:1 respectively by day40. The C:N ratios of treatments 1 and 3 gradually decreased from the start to end (from 50:1 to 36:1). Treatment 2 reached a C:N ratio of 27:1 by day 30 and Treatment 4 reached a ratio of 25:1 by day 20.

Germination bioassay for different treatments

The germination results are shown in Table 2 and Figure 4.

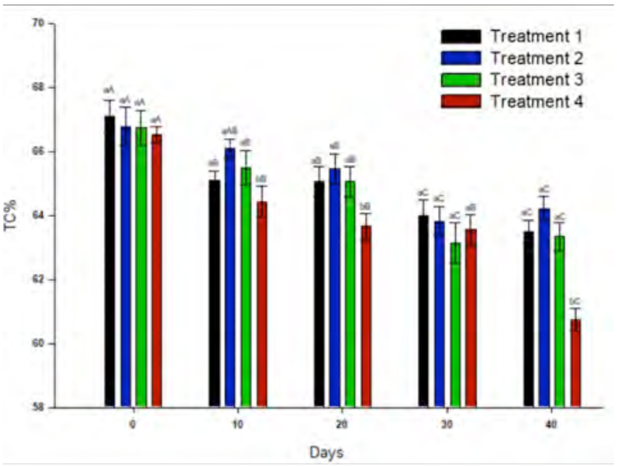


Figure 2. Changes in total carbon percentage (TC%). Lowercase letters on top of bars denote comparisons of different treatments within days and uppercase letters the same treatment between days, with the same letter signifying no difference in means (Tukey's test at P<0.05).

Plant growth bioassay of different treatments

Maize plants in all treatments showed rapid growth (Fig. 5). Plant height of treatment 1 was the lowest (P<0.05), and urea added treatments (2 and 4) the highest (P<0.05) in the last 20 days of the bioassay. When comparing the plant heights of treatments 1 and 3 against the control, plant height of both treatments was lower (P<0.05) than the control in the last 20 days. Figure 6 shows the plants grown for 40 days.

Discussion

Time to decomposition

Traditional composting takes several months to produce compost (Liu *et al.* 2011). Therefore, rapid composting methods are required for dealing with large volumes of raw waste. In this study, we measured the C:N ratio of four treatments to evaluate the rapidity of composting of elephant dung with different treatments. The C:N ratio is an indicator of the decomposition rate. In composting, microorganisms utilise substrate carbon for cellular growth and energy. Consequently, carbon and therefore the C:N ratio decreases. The magnitude of change in the C:N ratio reflects the intensity of microbial activity (Mupondi *et al.* 2006). We found a rapid decrease of the C:N ratio when urea was added to dung. The fastest decrease in the C:N ratio was in treatment 4 which reached a low

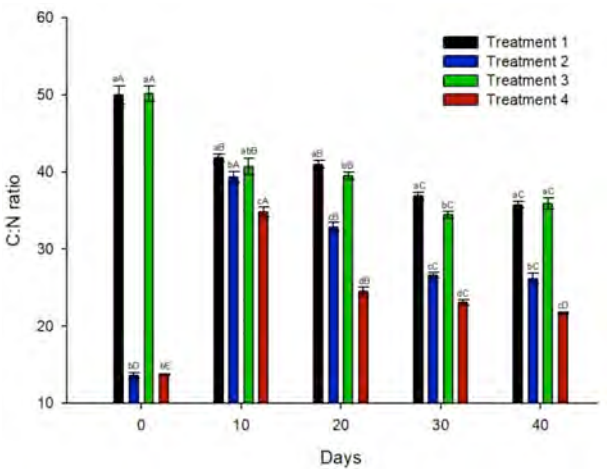


Figure 3. Changes in C:N ratios. Treatments followed by the same uppercase letter along the days and the same lowercase letter within a particular day do not differ significantly according to Tukey's test at P<0.05.

level by day 20, indicating that decomposition was faster when elephant dung was treated with both EM and urea.

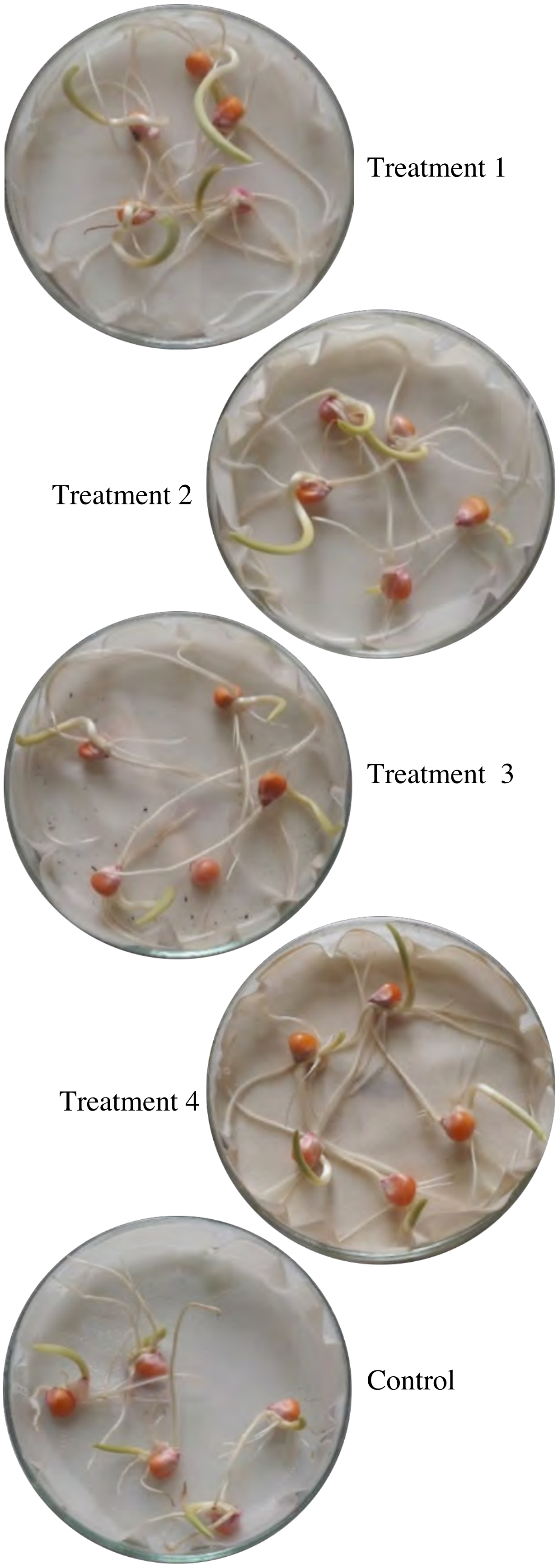


Figure 4. Germination of maize seedlings in the germination bioassay.

High C:N ratios in composting material indicate late maturity (Adediran *et al*. 2014) hence longer time to decomposition. A cause of high C:N ratios is lignocellulosic materials, which hinder the composting process due to their recalcitrance to enzymatic attack by microorganisms (Sanches *et al*. 2017). Elephant dung has a high level of lignocellulosic material as it is high in fibre. We found that elephant dung alone and treatment with EM only had high initial C:N ratios, indicating that they would have decomposed at a slow rate, whereas adding urea decreased the C:N ratio.

The C:N ratio is also an indicator of the quality of organic matter, with the preferred C:N ratio for compost ranging between 15:1 to 30:1 (Haug 1993). We found, treatments 2 and 4 reached the preferred C:N ratios by the 40th day of composting indicating maturity. Thus, treating elephant dung with urea or urea and EM enabled reaching maturity earlier than when composting elephant dung alone or treating with only EM.

Germination bioassay

Phytotoxicity is a major criterion for evaluating the suitability and maturity of composts. Compounds such as phenolic acids are able to induce inhibiting effects on seed germination and plant growth (Rejila *et al*. 2012).

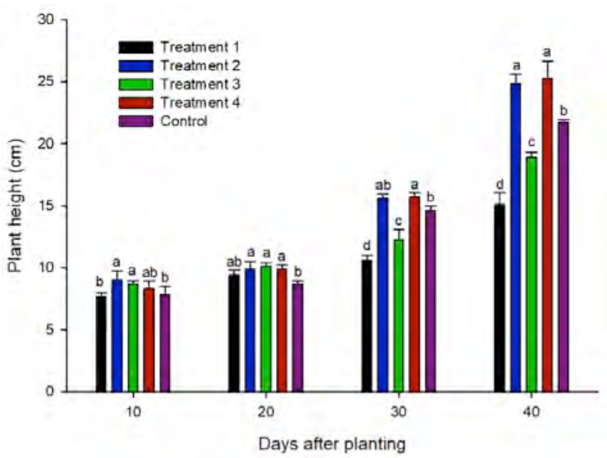


Figure 5. Plant height of maize grown in different treatments. Treatments followed by the same letter within a particular day do not differ significantly according to Tukey's test at P<0.05.

Table 2. Results of maize seed germination bioassay with different treatments. Treatments with the same letter within a line do not differ significantly according to Tukey's test at P<0.05.

Parameter	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Control*
Germination [%]	90.00	100.00	80.00	90.00	100.00
Relative seed germination	90.00	100.00	80.00	90.00	-
Radicle length [cm]	4.52^{C}	6.51^{AB}	7.06^{A}	7.63^{A}	4.69^{BC}
Relative radicle growth	96.38^{C}	138.81^{AB}	120.47^{B}	145.20^{A}	-
Germination index	86.44^{A}	138.81^{A}	96.37^{A}	131.18^{A}	-
Seed tolerance index	148.41^{C}	121.42^{D}	179.55^{A}	163.98^{B}	-

* no dung

Germination percentage (G%)

We found that germination was inhibited in EM added treatments and with dung only, while there was no inhibition in the urea only treatment and the control. Seed germination inhibition can occur due to high levels of dissolved solids, which are absorbed by seeds before germination (Sujatha *et al*. 2017). Adding EMs could increase dissolved solids, causing inhibition of seed germination.

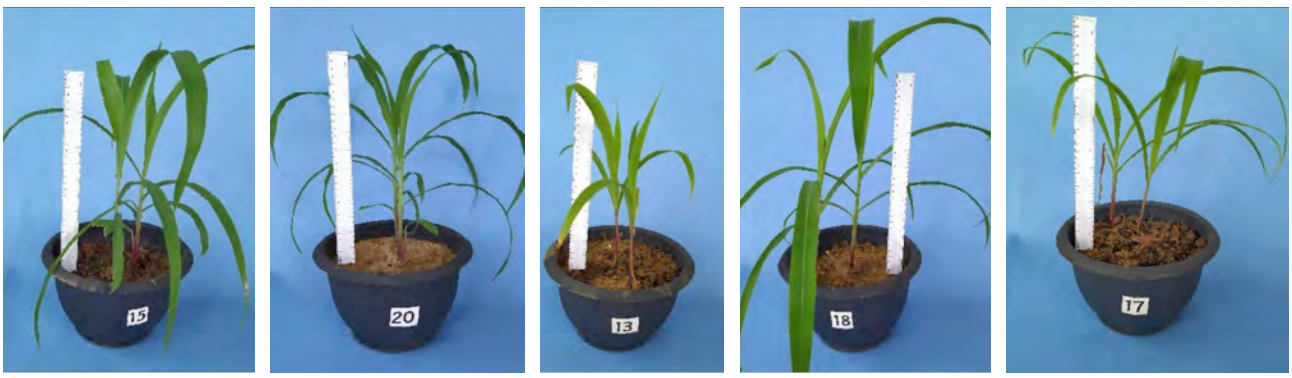
Germination is less sensitive than seedling growth to phytotoxic substances (Verma *et al*. 2012). Therefore, relative radicle growth (RRG) and germination index (GI) are more sensitive indicators of phytotoxicity of composts.

Relative radicle growth (RRG)

The radicle of a germinating seed emerges first, coming into contact with any phytotoxic compounds in the substrate. Thus, radicle length is very sensitive to extracts (Verma *et al*. 2012). The lowest RRG was observed in the treatment with elephant dung only, which could be due to the slow breakdown of existing phytotoxic compounds in dung composted without additions. Adding urea or EM showed greater RRG and adding both, the highest RRG, indicating the least phytotoxicity was achieved by adding both urea and EM to elephant dung.

Germination index (GI)

GI is a common and sensitive biological indicator for assessing phytotoxicity and maturity (Bougnom *et al*. 2020). We observed, higher GI values in treatments with urea than without, which suggests that adding urea overcomes phytotoxicity and promotes the maturity of compost. Dung without additions had the lowest GI value, even though it had a higher germination percentage than when only EM was added. This suggests that root growth was restricted due to inhibitory substances that remained at the end of the 45-day period, when elephant dung was composted without additions. Germination index values greater than 80% indicate maturity and the lack of toxic effects of compost (Bougnom *et al*. 2020). Based on an 80% cut-off value, all of the treatments showed maturity and lack of phytotoxic compounds by 45 days.



Treatment 1 Treatment 2 Treatment 3 Treatment 4 Treatment 5

Figure 6. Plant growth bioassay after 40 days growth.

Seedling tolerance index (STI)

Soluble salts affect root growth of seedlings (Sujatha *et al*. 2017), therefore root length could be influenced by the salinity of the growth medium. The lowest seed tolerance index (STI) was recorded in urea only treatment and the highest in EM only treatment, with a mid level value observed when both urea and EM were added. This suggests a negative impact of urea and a positive impact of EM on root growth.

Plant growth bioassay of different treatments

Growth rates between treatments were similar during the first 20 days. This is possibly due to initial shoot and root growth being dependant on seed reserves (Nadeem *et al*. 2011). Plant heights of treatments differed in the last 20 days, which may be due to effects of phytotoxic substances in compost. Plant height was lowest at 40 days, with dung composted without additions, and those with added urea the highest. This also suggests the slower decomposition of elephant dung alone. Also, application of unstable composts can cause low plant growth and damage crops by competing for oxygen (Mupondi *et al*. 2006). On the other hand, compost with EM only had higher plant height than only dung and the compost with urea the highest. Therefore, EM and particularly urea treatment of elephant dung, has a positive impact on plant growth.

In conclusion, this study shows the possibility of rapid composting of elephant dung by treating with EM and urea in around 40 days as opposed to composting without treating which would take longer. The highest decomposition rate and the lowest level of phytotoxicity occurred in elephant dung treated with both urea and EM, hence it is the best suited for rapid composting of elephant dung.

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Elephants at the PEO.

Research Article Gajah 55 (2022) 30-39

Size-Age Class Scale for Asian Elephants

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Abstract. Population structure provides important information for managing and conserving free ranging Asian elephant populations. A variety of size-age classes, based on estimating height or age and measuring captive animals of known age, have been used previously. Here we propose a simple scale, using the individual's height relative to an adult female. We also indicate morphological characters of relevance, where determining relative height maybe an issue, as in the case of adult males.

Introduction

Elephants have potential life spans exceeding six decades and an extended period of growth and maturation. Therefore, elephants are among a handful of species, where body size can be used to delineate a number of age classes. Asian elephants (*Elephas maximus*) have a gestation period of around 22 months, the longest of any mammal (Hildebrandt *et al.* 2007). Consequently, at birth elephant offspring are comparatively large, fully formed and functional. Female Asian elephants start reproducing around 10–15 years of age (Mumby *et al.* 2015; Pushpakumara *et al.* 2016; Mendis *et al.* 2017). While males also become capable of reproduction around this age, they may not become reproductively active till later, due to social immaturity (Eisenberg & Lockhart 1972).

Population health is an important indicator for the conservation and management of wild populations. Asian elephants tend to occupy human-dominated habitats with poor visibility and actively avoid people due to conflict with them (Fernando 2000). Therefore, assessing the health of free ranging Asian elephants can be challenging. Body condition scoring based on a visual scale (Fernando *et al.* 2009) reflects relative fat mass (Chusyd *et al.* 2019). It is a useful indicator of short-term health and resource availability (Ranjeewa *et al.* 2018; Liyanage *et al.* 2021). However, population structure is a better indicator of long-term population health, as it reflects changes in reproductive output and survival over a period of years. It facilitates assessing the conservation status and viability of elephant populations and in detecting impacts of environmental events such as droughts and vegetation succession. Demographic data also enables monitoring impacts of anthropogenic habitat alteration, fragmentation and loss, hence of management actions such as habitat enrichment, elephant drives and movement restriction by electric fencing.

Assigning free ranging individuals to size-age classes is essential for cross sectional and short-term studies. Decades-long studies with individual identification can provide annual age structures, but still need to assign ages to individuals present at the studies' commencement. A few studies based on individual identification of free ranging African elephants have spanned over a decade (Moss 1988; Turkalo *et al.* 2018). In contrast, demographic information on Asian elephants has been based on shorter-term studies with and without individual identification (Eisenberg & Lockhart 1972; McKay 1973; Kurt 1974; Sukumar 1989; de Silva *et al.* 2011, 2013), and on records and measurements of captive elephants (Kurt & Kumarasinghe 1988;

Sukumar *et al.* 1997; Mumby *et al.* 2015; Pushpakumara *et al.* 2016).

Growth

Growth in elephants extends over many years, with height at birth being around 40% of adult size. Males and females achieve about 90% and 95% respectively of their adult height by age 15 (Mumby *et al.* 2015). Early literature on elephants suggested indeterminate growth or a secondary growth spurt (Laws *et al.* 1975; Sukumar *et al.* 1988). However, recent studies have shown that elephants also conform to determinate growth, which is the norm in mammals (Mumby *et al.* 2015).

Number of size classes

Change in height occurring over many years facilitates assignment of individuals to size-age classes. The number of classes used in previous studies of elephants has varied widely, ranging from 4 to 21 (Table 1).

The higher the number of classes, the more likely changes in age-specific survivorship can be detected. With increasing number, class width narrows and natural variation in height can result in greater overlap of heights between age classes. Consequently, incorrect assignment of individuals becomes more likely. Hence there is a trade-off between the number of size-age classes and unambiguous assignment. Additionally, with narrower size-age classes, reproductive stochasticity is likely to cause varying numbers of individuals in classes, which maybe confused with differences due to age-specific survivorship. Conversely, with fewer hence wider classes, the chance that differences could be missed is greater, particularly if they are transitory, affecting cohorts of one or a few years. As generalist herbivores, elephants are fairly resilient, especially as adults. Factors such as food scarcity due to drought, habitat loss or range restriction, causing malnutrition and increased disease susceptibility, are likely to disproportionately impact the younger age groups. Therefore, having the maximum number of size-age classes of younger age groups, to which individuals can be assigned with confidence, is desirable.

Height variability

Height in humans has an approximately normal distribution with a coefficient of variation of around 4.25, which means the heights of 95% of the population will be within a range of ±8.5% of the mean (Roser *et al.* 2019). Other species may have somewhat greater height or body length variation than humans (McKellar & Hendry 2009) but should have approximately normal distributions once controlled for sexual

Table 1. Number of size classes and method of assignment of Asian elephants in selected studies. M = male, F = female, 'Comparative height' = height assessment in relation to an adult female.

Study	Number of size classes			Method
	Total	Adult	Non-adult	
Eisenberg & Lockhart (1972)	4	1	3	Height
McKay (1973)	4	1	3	Height
McKay (1973)	9	M2, F1	7	Comparative height
Kurt (1974)	9	2	M7, F6	Comparative height
Kurt (1974)	4	1	3	Comparative height
Sukumar (1989)	12	5	7	Height
Arivazhagan & Sukumar (2008)	4	1	3	Height
Arivazhagan & Sukumar (2008)	6	1	5	Comparative height
Arivazhagan & Sukumar (2008)	21	M5, F4	16	Height
de Silva *et al.* (2011)	5	1	4	Comparative height
This study	6 (7*)	1 (M2*)	5	Comparative height

*Optional division of adult males into 2 classes.

and/or phenotypic polymorphism. Scatter in the age-height charts of captive elephants by Sukumar *et al*. (1988), Kurt & Kumarasinghe (1988) and Mumby *et al*. (2015) suggests that individual variation in height in elephants is similar to or greater than in humans. While constructing annual size-age classes are the ideal for assessing age structure, it is not practical to do so based on height, due to its inherent variability.

Genetics is likely to be the main determinant of intra-population variation in height. Height has a high heritability in humans and horses with a complex polygenic inheritance (Allen *et al*. 2010; Signer-Hasler *et al*. 2012) and can be assumed to be similar in other mammals. Inter-population variation may lead to particular populations of a species being noticeably different in size. In elephants, height variation between populations may be more than within a population (Kurt & Kumarasinghe 1988). Population level variation in height may occur due to genetics, evolutionary history (Cavallini 1995) and environmental factors (Yom-Tov *et al*. 2006).

Method of assignment

Free ranging elephants can be assigned to size-age classes based on height estimation through photographic methods (Arivazhagan & Sukumar 2008) or footprint measurements (Eisenberg & Lockhart 1972). A more commonly used alternative is to use relative height, by comparing an individual with an adult female (Table 1). Arivazhagan & Sukumar (2008) found assignment by photographic estimation and relative height to give comparable results in the field. However, height estimation of free ranging elephants is difficult, while scaling in relation to an adult female is relatively easy due to their adult female centric social organization. Scaling of height in relation to the mother (Turkalo *et al*. 2018) or an adult female in the group, controls for intra- and inter-population variation, as opposed to actual measurement and assignment in relation to a reference.

Nomenclature

Calf/new-born/infant/neonate

The word 'calf' is used to denote young of cattle and other animals as a general term. In cattle it is also used explicitly to refer to a specific age class from birth to weaning (8–9 months). In humans the term new-born/neonate is used from birth to 4 weeks and infant from birth to 1 year (MedicineNet.com). The terms calf, new-born, infant and neonate have been applied to elephants with wide variation (Table 2) and mostly without explaining the rationale, making their use confusing.

Juvenile

The term 'juvenile' is used in humans for those up to 18 years. In animal studies it is mostly used as a general term to refer to individuals that are not adult. In contrast, in elephants it has been used to denote a specific size-age class, but with wide variation in ages assigned (Table 2).

Sub-adult

The term 'sub-adult' is sometimes used to denote all ages below adult (Stull *et al*. 2021). The commoner use of the sub-adult moniker is as a specific non-adult category. In this usage, it denotes individuals that are morphologically but not functionally adult, where adult functionality is defined as being reproductively active. This usage has been applied across taxa, ranging from fish to birds and mammals. However, in elephants, the term sub-adult has sometimes been applied to animals of ages with juvenile morphology and not reproductively active, as well as those with adult morphology and are reproductively active (Table 2).

Estimated age of first reproduction in free ranging Asian elephant females is around 10–18 years (McKay 1973; Sukumar 1989; de Silva *et al*. 2013). As there have been no long-term field studies, confirmed age of first reproduction is available only for captive Asian elephants. The mean age of first reproduction of 7 captive-born females at the Pinnawala Elephant Orphanage, Sri Lanka was 12.5 ± 0.5 years (Pushpakumara *et al*. 2016) and in 416 captive-born females under Myanmar Timber Enterprise, Myanmar, it was 19.48 years (Hayward *et al*. 2014). An endocrine study of 11 females aged 3.5–15 years (age estimated at arrival as orphans for 9 individuals, 2 individuals captive-born) at the Pinnawala Elephant Orphanage, found 6 females aged 5.5–12 years, cycling at the commencement of the study and 4 to start cycling during the study at 4.5, 5.5, 7.5 and 15 years of age (Mendis *et al.* 2017). Age of puberty is related to nutrition (Schillo *et al.* 1992) and may occur at a younger age in captive elephants due to better nutrition. However, the mean age of first reproduction of the same Pinnawala Elephant Orphanage population was 14.6 ± 0.7 years (Pushpakumara *et al.* 2016). Therefore, age of first conception in captivity appears to occur well after puberty, whereas in the wild it is likely to be at or soon after, as males have unhindered access to females coming into oestrous. This creates an issue in the use of the term 'sub-adult' for female elephants, as those aged 10–15 years are likely to be functionally adult but since they continue to grow in height till about 15 years (Mumbi *et al.* 2015), they are not strictly morphologically adult.

Males are also likely to go through puberty around 10 years of age. However, in the wild they may not get to mate for over another decade, due to dominance of older males and female choice (Eisenberg & Lockhart 1972). Males continue to grow in height till at least 20 years (Mumbi *et al.* 2015). Therefore, males aged 10–15 years are physiologically adult, but not functionally or morphologically adult, hence the term 'sub-adult' appears well suited to them.

Adult

Adults are generally defined as those that are fully-grown and are reproducing. Most previous studies on elephants have used a single size class for adults (Table 1). Subdivision of adult elephants into multiple size-age classes has been based on assumed growth in height till about 40 years in females and 40+ years in males (Arivazhagan & Sukumar 2008). However, female elephants reach 95% of their height by 15–16 years age and males by 21 years (Mumbi *et al.* 2015). Therefore, division of adults into multiple size-age classes based on height appears unwarranted.

Table 2. Size-age classes used by selected studies on Asian elephants (M = Male, F = Female, AF = Adult Female).

Study	Calf/New-born/Infant/Neonate			Juvenile		Sub-adult		Adult	
	Term	Age	Size	Age	Size	Age [years]	Size	Age [years]	Size
Eisenberg & Lockhart (1972)	Calf	0–14 months	91–120 cm	14–40 months	121–150 cm	F 3.5–7 M 3.5–9	F 151–180 cm M 151–210 cm	F > 7 M > 9	F >183 cm M >210 cm
McKay (1973)	Infant*	–	<120 cm	–	F 120–180 cm* M 120–200 cm	–	F 180–200 cm M 200–220 cm*	–	F >200 cm M >220 cm
Arivazhagan & Sukumar (2008)	Calf	0–12 months	F <119 cm M <121 cm	1–5 years	F 119–170 cm M 121–180 cm	5–15	F >170–213 cm M 181–235 cm	>15	F >213 cm M >235 cm
Kurt (2009)	Neonate Infant	0–2 years 3–4 years	–	5–10 years	–	11–15	–	>15	–
de Silva *et al.* (2011)	New-born Calf	0–6 months 0–36 months	up to AF belly up to AF chin	3–7 years	up to 50% of AF height	8–12	up to AF height	>12	–

* Developmental/behavioural characters also given.

Table 3. Definition of the size classes proposed in this study. See also Figures 1 and 2.

Class	Name	Reference point on a fully-grown adult female: Lower bound	Reference point on a fully-grown adult female: Upper bound	Approx. age [years]
1	Juvenile I	–	chest*	0–1
2	Juvenile II	chest*	lower border of neck	1–3
3	Juvenile III	lower border of neck	lower border of eye	3–6
4	Juvenile IV	lower border of eye	upper border of nasal protuberance**	6–10
5	Sub-adult male Adult female	upper border of nasal protuberance**	shoulder top	10–15
6	Adult male	shoulder top	–	15 +

* the inferior margin of chest wall and not the breasts

** the point of the angle between the nasal protuberance and the forehead

Proposed scale

The scale presented here is based on shoulder height. The defining height limits of a size-class are related to specific points on an adult female and virtual horizontal lines through those points provide the reference limits for each class (Figs. 1–3). Given that the difference in height from birth to 20 years is about 1.5 m, we divide elephants into 6 or 7 size classes. This gives a scale with fairly wide intervals, reducing overlap. The classes have more or less equal increases in height. Age-width attributed to each higher class is progressively wider (Table 3) to account for the slowing of growth with age.

Adult female

The mismatch between functionality and morphology in elephants creates an issue in terminology. Giving precedence to function over stature, we define an adult female as one that is reproductively active. In the field, any female with an offspring is identified as an adult. However, this results in the adult female class consisting of 'fully-grown' and 'not fully-grown' individuals, creating some contradiction in terminology.

A fully-grown adult female should be selected for use as a standard for relative height comparison. Field identification of fully-grown adult females is based on the presence of two or more offspring or post-reproductive (as indicated by not having any dependant offspring and empty breasts with elongated nipples, see Figure 4) or being one of modal height in a group with multiple adult females. In a multi-female group, the majority of adult females would fulfil the above criteria. Typically, multiple females are used as 'standards' in assigning members of a group to size classes. Obviously, any female that fulfils above criteria, but is atypical in height, should

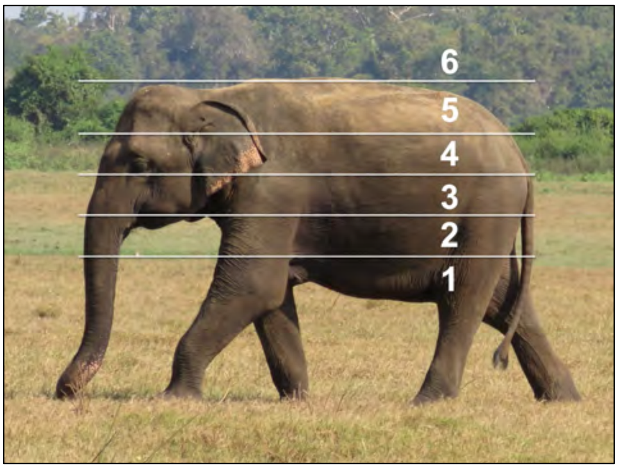

Figure 1. Adult female with lines indicating the boundaries between size classes.

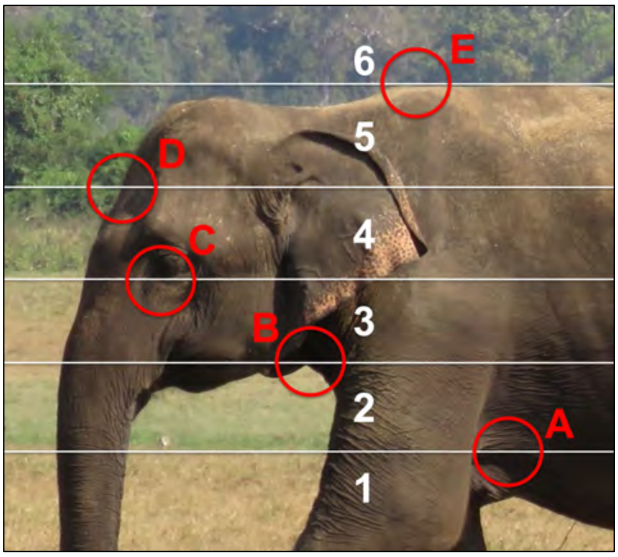

Figure 2. Points A–E (red circles) to set the boundaries (white lines) between size classes 1–6 on an adult female (see Table 1).

not be used as standard. As some of the reference points for the defining lines are on the head (Fig. 2), the head should be in a 'neutral' position, i.e. not looking up or down, when the assessment is made.

We recommend assignment be based on photographing elephants in the field and subsequent analysis, rather than direct visual assessment in the field. Ideally individuals should be photographed when standing on level ground next to a fully-grown adult female.

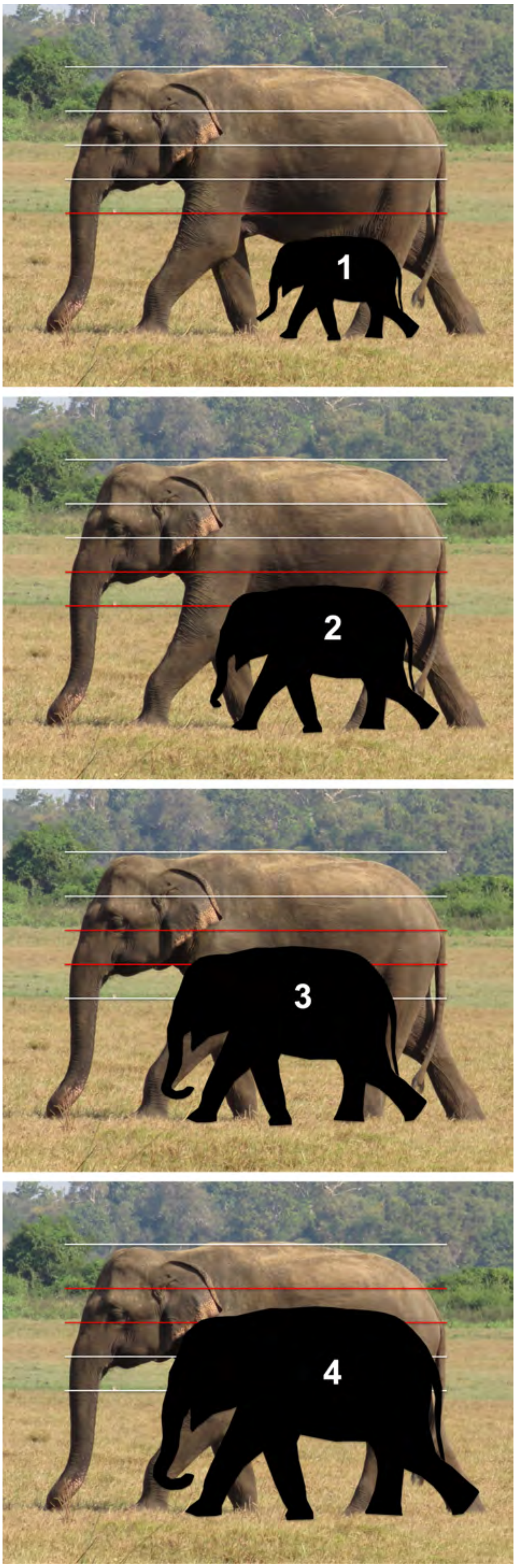

Figure 3. Size class scale with juveniles from size classes 1–4.

Juveniles

Juveniles are those in size classes I to IV (Table 3, Fig. 3).

Sub-adults

Females: The term sub-adult is not used for females. Therefore, females transition directly from juvenile size 4 to adult. Consequently, size 5 females are considered adult.

Males: Size 5 males are considered 'sub-adult'. Although post-pubertal, sub-adult males are socially immature and may display 'moda-musth' characterised by differences in chemical composition and mellifluous odour, as opposed to the malodorous odour of adult-musth secretions (Rasmussen *et al*. 2002).

Adult males

Adult males are those that are taller than an adult female.

Figure 4. Post-reproductive female. Note the empty breasts and elongated nipples.

Table 4. Characters for sub-dividing adult males.

Character	Young-adult	Mature-adult
Head		
Proportion head:body	Similar to adult female's	Proportionately larger
Parietal domes	Not well developed	Pronounced
Nasal protuberance	Not well developed	Pronounced
Trunk base	Narrow	Broad
Penis		
Penile bulge	Not prominent	Prominent
Penis shape	Slender	Bulky, venation prominent
Musth		
Urinating	Penis often extruded	Penis not extruded
Duration	<30 days	>30 days
Temporal discharge	Mild – moderate Mellifluous*	Copious, with staining of cheeks Malodorous*
Urine dribbling	None or spotty	Continuous, with staining of legs

* Rasmussen *et al*. (2002)

'Young-adult' and 'mature-adult' males

Males continue to grow in height into their twenties, gain in mass throughout their life (Mumby *et al*. 2015) and develop secondary sexual characteristics gradually. Therefore, adult males could be sub-divided into two size-age classes as 'young-adult' and 'mature-adult', representing the approximate ages of 15–25 and 25+ years, respectively. This would be useful for some studies, as there are likely to be behavioural differences between the two groups.

While mature-adults would be taller than young-adults, height comparison is not easy in males as they are often solitary. Young-adult males are characterised by secondary sexual characteristics that are relatively less developed (Table 4, Figs. 5–10). Characters such as increased folding of the superior border of ears, de-pigmentation, and tusk growth (Arivazhagan & Sukumar 2008) can also provide some indication of maturity but tend to be very variable. Individual variation also occurs in the characters listed in Table 4. Therefore, the assignment of individuals as young-adult or mature-adult should be done in consideration of a majority of the characters listed in Table 4 rather than just one or two of them. Since the categories are very broad, it should still be possible to assign individuals with confidence.

Figure 5. Mature adult male, adult female, young adult male (from left to right). Note the respective differences in heights and the head:body proportions and development of the three individuals.

Figure 6. Young adult male. Note small head and slender penis. Parietal domes, nasal protuberance and trunk base not well developed.

Figure 7. Mature adult male. Note the large head, prominent parietal domes, nasal protuberance and penile bulge.

Additional notes

Height estimation is ideally done in relation to the mother. However, mother-offspring pairs can only be identified with certainty for size classes I and II. For size classes III and IV, if the mother cannot be identified, which is particularly likely in the case of male offspring, any fully-grown adult female in the group can be used for comparison. For offspring of adult females that are not fully-grown, height is ideally assessed relative to a fully-grown adult female in the group, and not the mother. This creates a problem if an adult female that is 'not fully-grown' is observed with her offspring but without other adult females nearby. However, such observances are likely to be infrequent and in long-term studies the assignment can be corrected, as they are likely to be observed in larger groups at other times.

Figure 8. Mature adult male. Note the prominent parietal domes and nasal protuberance. However, the head is small in proportion.

While it may not be possible to obtain comparative height of all individuals at a single encounter, this scale can be easily applied to studies where repeated observations of the same individuals can be made, as detectable change in height occurs over months to years.

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Figure 9. Typical copious temporal discharge of mature-adult male in musth. Also note the prominent parietal domes and fairly developed nasal protuberance.

Figure 10. Mature adult-male in musth. Note the extensive urine dribbling, wetting and staining of the rear legs, prominent nasal protuberance and parietal domes, and broad trunk base. However, the temporal discharge is mild.

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The First Twin Birth at Pinnawala Elephant Orphanage, Sri Lanka

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Introduction

The Sri Lankan elephant (*Elephas maximus maximus*) is one of the four subspecies of the Asian elephant and is listed as endangered (IUCN 2021).

The Pinnawala Elephant Orphanage (PEO) was established by the Department of Wildlife Conservation (DWC) in 1975 to take care of wild elephant calves that were orphaned (Rajapaksa 2007). It was started with five such calves (DNZG 2020). In 1982, its administration was transferred to the Department of National Zoological Gardens (DNZG 2020). The Elephant Orphanage received calves orphaned in the wild through the DWC till 2013 after which the DWC promoted the program of caring for them at the Elephant Transit Home in Udawalawe and returning them to the wild. The PEO currently cares for 75 elephants, consisting of 34 males and 41 females (DNZG 2022).

The main objective of the PEO is the conservation, breeding and welfare of Sri Lankan elephants. A captive breeding program has been in place since the beginning of the PEO. The first elephant born at the PEO, "Sukumali", a female, was born in 1984 (DNZG 2022). There have been many successful births at the facility, with 75 captive births so far. The highest number of births in a single year was recorded in 2011, with 17 births (DNZG 2022).

On 31st August 2021, PEO reported its first twin birth (DNZG 2022). In Asian elephants, twin births are rare and have been mainly observed in captivity (Pastorini *et al*. 2020). The first twin birth recorded in Sri Lanka was from the wild and was recorded from Minneriya National Park in 2020 (Pastorini *et al*. 2020).

Breeding at the PEO

Elephants at PEO are managed as a herd and individually. The herd comprises of females and males up to around 10 years old. Males are then separated from the herd and cared for individually. Adult males have no access to females under normal management. Mahouts identify female oestrus by observing changes in the behaviour and external signs. The main behavioural signs looked for are, the female approaching a male and turning her back to him, or the male following a female and touching the vagina with the trunk. The main external sign looked for is discharge from the vagina. To maintain an optimal population size, active intervention to mate oestrus females is regulated. To prevent inbreeding, pedigrees of the oestrus females are examined and candidate males are selected for mating. PEO has more elephants originating from the wild than captive borns. Consequently, pedigree analysis does not indicate non-mating between most males and females. A pair for mating is chosen according to the elephants' behaviour. Some females avoid some males and some males or females attack certain males or females. For example, the female Manika does not accept any male in the PEO, and the female Mayuri attacks other elephants. Consequently, although both are of wild origin but are not used for mating. Similarly, a male's behaviour such as aggressiveness and preference towards particular females is considered, based on experience of the staff. When breeding a female in oestrus is desired the chosen male is released to the herd at the free-roaming area and river Ma Oya or the female and male are taken to an isolated area if the male is aggressive. Sexual contact with the female can last from 3 days to a week or more. Sometimes, if there are additional matching males to the female in oestrus,

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the males are switched each day but only one male is put in at a time.

The parents of the twins

The mother of the twins is "Surangi" and the father is "Pandu", both of whom were wild born. When the twins were born, Surangi was 26 years old and Pandu was 17 years old. Surangi was brought to the PEO from Surangalgama, Trincomalee on 3rd December 1997 as an orphan about 1 year old. The twins are Surangi's second pregnancy. Her first born is a male named "Kanaka", born on 24th May 2011. Pandu was brought to the PEO from Settikulam, Vavuniya, on 26th September 2004 as an orphan about two months old. This twin birth is the first time Pandu fathered any offspring.

Surangi became pregnant through a mating intervention conducted in 2019. Pandu and Surangi successfully mated on 14th December 2019, which was the only successful mating recorded by Surangi this time.

Birth of the twins

Signs of pregnancy were not seen in Surangi until near the end of the gestation period. However, once pregnancy was suspected, she was separated from the herd and kept in a special room two weeks before delivery (Fig. 1). A few hours before delivery, she showed an unusual brownish vaginal discharge. At 4:50 am on the 31st August 2021 Surangi delivered a calf (Fig. 2). The placenta is usually expelled a few hours after delivery. However, in this case, it did not happen for about three hours after delivery. The staff tried to get the calf to suckle from the mother for about three hours after birth by lifting the calf behind its forelimbs so that the calf's mouth touched the mother's nipple, but it was unsuccessful. Unexpectedly the mother delivered another calf at 10:12 am (Fig. 3). The mother tried to break the embryonic sac by kicking it and the staff quickly moved her away, safely broke it and took the calf out. After about an hour of the second calf's delivery, the placenta was discharged (Fig. 4). Presumably the twins shared the placenta.

Figure 1. Mother Surangi 13 h before the twin births.

Figure 2. Shortly after giving birth to the first calf (Sajjana).

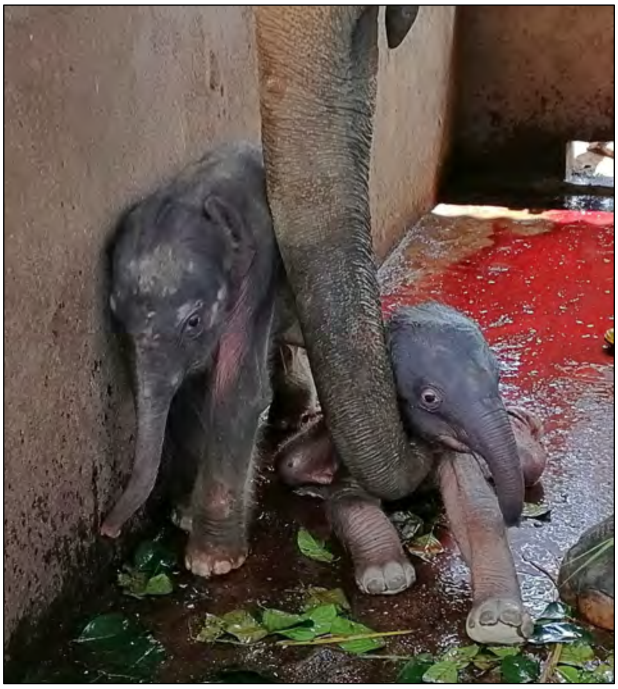

Figure 3. Shortly after giving birth to the second calf (Disa).

Figure 4. The placenta.

The elder of the twins was named "Sajjana" and the younger "Disa". Both calves were males, but their body size was relatively small compared to other calves. The birth weight of the elder calf was 67 kg, while the younger was 55.5 kg. In comparison, the birth weights of 20 calves at the PEO (14 male and 6 female) were 83.1 ± 4.6 kg (range 49–114 kg) for males and 82.8 ± 8.4 kg (range 50–103 kg) for females (Pushpakumara *et al*. 2016). The elder calf was about 10 cm taller than the younger (Fig. 5, 6 & 7).

Figure 5. On the evening of the day of birth.

Figure 6. Third day after birth.

Care of the calves

Both calves were a little weak at birth and at the lower end of normal weight and height. Initially, they had difficulty suckling because they could not reach the mother's breast due to insufficient height. The mother's milk was also thought to be insufficient to feed the two calves. In the first three days after birth, the staff milked the mother and fed the calves using a saline tube (Fig. 8). Then a bench around 20 cm in height was made, so that the calves could get on it and suckle (Fig. 9). The first to use the bench to suckle was the younger calf and then the elder calf also adapted.

However, by seven days after birth, both calves had lost some weight and the elder calf's weight was 66.4 kg and the younger calf 52.8 kg. Several attempts were made to give the twins milk formula for 2-year children, but they did not

Figure 7. Fourth day after birth.

Figure 8. Mahouts feed the calves using a rubber tube.

take it. Eventually, a soya milk formula was found which they accepted. Subsequently the two calves have been suckling together on either side of the mother at the same time and in addition feed on soya milk formula three times a day.

The mother was observed hitting the younger calf with the trunk and kicking, when the twins were around two weeks old, presumably rejecting him. Even at 10 months old, the mother sometimes tries to reject the younger calf. The staff pays close attention to the younger calf and reprimands the mother when she tries to hit him. Due to the quick response of the staff, any adverse result has been avoided.

Issues such as small size, low birth weight, feeding problems and rejection by the mother as observed with the PEO twins, may contribute to the rarity of twins observed in the wild.

On 6th January 2022, the 4-month-old twins went to the river Ma Oya to bathe with the mother for the first time (Fig. 10). When they were 7 months of age, they adapted to solid foods by sampling the food provided to the mother (Fig. 11).

Most external features of twins are similar to each other, but a few features differ. The elder calf is a little taller. The tail of the younger calf is longer and has more hair at the end. There are slight differences between the two in the ear folds with the folds in the younger calf on left and right ears being different (Fig. 12).

On 20th February 2022, the elder calf's weight was 131 kg, and the younger calf's 105 kg. At 10 months old they are living healthily under care of the PEO. The twins will be released to the main herd at PEO very soon.

Figure 9. Younger calf getting on the bench and suckling from the mother.

Figure 10. Twins enjoying the river bath.

Figure 11. Twins trying to sample the solid food provided to the mother.

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Figure 12. Elder calf Sajjana (top) and younger calf Disa (bottom).

Short Communication

Gajah 55 (2022) 45-49

Feeding Behaviour of Asian Elephants in Northern Odisha, India

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Introduction

Elephants are regarded as mega-herbivores and consume up to 150 kg of food per day (Samansiri & Weerekoon 2007). They are non-ruminants and exploit microbial action for the digestion of cellulose in the caecum and colon (Clemens & Maloiy 1982). In elephants, a rapid rate of passage through the gut enables consumption of large quantities of forage (Roy 2010). The availability of plant species in a habitat determines the carrying capacity for elephants. Elephants do not have specialised diets and consume a variety of plants but factors such as nutritive value and toxicity of plants influences the selection of food plants. Different plant types contribute different percentages of their diets (Pradhan *et al*. 2015). The trunk acts as an efficient screening instrument to distinguish between palatable and non-palatable forage. Surveys on the food plants of Asian and African elephants have shown that the types and amounts of plant species in the diet vary from one area to another (Sukumar 1989, 1990; Pradhan *et al*. 2015). The present study documented fodder species for Asian elephants (*Elephas maximus*) in Odisha India.

Materials and methodology

Study area

Odisha is located on the east coast of India and is 155,707 km^2 in extent. It lies between latitudes of 17°47’N and 22°34’N and longitudes of 81°22’E and 81°22’E. Physiographically, the state can be divided into four regions consisting of the Eastern Ghats, Northern Plateau, Coastal Plains and Central Tableland. The northern area neighbours the states of West Bengal and Jharkhand.

The vegetation consists of tropical moist deciduous forest comprised of sal (*Shorea robusta*), asan (*Terminalia elliptica*), teak (*Tectona grandis*), arjun (*Terminalia arjuna*) and bamboo (*Bambusa* sp.). The study was conducted in five selected forests in the northern area, consisting of Kuldiha (21°25’57"N, 86°36’ 58’’E), Nilagiri (21°28’59"N, 86°46’06"E), Krishnachandrapur (21°49’42"N, 86°52’28"E), Badampur (21°44’21"N, 86°59’42"E), and Bhattchatar (21°54’59"N, 86°59’13"E). The temperature ranges from 38°C to 41°C during summer and in winter it goes below 7°C. The annual rainfall in Baleshwar is about 1565 mm and in Mayurbhanj about 1648 mm.

Methodology

The study was conducted from April 2017 – December 2019. Searches were conducted for elephants from early morning till dusk. Upon finding elephants feeding at a place, the plants on which they had fed were collected after they left. Trails taken by elephants were followed and plants on which the elephants had fed were also collected, Collected plant species were identified by use of field guides, Forest Survey of India reports, and the Botanical Survey of India and by consultation with Botanists. Fresh dung piles were examined to identify fruit species consumed by elephants. Undigested fruit remains such as seed, pericarp were used in identifying the species ingested.

Results and discussion

We observed 58 elephants and collected 200 dung boli from the field. A total of 136 species of plants belonging to 55 families were recorded as being consumed by elephants (Table 1). The

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percentages of dicotyledon and monocotyledon species were 93% and 7% respectively.

Asian elephants are known to feed on a wide diversity of plant species (Sukumar 1990; Samansiri & Weerakoon 2007; Mohapatra *et al*. 2012) African elephants were recorded to consume 133 plant species belonging to 41 families and 95 genera at Sengwa Reserve, Zimbabwe (Guy 1976). Asian elephants in Southern India were recorded to consume 112 plant species, out of which 25 species provided 85% of their diet (Sukumar 1990). Elephants in Rajaji National Park consumed 74% tree species, 14% grass species, 8% shrubs, and 4% climbers out of a total of 262 flowering plant species (Joshi & Singh 2008). Mohapatra *et al*. (2013) reported 71 plant species consumed by elephants in Kuldiha Wildlife Sanctuary, Odisha. Pradhan *et al*. found 110 plant species consumed in Satkosia Tiger Reserve and recorded that feeding of grass species (55%) topped the list, with trees (37%) shrubs (5%) and herbs (3%) also being consumed. In the Shangyong National Natural Reserve in Xishuangbanna, China, elephants consumed 106 plants (Chen *et al*. 2006). However, in Manas National Park elephants consumed only 18 different flowering plant species in the dry season (Lahkar *et al*. 2007). Of 143 species of plants found in the Chunati Wildlife Sanctuary in Bangladesh, only 17 were used by elephants (IUCN 2007). Therefore, our observations in Odisha are consistent with Asian and African elephant feeding on a large number and broad diversity of plant species as has been observed by most studies.

In Asian elephants only males carry tusks. We observed that males used their tusks to remove bark, whereas cows wrapped their trunk around tree branches and pulled them down so the bark could be removed. We observed elephants to consume fruits of mango, jackfruit, blackberry. and mahula (*Madhuca indica*). The dung analysis showed seeds of mango, jackfruit, bel, jastimadhu, mahula, palm, tamarind and blackberry.

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Table 1. Forest plant species. Parts consumed are indicated as L: Leaf, F: Fruit, S: Shoot.

Family	Scientific name	Local name	Parts consumed
Rutaceae	*Aegle marmelos*	Belo	L, F
	Citrus sp.	Jungli lemon	L, F
	Chloroxylon swieteni	Bheru	L
	Limonia acidissima	Kaitho	L, F
Phyllanthaceae	*Antidesma ghaesembilla*		L
	Antidesma acidum		L
Moraceae	*Artocarpus heterophyllus*	Panasa	L, F, S
Anacardiaceae	*Buchanania lanzan*	Bana badam	L, F
	Buchanania cochinchinensis		L
Phyllanthaceae	*Briedelia retusa*		L
Fabaceae	*Acacia ferruginea*		L, S
	Albizia odoratissima	Tantra	S
	Bauhinia vahli	Siali lata	L
	Butea superba	Budhuli	L
	Butea monosperma	Palasho	L
	Dalbergia sissoo	Sisoo	L
	Dalbergia latifolia		L, S
	Dalbergia paniculata	Barbakuliaa	L, S
	Desmodium oojeinensis	Bandhana	L, S
	Cassia fistula	Sunari	L
	Caesalpinia digyna		L
	Cajanus cajan	Harada	L, S, B, F
	Millettia racemosa	Gaharani lata	L
	Mimosa pudica	Lajkuli lata	Entire plant
	Pterocarpus marsupium	Bijaa	L
	Senegalia catechu	Khairo	L
	Soymida febrifuga	Ruhini	L
	Senna siamea	Chakunda	F
	Petrocarpus marsupium	Piasal	L, S, B
	Pongamia pinnata		L
	Tamarandus indica	Tentuli	L, S
	Vigna sp.	Bana biri	L
Poaceae	*Arthraxon hispidus*		Entire plant
	Arundinella setosa		Entire plant
	Arundinella pumila		Entire plant
	Bothriochloa bladhii		Entire plant
	Bothriochloa pertusa		Entire plant
	Brachiaria ramosa		Entire plant
	Brachiaria reptans		Entire plant
	Chloris barbata		Entire plant
	Chrysopogon fulvus		Entire plant

Family	Scientific name	Local name	Parts consumed
Poaceae	*Coix lacryma-jobi*		Entire plant
	Cymbopogon flexuosus		Entire plant
	Cyrtococcum patens		Entire plant
	Oryza sativa	Dhana	Entire plant
	Saccharum officinarum	Aakhu	Entire plant
	Sehima nervosum		Entire plant
	Setaria palmifolia	Talo ghaso	Entire plant
	Thysanolaena maxima	Phuljharu	Entire plant
	Themeda triandra		Entire plant
	Vetiveria zizanioides		Entire plant
	Zea mays	Makka	Entire plant
Apocynaceae	*Alstonia scholaris*	Genduli	L
	Cosmostigma cordatum		L
	Holarrhena pubescens	Kureyi	L
	Ichnus frutocarpescens	Paso	L
Oleaceae	*Chionanthus ramiflorus*		L
Combretaceae	*Anogeissus latifolia*		L
	Combretum decandrum		L
	Getonia floribunda		L
Euphorbiaceae	*Croton persimilis*		L
	Cleistanthus collinus	Gurikanthi	L
	Mallotus philippensis	Kmalagundi	L
	Macaranga peltata		L, S
Ebenaceae	*Diospyros montana*		Entire plant
	Diospyros melanoxylon	Kendu	L, F, B
Dilleniaceae	*Dillenia pentagyna*	Raii	L, F
Moraceae	*Ficus benghalensis*	Bara	L, F
	Ficus glomerata	Dumburi	L, F
	Streblus asper	Jeleri	L
Salicaceae	*Flacourtia indica*		L, S
Convolvulaceae	*Ipomoea aquatica*	Kalama	Entire plant
Lauraceae	*Litsea glutinosa*		L
	Litsea monopetala		L
Melastomataceae	*Memecylon umbellatum*	Nireso	L
Annonaceae	*Annona squamosa*	Aato	L, S, F
	Miliusa tomentosa		L
	Polyalthia cerasoides		L, S
Ochnaceae	*Ochna obtuse*		L
Malvaceae	*Helicteres isora*	Orola	L
	Sterculia villosa	Odal	L
	Bombax ceiba	Simili	L
	Kydia roxburgianna	Ban kapasia	L
	Grewia tiliaefolia	Dhamana	L
	Pterospermum acerifolium	Kanaka champa	L
Rubiaceae	*Ixora perviflora*	Lohajhuri	L
	Ixora pavetta	Telkurma	L
	Mitragyna parvifolia	Kadamba	L, S
	Pavetta indica		L
	Psychotria adenophylla		L
	Gardenia gummifera		L
	Morinda citrifolia	Noni	L
	Tamilnadia uliginosa		L

Family	Scientific name	Local name	Parts consumed
Sapindaceae	*Schleichera oleosa*	Kusumo	L, S
Dipterocarpaceae	*Shorea robusta*	Salo	L, S, R, B
Bignoniaceae	*Sterospermum colais*		L
Myrtaceae	*Syzygium cumini*	Jambu	L, S, B, F
Rhamnaceae	*Ziziphus jujube*	Bar koli	L, S, F
	Ziziphus oenoplia	Char koli	L, S, F
	Ziziphus xylopyrus	Ghonta	L, S, F
Salicaceae	*Casearia tomentosa*		L
	Casearia graveolens		L
	Flacourtia jangomas	Bhaincha	L
Sapotaceae	*Madhuca indica*	Mahulo	L, F
	Manilkara zapota	Sapeta	L, S, F
	Xantolis tomentosa	Jasti madhu	L, R
Smilacaceae	*Smilax zeylanica*	Muturi	L
Solanaceae	*Leea indica*	Pitchkundi	L
Vitaceae	*Ampelocissus latifolia*	Pani lahara	L
	Cissus quadrangulari	Hadabhanga	L
Anacardiaceae	*Lannea coromandelica*	Moi	L
	Mangifera indica	Ambo	L, S, F
	Semecarpus anacardium	Valia	L
Arecaceae	*Phoenix acaulis*		L
	Borassus flabellifer	Talo	L, R, F
	Cocos nucifera	Nadia	L, F
	Areca catechu	Gua	L, F
Combretaceae	*Anogeissus latifolia*	Dhaure	L, S
	Combretum decandrum	Atundi	L
	Terminalia arjuna	Arjun	L, S
	Terminalia tomentosa	Asana	L
	Terminalia bllirica	Bahada	L, S, F
	Terminalia chebula	Harada	L, S, F
Lecythidaceae	*Careya arborea*	Kumbhi	L
Phyllanthaceae	*Phyllanthus emblica*	Anala	L, S, F
Boraginaceae	*Cordia macleodii*	Koksa dumuar	L
Caesalpiniaceae	*Caesalpinia cucullata*	Pursinga	L
Zingiberaceae	*Alpinia* sp.	Kiya	Entire plant
Bromeliaceae	*Ananas comosus*	Sapuri	Entire plant
Cyperaceae	*Cyperus* sp.	Mutha ghaso	Entire plant
Symplocaceae	*Symplocos racemosa*	Budhikunthi	L
Flacourtiaceae	*Homalium nepalense*		L
Typhaceae	*Typha* sp.		L
Orchidaceae	*Eria bambusifolia*	Parijata	Entire plant
	Dendrobium sp.	Parijata	Entire plant
Annonaceae	*Miliusa tomentosa*	Gadha sal	L
Costaceae	*Costus speciosus*	Baspara ghaso	Entire plant
Burseraceae	*Garuga pinnata*		L
	Protium serratum		L
Magnoliaceae	*Michelia champaca*	Champa	L
Musaceae	*Musa paradisiaca*	Kadali	Entire plant
Dilleniaceae	*Dillenia indica*	Oou	L, F
Myrtaceae	*Syzygium samarangense*	Jamrul	L, S, F
Anacardiaceae	*Anacardium occidentale*	Kaju	L, S, F, B
Loranthaceae	*Loranthus* sp.	Malango	Entire plant

Census of Temple and Privately Owned Captive Elephants in Sri Lanka

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Introduction

Asian elephants (*Elephas maximus*) were tamed in Asia during the Indus Valley Civilisation (3300–1300 BC) (Sukumar 2003). Elephants were an integral part of society in ancient Sri Lanka (Deraniyagala 1955; Jayewardene 2013). A 1st century BC inscription at Navalar Kulam in Eastern Sri Lanka refers to a religious donation by 'Ath Acharia' or Master of the elephant establishment, indicating the presence of captive elephants. The Sanskrit Hindu epic Ramayana also mentions King Ravana from the kingdom of Lanka possessing elephants (Sukumar 2003).

In Sri Lanka, during ancient times elephants were used as royal mounts, in festivals, war, arena sports, execution of criminals, as diplomatic gifts and for hauling heavy items. Currently the main use of captive elephants is for religious-cultural processions called "pereheras" (Fig. 1). A few elephants are used for elephant rides for tourists (Fig. 2).

The last census of captive elephants in Sri Lanka was in 2002, which recorded 189 elephants. Here I report on a survey of elephants owned by private owners and temples. The survey did not include elephants from orphanages or zoos.

Methods

Information on the location of captive elephants was obtained through nearly two decades of records that were gathered at visits during festivals in which captive elephants participated. Also, by contacting elephant owners, veterinary surgeons and people enthusiastic about elephants, more information on the whereabouts of captive elephants was collected. Locations of captive elephants were visited and data on the individual elephants collected from 2018–2021.

Results and discussion

In 2018 a total of 117 elephants were recorded, consisting of 77 males and 40 females (Table 1). There were 19 tuskers among the males. There were 77 owners of elephants. Two male elephants and one female died in 2018 and three males and three females died in 2019–2021. As no additions occurred during this period, the number of elephants in 2021 was 108. During 2018–2021 one tusker died. Out of the remaining 18 tuskers 11 were of foreign origin, 3 being from India, 5 from Myanmar and 3 from Thailand. All foreign elephants were tuskers. Only one foreign elephant was privately owned and others by temples. The highest number of elephants owned by a single entity was 12 at the Sri Dalada Maligawa Temple in Kandy.

The privately owned foreign elephant was Nadumgamuwa Raja, also known as Vijaya Raja, owned by ayurvedic physician Dr. Harsha

Figure 1. Elephant taking part in a perahera.

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Table 1. Previous surveys of captive elephants reproduced from Jayewardene (2013).

Year	Survey	Males	Females	Tuskers	Total	Owners
1946	Department of Wildlife Conservation				736	
1950	P.E.P. Deraniyagala	225	211	16	452	
1955	P.E.P. Deraniyagala				670	
1970	Jayasinghe & Jainudeen				532	378
1982	Department of Wildlife Conservation	183	161	29	344	
1988	W.H. Ranbanda				400–450	
1994	Dr. Cheong	148	166		316	154
1997	Jayewardene & Rambukpotha	107	107	23	214	150
2002	Jayewardene	101	88	19	189	131
2018	This study	77	40	19	117	77
2021	This study	72	36	18	108	72

Dharmavijaya (Fig. 3). This elephant was one of the most celebrated captive elephants since he was the main casket bearer at the Kandy Esala Perahera festival. In Sri Lanka he was the second elephant to be declared as a national treasure by the President. Raja passed away on 7. March 2022.

The elephants were distributed among 12 districts as; Badulla - 6, Colombo - 18, Gampha - 16, Hambantota - 1, Kalutara - 7, Kandy - 18, Kegalle - 14, Kurunegala - 7, Matara - 5, Monaragala - 5, Polonnaruwa -1 and Ratnapura - 10.

Most of the captive elephants were located in the wet zone of the country, whereas the wild population is almost entirely in the dry zone. Even 50 years ago the wet zone districts of Colombo, Gampaha, Kegalle and Kandy had the highest number of elephants probably because more wealthy and aristocratic families resided in those districts (Jayasinghe & Jainudeen 1970). The staple food given to captive elephants in Sri Lanka, which consists of coconut leaves (*Cocos nucifera*), jak leaves (*Artocarpus hetrophyllus*) and kitul leaves/trunk (*Caryouta urens*), is relatively easily found in these districts.

Figure 2. Elephant used for a tourist ride.

During the Kandyan Kingdom (1469–1815) wealthy families in Kandy and surrounding districts possessed tame elephants (Jayewardene 2013). Prior to that, captive elephants were

Figure 3. Vijaya Raja alias Nadungamuwa Raja.

royal property and could only be owned by the king. During the Dutch period, local chieftains, who captured wild elephants for their colonial masters as tribute, were allowed to keep some for themselves (Jayewardene 2013). From then on, ownership of elephants has been considered a status symbol. The last permits for capturing of elephants were issued under the request of Minister P.B. Kalugalla in 1975 and since the Minister was from Kegalle, many permits were given to people of Kegalle.

The captive elephant population has been decreasing continuously (Table 1). The reason for this is that elephant capture was banned in 1975 and the only way to obtain elephants for private ownership was from the Pinnawala orphanage, which happened only occasionally. Many owners agree that breeding elephants in captivity should be done, yet are reluctant to do it.

Only two privately owned captive born elephants were recorded, one of them was a female elephant named Pooja born on 5th August 1986 to a female named Lakshmi, owned by Mrs. Samarasinghe from Kegalle and fathered by the male Kandula, owned by Mr. Kivulpane Ranbanda. The other was a male elephant named Bandara born on 13th October 1992 to a female named Kumari owned by Mr. Kamal Kithsiri from Kottawa and fathered by Vijaya from the Pinnawala Elephant Orphanage. Previously, Kumari was mated by a male elephant named Raja and gave birth to Jayathu in 1975, but he died in 1980. In Sri Lanka, the law protects elephants and captures from the wild are illegal. However, there is insufficient vigilance about illegal capture and illicit trade in captured elephants occurs (Prakash *et al.* 2020).

Of five previous surveys that recorded the number of males and females, that in 1994 showed a higher female number, while an equal number of males and females were observed in 1997 and a higher number of males was observed in 2002 and this study (Table 1). Reasons for the current male bias maybe because addition to the temple and private captive population since 1975 has mostly been from elephants given away by the Pinnawala Elephant Orphanage, which are mainly males. Also, all foreign elephants owned by temples and private individual are tuskers, therefore males.

Considering the names given to elephants, the suffix “Raja”, which means ‘king’ in the vernacular, was the most common among male elephants with 14.91% (n = 17) thus named. Some prefixes of ‘Raja’ had conventional names like Vijitha, Jana, Surathala and Muthu as the prefix. Others had prefixes referring to the origin as in Indi for India, Miyan and Buruma for Myanmar, or the location of the elephant as in Kotte. The second most common male name was “Kandula” with 6.14% (n = 7). Kandula was the name given to the war elephant of King Dutugamunu (101–77 BC), a famous king in Sri Lanka. Among females, the most common name was “Menike” which means ‘gem’ in Sinhala, with 8.77% (n = 10) and the second commonest was “Kumari”, which means princess with 5.26% (n = 6). The third commonest was “Rani” which is a Sanskrit name for princesses, with 4.38% (n = 5).

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Faecal Cortisol, Haematological and Serum Biochemical Parameters in Captive Asian Elephants in Three Protected Areas of Madhya Pradesh, India

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Introduction

The Asian elephant (*Elephas maximus*), a charismatic 'flagship species', is threatened by extinction. The development of self-sustainable captive populations is important to prevent captures from the wild.

Most trained captive elephants in India are maintained by the Forest Department and used for purposes such as immobilisation of carnivores, visiting and patrolling protected areas. Captive populations continue to decline due to failure in reproduction, diseases, and poor husbandry practices (Sarma 2011).

Traditionally mahouts manage the captive elephants. However, the skills and quality of mahouts have declined due to reduced monetary benefits, which affect the welfare and management of captive elephants (Vanitha *et al.* 2011). Increased use of non-traditional, unskilled and inexperienced mahouts leads to stress of elephants, which makes them violent and could cause human casualties. Also, stress may negatively impact immunity, agility and strength (Hing *et al.* 2016).

Stress may be evaluated by analysis of excreted hormones, particularly cortisol, which is found in faeces, urine, saliva and tears. Cortisol secretion in elephants is diurnal, with the highest levels in early morning, decline throughout the day and increase after midnight (Paudel *et al.* 2016).

Methodology

The study was conducted on captive elephants in the Kanha, Bandhavgarh and Panna Tiger Reserves of Madhya Pradesh.

Blood and faecal samples were collected from 30 elephants consisting of 14 males and 16 females in different age groups, comprising of 9 calves, 9 sub-adults and 12 adults. Age groups were defined as calves <5 years, sub-adults, 5–15 years and adults >15 years. All the animals sampled were apparently healthy and one female was pregnant. None of the sampled males were in musth but 5 in post-musth.

Blood samples were collected from ear veins (Fig. 1) in sterile vacutainers containing EDTA as an anticoagulant for haematological studies and without anticoagulant for serum biochemical analysis. The serum was separated within 2–3 hours of blood collection and stored at 4ºC prior to analysis. Haematological values were assessed using a semi-auto haematology analyser (PG-6800), liver function and kidney function tests were done using ERBA diagnostic kits and semi-auto analyser mini CHEM 100, ARK diagnostics, Mumbai.

Freshly voided faecal samples were collected in a plastic container and stored at -20ºC prior to analysis of faecal cortisol metabolites (Fig. 2)

Figure 1. Collection of blood sample.

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Table 1. Faecal cortisol metabolite levels of 30 elephants in three Tiger Reserves (mean±SE).

Location	N	Sex		Age group			Total
		Male	Female	Calf	Sub-adult	Adult	
Kanha	10	265.3 ± 22.5	187.5 ± 56.2	220.0 ± 90.2	173.3 ± 96.1	272.7 ± 21.5	234.2 ± 27.4
Panna	10	252.3 ± 22.3	262.0 ± 36.1	176.7 ± 92.6	290.0 ± 12.7	277.0 ± 54.5	250.8 ± 16.8
Bandhavgarh	10	219.4 ± 23.4	168.7 ± 76.8	173.3 ± 96.1	272.7 ± 21.5	246.0 ± 35.5	232.2 ± 19.6
Total	30	245.7 ± 22.7	229.6 ± 44.1	190.0 ± 93.0	280.9 ±19.3	266.8 ±37.1	239.6 ± 12.2

using ELISA diagnostic kits (Cortisol Enzyme Immunoassay Kit, DetectX, ARBOR ASSAYS).

Results and discussion

Cortisol metabolite levels

The mean faecal cortisol metabolite levels observed from Kanha, Panna and Bandhavgarh were similar ($p>0.05$) (Table1). Estimates of faecal cortisol levels by Chichilichi *et al*. (2018) in Odisha, also found no significant variation between three free ranging populations, which however were higher than in captive elephants from a single location. Therefore, faecal cortisol may be similar in populations living in comparable circumstances.

We found no significant difference in cortisol metabolite levels between males and females (Table 1). Cortisol metabolites were significantly higher in sub-adults and adults than in calves (Table 1). Stead *et al*. (2000) reported higher levels of glucocorticoids in juvenile African elephants kept in small enclosures, compared to those housed in a large area. The elephants we sampled were kept under semi-captive conditions, but sub-adults were confined for training and used for patrolling in the dense forest areas inaccessible to vehicles. This may explain their having higher levels of cortisol metabolites among the three age classes in Panna and Bandhavgarh (Table 1). However, this pattern was not observed in Kanha, which also had high levels in calves, due to unknown reasons.

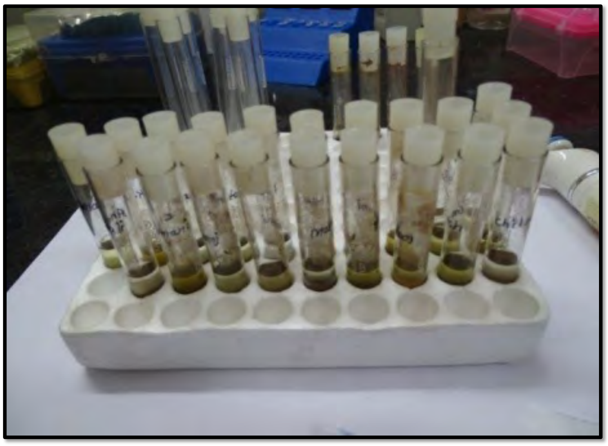

Figure 2. Preparation of faecal samples for cortisol analysis.

Haematological and biochemical parameters

Overall, elevated values of total erythrocyte, leukocytes and neutrophils as well as SGPT, SGOT, alkaline phosphatase and blood urea nitrogen were recorded (Table 2). High RBC and neutrophil counts may be correlated to secretion of glucocorticoids in stressful conditions (Benjamin 2013). Elevation of SGPT and SGOT may indicate parasitic infestation.

There were no significant differences between males and females in haematological and biochemical parameters ($p>0.05$, Table 2). Similar findings were observed by Silva & Kuruwita (1993), Wijesekera *et al*. (2008) and Jayamethakul *et al*. (2017).

The observed mean values of TLC, TEC, HB, HCT, monocytes and neutrophils were significantly above ($p<0.05$) normal values. Similarly,

Table 2. Haematological and biochemical values of male and female elephants.

Parameters	Male	Female
TLC (x$10^3\mu$l)	44.85 ± 9.39	46.79 ± 11.05
TEC (x$10^6\mu$l)	8.58 ± 0.61	7.40 ± 0.37
Monocytes (%)	5.50 ± 2.08	6.55 ± 2.02
Neutrophils (%)	59.55 ± 11.13	55.25 ± 8.05
SGPT (μg/l)	8.43 ± 1.24	7.43 ± 1.20
SGOT (μg/l)	42.15 ± 5.02	28.96 ± 4.46

Table 3. Age wise haematological and biochemical values (mean ± SE)

Parameters	Calves	Sub-adults	Adults
TEC (x10^6/μl)	4.40^b ± 0.47	9.01^{ab} ± 0.88	8.66^{ab} ± 0.71
HB (g/dl)	13.94^{ab} ± 2.77	17.35^{ab} ± 4.45	16.98^a ± 3.69
HCT (%)	43.66^b ± 4.95	58.73^{ab} ± 8.74	58.73^{ab} ± 8.74
Monocytes (%)	03.99^a ± 2.33	6.21^a ± 2.25	5.08^b ± 2.83
Lymphocytes (%)	41.22^a ± 10.07	74.88^b ± 11.43	63.91^a ± 8.59
Neutrophils (%)	44.88^a ± 7.03	68.22^b ± 9.63	65.00^a ± 13.73
SGPT (µg/l)	7.43^a ± 0.79	7.06^{ab} ± 0.87	7.1^a ± 1.52
SGOT (µg/l)	18.56^a ± 0.56	49.98^a ± 4.75	42.51^{ab} ± 5.29
Uric acid (mg/dl)	3.84^a ± 0.21	4.88^{ab} ± 0.17	3.99^a ± 0.25

^{a,b,c} Means with different superscripts are significantly different ($p<0.05$).

biochemical parameters, SGPT, SGOT, blood urea nitrogen, uric acid, alkaline phosphatase were significantly ($p<0.05$) higher than normal (Table 3). Possible reasons for increased haematological and biochemical values may be gastrointestinal parasitism and stress.

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"Mainao" – An Account of How Wildlife and People Continue to Get Caught in Our Struggle to Balance Livelihoods and Conservation

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A cold December night. Mist lies over the village of Kokilabari in the Baksa district of Assam as people take in the last traces of warmth before the winds douse the bonfires. Children are already half-asleep, and the lights fade from the porches of the villages one by one. Time approaches 9 p.m. and there is a zip and a zap – far out of the reach of the ears of sleep-lulled people. Little did they know, within less than 300 m of their boundary with Manas National Park, an elephant mother struggles to breathe her last dying breaths. The worse part? Her one-year-old calf is right beside her, standing witness to her death.

On the night of 3rd December 2021, a female elephant was electrocuted near the Kokilabari Seed-farm of Baksa, along the southern boundary of Manas National Park (MNP) in its easternmost range of Bhuyanpara. The reason was an illegally installed electric fence. MNP, which unfortunately doesn't have a buffer zone like Kaziranga National Park, has a shared boundary with a large area of paddy fields, agricultural plots, plantations and even backyards of people's homes in some villages. A small dirt road is what separates the protected and non-protected area. This close association results in a multitude of issues, human-wildlife conflict being the main one. People here have many strategies to deal with conflicts of this sort. The biggest conflict is with elephants, which occurs during the agricultural seasons, which roughly fall in the months of May-June to November-December.

It is a common occurrence during the fall or winter, for elephants to come out of their habitats, lured by the prospect of plentiful agricultural produce including numerous standing paddy varieties that Assam is famous for. On the other hand, people desperately try to protect the fruits of their hard labour. They use a number of tactics like fire torches, firecrackers, loud sounds with bamboo instruments and light. They spend many a night, freezing, on platforms commonly called machaans, made on high stilts or trees, while guarding their crops. Forest officials also remain vigilant all night, responding to calls of elephant stray-outs. Government installed electric fences in the central range (Bansbari) of MNP has brought down the number of incidents of human-elephant conflicts to an extent, but the eastern (Bhuyanpara) and western (Panbari) Ranges are still somewhat behind.

The next morning of the incident, forest officials from Bhuyanpara Range Office and Maozi anti-poaching Forest Camp (within 250 m of the incident) rushed to the spot where the villagers had already gathered. A gruesome scene awaited them. The body of the deceased lay on the ground with a thick aluminium wire near her head. The calf, beside the carcass of its mother, was scared and inconsolable. Villagers, officials from the department and conservationists gathered in the area and couldn't help but sob at the heart-breaking condition of the baby elephant. With tear-streaked cheeks, no one was entirely sure what they were witnessing. Was it a murder? Was it an accident? Is this survival? Is this injustice? No one could really answer. The calf struggled for a long time, shrieking in anger and being at times, quite violent towards the frontline staff trying to rescue her. After a tiresome ordeal, they were able to put her in a forest rescue vehicle (Fig. 1). She was immediately transported to the Hati Mahal Camp in Bansbari, a camp known very well for showcasing elephants with their mahouts.

The post-mortem was done on scene, the reason of death was confirmed to be electrocution and she was buried on the spot. After careful examination, it was revealed that she received a shock straight on her head in the front of her trunk. Failure of the central nervous system and haemorrhages in vital organs like heart, coronary vessels, brain and spinal cord revealed the impact of a severe electrical impulse, causing a few seconds of agonising pain and an almost instant death.

On the afternoon of 15th January 2022, I decided to visit the little orphaned calf. I was made aware that she was under rehabilitation in the same camp she was first taken to and under close observation by the park veterinarian. After a few calls with my supervisors and then the Range officer of Bansbari, I finally had the opportunity to see her. Standing among 5 other towering elephants, was this tiny (in elephant language) calf, eating fresh grass in the golden light of the setting sun (Fig. 2). The people who took care of her said they had never seen an angrier elephant calf before. She screamed for her mother for a week straight, sometimes through the entire night, having manic episodes of violence towards her caretakers so much so that they had to restrain her from harming anyone. But, through the anger, their hearts broke for this baby calf that just spent an entire night crying for her mother – who died right in front of her eyes. “We can’t even imagine what this little one went through… *Maakok amie marisu, eitya amie eir maak*” (Assamese translation: Since we have snatched her mother from her, we are her mother now)”, they sigh. Her primary caretaker said the first time he laid eyes on her, he named her Mainao, after Goddess Lakshmi. I asked why they decided on that name. They said Lakshmi represents abundance… this calf came to them with an abundance of grief, and slowly they will make her abundant in happiness. She has calmed down since then and is eating healthy. She has periods of low moods in which she becomes reclusive. This was expected, since the mother-daughter bond is extremely strong in elephants.

While the pre-weaning period in elephants lasts up to 2–3 years, the daughters stay with the mother their entire lives. Hence, they never really separate. There also have been studies on the psyche of elephants who, apart from being highly intelligent, also experience the same emotions as human beings - empathy and fear being the strongest ones. According to studies by prominent elephant psychologist Michele Franko, a Research Associate at the Kerulos Centre and a senior sanctuary elephant carer, “all elephants have permanent life-long injuries and are plagued with psychological trauma symptoms.” We can only hope our little Mainao has the strength to deal with her pain because she will definitely not forget it.

Mainao’s mother is one of the 70+ elephants that died in the Indian state of Assam in 2021, according to official records; and one of the around 14 elephants dying in the state due to

Figure 1. Carcass with village onlookers. Behind: Mainao is being reluctantly loaded on to a rescue vehicle by forest officials. Photo © Forest Department, Manas National Park, Assam.

electrocution by illegal electric fences installed around paddy fields. A few months before the Kokilabari incident, on 21st August 2021, two adult female elephants were electrocuted near the Batabari Reserve Forest in Baksa. On 3rd September 2021, an elephant was electrocuted near Mirza, Kamrup District while 15th and 25th October 2021, saw two elephants being electrocuted to death in Goalpara and Guwahati respectively. As many as 600 elephants have been killed by electrocution in India from 2009 to 2020, according to the Ministry of Environment Forests and Climate Change (MoEF& CC). Assam, with the State with the second largest elephant population in India with over 3700 elephants, also has the second largest number of conflict cases between people and elephants.

Apart from elephants, people involved in conflicts are affected a great deal too. A total of 60 people were reported to have died in Assam in 2021, in conflicts with elephants. Only a week after the Kokilabari Incident, on 10th December 2021, a mother and child were accidentally hit, when Forest department personnel shot at a stray elephant in the Bondapara area, Kamrup, a tactic sometimes used to chase stray elephants away from agricultural fields. Two-year-old Arbi Daimary died of a bullet wound while her mother survived with injuries. This is a stark reminder that while we deliberate and debate on solutions, both sides in the conflict continue to suffer.

Man-elephant conflict is not new in Assam, nor will it be easy to overcome. Crimes against elephants are also not out of variety - train accidents have already claimed 5 elephants this year while 4 were poisoned to death. Solutions are many, but which one would work? According to Dr. Bibhab Kr. Talukdar, the Secretary General and CEO of Aaranyak and the Chair, IUCN SSC Asian Rhino Specialist Group, immediate and doable things like mass awareness, immediate and reasonable compensation for damages, proper coordination between Forest and Railways officials and adequate facilities to village defence personnel to monitor movement of elephants should be undertaken. Habitat restoration is one potential solution but how long will it take to restore and refill the gaps that human beings have created? How many elephants will die till then? How many people? Is compensation really the solution? Is firing a solution? All of these remains a grey area in conservation. Since the incident in Kokilabari, single line electric fences have been installed by the Forest Department in the boundary of Bhuyanpara, MNP. Forest officials, who are at high alert for elephants entering the villages during the agricultural season, are hopeful that it will be instrumental in addressing the conflict issues next year.

Amongst all the snags and solutions, the cases of Mainao and Arbi reminds us that caught between the mess of conflict and conservation, we lose at both ends. Let us not forget that this case is among a hundred cases of human-elephant conflicts that plague Assam every year. They were victims of deliberations, debates, discussions and delayed decisions in conservation forums. Nobody wins-, everyone suffers. These two incidents serve as stark reminders that in the end, we cannot summarise everything into statistics and forget about it. While people who truly suffer will remember, it is time for those who do not suffer also, to remember, reflect and act.

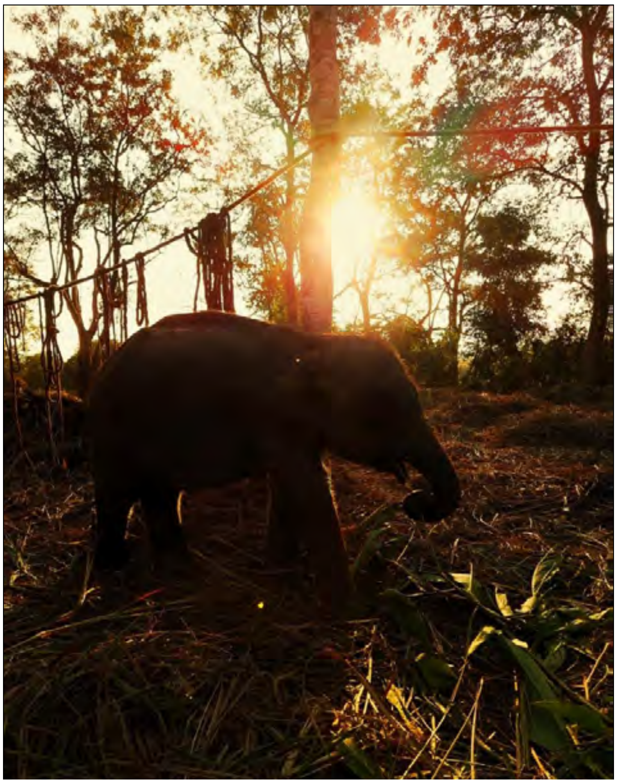

Figure 2. Mainao in the Hati Mahal Camp. Photo © Forest Department, Manas National Park, Assam.

 Gajah 55 (2022) 59-61

Third Asian Elephant Range States Meeting, Kathmandu, Nepal

Heidi S. Riddle

IUCN-SSC Asian Elephant Specialist Group Member, Nepal AsERSM Organizing Committee

Introduction

With a remaining population of about 50,000 individuals, the Asian elephant is endangered and at risk of local extinction in some range countries. Threats such as habitat loss and degradation, fragmentation of elephant populations, human-elephant conflict (HEC) and the illegal killing of elephants require significant effort to find solutions to mitigate these threats to ensure the long-term sustainability of the Asian elephant across its range.

An international workshop held in Malaysia in 2006 brought together representatives from all 13 Asian elephant range states to conduct a threats assessment and identify limiting factors affecting population abundance in Asian elephants. This workshop was followed by the *2nd Asian Elephant Range States Meeting* in 2017 in Jakarta, Indonesia. At this meeting, all Asian elephant range states (with the exception of Nepal, who was unable to participate due to national elections) sent two high level delegates to Jakarta to improve collaboration and cooperation amongst countries. This meeting, hosted by the Ministry of Environment and Forestry, Republic of Indonesia, took place in Jakarta from 18. – 20. April 2017.

The primary output of the 2017 meeting was "The Jakarta Declaration for Asian Elephant Conservation" signed by all delegates at the conclusion of the meeting. This is the first time that all Asian elephant range states declared a common vision to promote Asian elephant conservation range-wide, affirming their intent to cooperate based on the principles of sustainable development, science, education and training, fund raising, as well as other activities relevant to Asian elephant conservation and development within the range states.

The 2022 Range States Meeting

After a 2-year delay due to the Covid pandemic, the *3rd Asian Elephant Range States Meeting* was held 27. – 29. April 2022 in Kathmandu, Nepal. As some countries still had Covid-related travel restrictions in place, the meeting was a hybrid with half the range countries (Bangladesh, India, Lao PDR, Malaysia Peninsular, Malaysia Sabah, Nepal, Sri Lanka) sending delegates in person, and the other range countries (Bhutan, Cambodia, China, Indonesia, Myanmar, Thailand, Vietnam) participating via Zoom. The meeting was hosted by the Government of Nepal's Department of National Parks and Wildlife Conservation, facilitated by the

Range state delegates with Hon'ble Minister Ramsahay Prasad Yadav.

Asian Elephant Specialist Group (AsESG) of the IUCN-SSC, and supported by the Asian Elephant Conservation Fund of the U.S. Fish and Wildlife Service. Technical support was provided by the National Trust for Nature Conservation, Nepal.

The highest priority topics of discussion identified by the range states delegates for the 2022 meeting included HEC, habitat management and transboundary issues. New topics highlighted were the impacts of linear infrastructures, management of elephant corridors, emerging diseases in Asian elephants, and funding support for Asian elephant conservation. During the meeting, the delegates agreed to strengthen international collaborations, improve scientific monitoring to help restore the species' habitat, and create transboundary agreements.

The Kathmandu Declaration

The outcome of the 2022 meeting is the "Kathmandu Declaration for Asian Elephant Conservation" which builds upon and updates the Jakarta Declaration and where delegates agreed to add a timeline for initiating or completing priority items. Through the Kathmandu Declaration, Asian elephant range states call upon the international community to join them in protecting the Asian elephant and their forest habitat. Saving Asian elephants is a global challenge requiring strong government partnerships and a cohesive regional strategy.

The Kathmandu Declaration for Asian Elephant Conservation Kathmandu, Nepal April 29, 2022

We, the representatives of the government agencies from Asian Elephant Range States including the People's Republic of Bangladesh, the Kingdom of Bhutan, Kingdom of Cambodia, People's Republic of China, Republic of India, Republic of Indonesia, Lao People's Democratic Republic, Federal Democratic Republic of Nepal, Democratic Socialist Republic of Sri Lanka, Republic of the Union of Myanmar, Malaysia, Kingdom of Thailand, and the Socialist Republic of Vietnam, declare our common goal to conserve the Asian Elephant within its Range States, and:

Recognising that the Asian Elephant, a seriously endangered species and one of the most iconic animals, faces a challenging future with the loss of its habitat, fragmented populations, high levels of human-elephant conflict, illegal killing, as well as other factors that have resulted in population declines in some of the Range States, and that we should have a common vision to promote Asian Elephant conservation;

Acknowledging that the Asian Elephant is a keystone species and an umbrella species whose conservation helps ensure the conservation of myriads of other species. Asian Elephants are also culturally significant across Asia. A failure to protect Asian Elephants and their habitat will therefore not only result in the loss of elephants but also the loss of biological and cultural diversity and the tangible and intangible benefits provided by elephants and the ecosystems they inhabit;

Noting that while elephant conservation is primarily a national responsibility, there is an urgent need to synergize national actions with international cooperation amongst the Range States for the long-term conservation of Asian Elephants. The reversal of the crisis facing Asian Elephants is additionally dependent upon political, financial, and technical support from the international community;

Understanding the role of international agreements on the conservation of biological diversity and protection of rare and endangered species, including the Asian Elephant, such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Convention on Biological Diversity (CBD), and the Convention on the Conservation of Migratory Species of Wild Animals (CMS);

Acknowledging the presence and support of other governments, international organizations, non-governmental organizations, and other supporters of Asian Elephant conservation;

Building upon the Jakarta Declaration for Asian Elephant Conservation of the second Asian Elephant Range States Meeting of 2017

Thus, we declare:

- To enhance cooperation between the thirteen Range States both bilaterally and multilaterally, promoting transboundary conservation of the Asian Elephant, and sharing and learning to enhance national conservation measures;
- To promote coexistence by minimizing the negative impacts of humans on Asian Elephants and their habitats, address the root causes of human-elephant conflict, and develop long term solutions to minimize such conflict; engage with local communities to gain their participation in biodiversity conservation and land-use planning; and provide sustainable and alternative livelihoods through financial support, technical guidance and support, and other measures;
- To ensure effective law enforcement across the species' range to prevent illegal killing of Asian Elephants and the illegal trade in live Asian Elephants, ivory and its derivatives, and other elephant body parts;
- To promote and ensure the welfare of captive elephants is maintained at all times;
- To strengthen international collaboration, coordination, cooperation and communication based on bilateral and multilateral agreements where relevant, involving specialized expertise from national and international organizations, including but not limited to AsESG, IUCN SSC, CITES, INTERPOL, CBD, CMS, UNEP, ASEAN-WEN, SAWEN, and UNODC;
- To set up through appropriate mechanisms an Asian Elephant Fund, accessible to Range States and Range State civil society, to promote conservation of the species and its habitat;
- To develop an appropriate data sharing mechanism among Range States;
- Commit to develop, where necessary, and where applicable implement National Asian Elephant Conservation Action Plans that include, but are not limited to, the priorities listed in the annex to this Declaration.

And call upon the international community to join us in addressing the challenges facing Asian Elephants and achieving a harmonious coexistence between humans and Asian Elephants.

Annex: Priority Commitments by 2025

- Promote the maintenance and connectivity of large Asian Elephant conservation landscapes where new permitted developmental activities such as linear infrastructures are elephant- and biodiversity-appropriate;
- Promote the development of national guidelines on wildlife friendly linear infrastructure, including elephant, based on those developed by the Asian Elephant Specialist Group of the IUCN SSC and Connectivity Specialist Groups after Range States consultations;
- Develop bilateral transboundary agreements, protocols or understandings in relevant countries to ease movement of Asian Elephants through appropriate corridors and transboundary protected areas;
- Collectively develop, where relevant, and coordinate captive Asian Elephant registration programs in relevant countries, based on scientific research including, where appropriate, microchipping and/or DNA-based systems, and ensure cross-border movements of captive Asian Elephants are in compliance with all national and international laws and regulations;
- Ensure that all Range States have a National Asian Elephant Conservation Action Plan;
- Promote the development of national guidelines on Human Asian Elephant Conflict mitigation based on those developed by the Asian Elephant Specialist Group of the IUCN SSC after Range States consultations.
- The Range States support the development of range-wide Asian Elephant Conservation Plan by the Asian Elephant Specialist Group of the IUCN SSC;
- The Range States initiate the establishment of a national Asian Elephant Database with the technical support of the Asian Elephant Specialist Group of the IUCN SSC and CITES MIKE/ETIS;
- The Range States jointly initiate the creation of an Asian Elephant Fund assisted by the Asian Elephant Specialist Group of the IUCN SSC;

DONE in Kathmandu, Nepal on the Twenty Ninth Day of April in the Year Two Thousand and Twenty Two, in a single original copy in the English language.

Recent Publications on Asian Elephants

Compiled by Jennifer Pastorini

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If you need additional information on any of the articles, please feel free to contact me. You can also let me know about new (2022) publications on Asian elephants.

Abstract. No permission to print abstract.

T. Angkawanish, H.J.C.M. Vernooij, A. Sirimalaisuwan, M. Nielen, P. Charernpan & V.P.M.G. Rutten

Prevalence and demographic risk factors of *Mycobacterium tuberculosis* infections in captive Asian elephants (*Elephas maximus*) based on serological assays

Frontiers in Vet. Science 8 (2021) e713663

Abstract. To address putative TB statuses of elephants and to identify and quantify potential demographic risk factors for TB, three ELISAs specific for different mycobacterial antigens (ESAT6, CFP10, MPB83) and the TB Stat-Pak assay were used as surrogate serological markers for TB infection in elephants. In view of the low number of animals of which the infected status could be confirmed (4 out of 708) Latent Class Analyses of TB serology test outcomes was used to predict the putative TB status of each of 708 elephants as positive (17.3%), inconclusive (48.7%), or negative (34%) when assessed on a population basis. Correlation between test performance of the individual assays was high between the ELISAs, but low with that of the TB Stat-Pak assay. Risk factors, assessed based on cut off values for each of the ELISAs determined by ROC analysis, included sex, BCS, age, working time, feed type, management system, camp size and region. Old age elephants were more likely to show a positive TB serology test outcome, than younger ones. Elephants working 7 h per day and the ones in good condition BCS (7–11) were less likely to be positive in TB serology testing. In addition, fewer animals in the large camp size (31–50 elephants) were found to be positive in ELISA tests, compared to elephants in the other camp sizes. In this study, the North region had the lowest percentages of elephants with positive TB test outcome, the West region and to a lesser extend the other regions showed clearly higher percentages of positive animals. Even though assays used in the present study have not been validated yet, results obtained showed promise as diagnostic or screening tests. For the diagnosis of animals suspected to be infected, the ELISA tests, once further optimized for the individual antigens, can be used in parallel. For screening of complete camps for presence or absence of infection, a single optimized ELISA test can be utilized. © 2021 The Authors.

Ardiantiono, Sugiyo, P.J. Johnson, M.I. Lubis, F. Amama, Sukatmoko, W. Marthy & A. Zimmermann

Towards coexistence: Can people's attitudes explain their willingness to live with Sumatran elephants in Indonesia?

Conservation Science & Practice 3 (2021) e520

Abstract. Understanding coexistence between humans and threatened wildlife is a central focus in conservation. Way Kambas National Park in Sumatra Island, Indonesia, harbors one of the largest populations of the critically endangered Sumatran elephant (*Elephas maximus sumatranus*). The people who live alongside this population are affected by intensive crop foraging. Our study investigated the factors which influenced attitudes toward elephants. We then evaluated the implications of reported attitudes for future willingness to live with elephants. We surveyed 660 respondents in 22 villages around the park. People generally reported positive attitudes toward elephants (smartness 95%, usefulness 62%, importance 57%, and

pleasantness 53%), apart from where human safety was concerned (safety 11%). Each dimension of attitude was explained by different factors including age, gender, knowledge of elephants, and distance to crop foraging locations. Most respondents (62%) expressed no willingness to coexist with elephants. Such willingness was lower when elephants were perceived to be more dangerous, but higher if beliefs in the benefits of elephants were greater. Efforts to improve crop foraging mitigation practice and to increase people's awareness of elephant benefits may promote support for their conservation. Through this study, we advocate the integration of social science to promote human–wildlife coexistence strategies, an approach that is currently limited in Indonesia. © 2021 The Authors.

L.P. Barrett & S. Benson-Amram

Multiple assessments of personality and problem-solving performance in captive Asian elephants (*Elephas maximus*) and African savanna elephants (*Loxodonta africana*)

Journal of Comparative Psychology 135 (2021) 406-419

Abstract. No permission to print abstract.

U. Bechert, S. Hixon & D. Schmitt

Diurnal variation in serum concentrations of cortisol in captive African (*Loxodonta africana*) and Asian (*Elephas maximus*) elephants

Zoo Biology 40 (2021) 458-471

Abstract. Cortisol is involved in a broad range of physiological processes and enables animals to adapt to new situations and challenges. Diurnal fluctuations in circulating cortisol concentrations in elephants have been demonstrated based on samples from urine and saliva. The aims of this study were to demonstrate diurnal cortisol fluctuations based on blood samples and compare concentrations between seasons, species, and changes in reproductive hormone concentrations. Nine African (*Loxodonta africana*) and three Asian (*Elephas maximus*) elephants at two facilities in the United States were included in this study. Blood samples were collected every 2–3 h at one location and every 1–6 h at another. Peak serum concentrations of cortisol averaged 28 ng/ml for both African and Asian elephants, and diurnal cycles included a fivefold decrease from morning peak to evening nadir concentrations. Diurnal cortisol profiles varied uniquely among individual elephants. During the winter, nadir concentrations of cortisol were slightly higher, and the timing of peak concentrations was less predictable. There was no correlation between diurnal serum concentrations of progesterone and cortisol; however, a significant correlation ($p = 0.02$) was identified between serum concentrations of testosterone and cortisol when a time lag of ~2–3 h was considered. The physiological significance of the positive correlations between diurnal serum concentrations of cortisol and testosterone in male elephants remains to be determined. If cortisol concentrations are being used to evaluate elephant health or welfare, samples should be obtained at the same time each day to minimize variation due to diurnal fluctuations, and ideally seasonal variations and individuality in diurnal profiles should also be considered. © 2021 Wiley Periodicals LLC.

V. Berger, S. Reichert, M. Lahdenperä, J. Jackson, W. Htut & V. Lummaa

The elephant in the family: Costs and benefits of elder siblings on younger offspring life-history trajectory in a matrilineal mammal

Journal of Animal Ecology 90 (2021) 2663-2677

Abstract. Many mammals grow up with siblings, and interactions between them can influence offspring phenotype and fitness. Among these interactions, sibling competition between different-age offspring should lead to reproductive and survival costs on the younger sibling, while sibling cooperation should improve younger sibling's reproductive potential and survival. However, little is known about the consequences of sibling effects on younger offspring life-history trajectory, especially in long-lived mammals. We take advantage of a large, multigenerational demographic dataset from semi-captive Asian elephants to investigate how the presence and sex of elder siblings influence the sex, survival until 5 years old, body condition, reproductive success (i.e. age at first reproduction and lifetime reproductive success) and long-term survival of subsequent offspring. We find that elder siblings have heterogeneous effects on subsequent offspring life-history traits depending on their presence, their sex and the sex of the subsequent offspring (named focal calf). Overall, the presence of an elder sibling (either sex) strongly increased focal calf long-term survival (either sex) compared to sibling absence. However, elder sisters had higher impact on the focal sibling than elder brothers. Focal females born after a female display higher long-term survival, and decreased age at first reproduction when raised together with an elder sister rather than a brother. Focal males born after a female rather than a male showed lower survival but higher body weight when both were raised together. We did not detect any sibling effects on the sex of the focal calf sex, survival until 5 years old and lifetime reproductive success. Our results highlight the general complexity of sibling effects, but broadly that elder siblings can influence the life-history trajectory of subsequent offspring. We also stress the importance of considering all life stages when evaluating sibling effects on life trajectories. © 2021 The Authors.

K. Budd, C. Sampson, P. Leimgruber, D. Tonkyn, K. Storey, M. Garrett & L.S. Eggert

Population structure and demography of Myanmar's conflict elephants

Global Ecology and Conserv. 31 (2021) e01828

Abstract. Despite containing the largest extent of unfragmented landscape in the Asian elephant (*Elephas maximus*) range, Myanmar has high levels of human-elephant conflict. The Bago Yoma mountain region of central Myanmar has previously been identified as an elephant conflict hotspot, characterized by high levels of crop-raiding and illegal killing of elephants for the ivory and skin trades. We used non-invasive fecal sampling to evaluate the population structure and demography of wild and captive elephants in the Bago Yoma using microsatellite loci and mitochondrial DNA in combination with crop-raiding status, age, and sex. We were able to collect 252 samples from wild elephants – 119 directly following conflict events – and 25 from captive elephants from which we identified 127 unique wild and 21 captive individuals. The population was biased toward subadults, which could be an important contributor to the high rates of conflict, as these individuals may lack the experience to avoid dangerous behaviors. Conflict elephants were primarily male, although both sexes and all ages engaged in crop-raiding, including females with juveniles. We found that elephants that commit solo raids were all male, while larger raiding parties often included both related and unrelated individuals of both sexes. Repeat offenders were common. These wild elephants contained high levels of genetic diversity, differentiated from local captive populations, and valuable for the species' conservation. Overall, the elephants of Bago Yoma, Myanmar have been heavily affected by conflict, and managers could utilize the knowledge presented to aid in the preservation of this population. © 2021 The Authors.

A. Campos-Arceiz, J.A. de la Torre, K. Wei, X.O. Wu, Y. Zhu, M. Zhao, S. Chen, Y. Bai, R.T. Corlett & F. Chen

The return of the elephants: How two groups of dispersing elephants attracted the attention of billions and what can we learn from their behavior

Conservation Letters 14 (2021) e12836

Abstract. none.

A. Chaitae, R. Rittiron, I.J. Gordon, H. Marsh, J. Addison, S. Pochanagone & N. Suttanon

Shining NIR light on ivory: A practical enforcement tool for elephant ivory identification

Conservation Science & Practice 3 (2021) e486

Abstract. The elephant ivory trade remains controversial because of concerns about the extinction risk of elephants and the different needs of CITES member states. Thailand's situation is particularly contentious because of the different legal status among types of elephant ivory. Thai law allows the local sale of ivory from domesticated Asian elephants, which creates challenges for Thai enforcement officers in identification of ivory provenance. We investigated the capacity of non-destructive Near Infrared (NIR) spectroscopy (600–1700 nm), combined with Partial Least Squares Discriminant Analysis (PLS-DA), to discriminate between ivory from African, wild Asian and domesticated Asian elephants. Ivory spectra of 64 elephants were divided randomly into calibration and validation datasets. We were able to determine elephant ivory provenance at both the interspecies (African and Asian elephant ivory), and within species (wild and domesticated Asian elephant ivory) classifications with 100% accuracy.

These results showed the potential use of handheld NIR spectrometers for rapid assessments of ivory provenance, as well as a forensic tool for wider enforcement. © 2021 The Authors.

Russell Clemens
Asian elephant futures: A causal layered analysis with Gregory Bateson in mind
World Futures Review 12 (2020) 55-80
Abstract. Human population growth and dwindling fragmented natural habitats for elephants in Asia are leading to increasing conflict between humans and wild elephants. Sohail Inayatullah's Causal layered analysis (CLA) is applied to understand the human-elephant conflict (HEC) situation. Gregory Bateson's "ecology of mind" (EoM; epistemology, recurrence, abduction, and metaphor) is also employed to focus on possible implications of metaphor, epistemology, and social-psychological misalignments. The article aims to inform multidisciplinary practitioners on the relevance of applying both CLA and EoM to social-ecological issues in the twenty-first century. CLA and EoM are compatible and complementary multilayered approaches which, as metaphorical approaches, share mixed entailments. Bateson's "double bind" theory is applied within CLA to explore the implications of possible Asian elephant extinction within the Anthropocene in respect to Indian (Hindu and Buddhist) cosmologies. © 2019 The Authors.

S.M. Common, Y. Yun, A. Silva-Fletcher, C. Thitaram, T. Janyamethakul, S. Khammesri & F.M. Molenaar
Developing a non-invasive method of detecting elephant endotheliotropic herpesvirus infections using faecal samples
Vet Record 190 (2021) e833
Abstract. Elephant endotheliotropic herpesvirus (EEHV)-associated haemorrhagic disease (EEHV-HD) is a leading cause of death in Asian elephant calves across the world. Cases of EEHV-HD have been detected in free-living calves through post-mortem examination (PME) indicating the presence of the virus in the wild. In the absence of a non-invasive sampling method, little research into free-living populations has been possible. This study aimed to provide evidence that faeces can be used as a non-invasive sampling method for the detection of EEHV excretion using quantitative polymerase chain reaction. Serial saliva swabs and faecal samples were taken from five captive Asian elephants in Thailand over 12 weeks. To ensure the presence of detectable elephant DNA within the sample, qPCR was run for amplification of the Asian elephant tumour necrosis factor (TNF-α) gene, EEHV1 and EEHV4. Of 28 sample pairs, seven saliva samples were positive for EEHV, of which two had paired positive faecal samples. This study presents the first evidence that EEHV is excreted in faeces at detectable levels. This method may in future be used for improved understanding of the epidemiology of EEHV in free-living elephant populations, as well as detection of EEHV excretion in captive herds. © 2021 British Veterinary Association.

P. Dagenais, S. Hensman, V. Haechler & M.C. Milinkovitch
Elephants evolved strategies reducing the biomechanical complexity of their trunk
Current Biology 31 (2021) 4727-4737
Abstract. The elephant proboscis (trunk), which functions as a muscular hydrostat with a virtually infinite number of degrees of freedom, is a spectacular organ for delicate to heavy object manipulation as well as social and sensory functions. Using high-resolution motion capture and functional morphology analyses, we show here that elephants evolved strategies that reduce the biomechanical complexity of their trunk. Indeed, our behavioral experiments with objects of various shapes, sizes, and weights indicate that (1) complex behaviors emerge from the combination of a finite set of basic movements; (2) curvature, torsion, and strain provide an appropriate kinematic representation, allowing us to extract motion primitives from the trunk trajectories; (3) transport of objects involves the proximal propagation of an inward curvature front initiated at the tip; (4) the trunk can also form pseudo-joints for point-to-point motion; and (5) the trunk tip velocity obeys a power law with its path curvature, similar to human hand drawing movements. We also reveal with unprecedented precision the functional anatomy of the African and Asian elephant trunks using medical imaging and macro-scale serial sectioning, thus drawing strong connections between motion primitives and muscular

synergies. Our study is the first combined quantitative analysis of the mechanical performance, kinematic strategies, and functional morphology of the largest animal muscular hydrostat on Earth. It provides data for developing innovative "soft-robotic" manipulators devoid of articulations, replicating the high compliance, flexibility, and strength of the elephant trunk. © 2021 The Authors.

Yunchuan Dai

The overlap of suitable tea plant habitat with Asian elephant (*Elephus maximus*) distribution in southwestern China and its potential impact on species conservation and local economy

Environmental Science and Pollution Research 29 (2022) 5960-5970

Abstract. No permission to print abstract.

R. De, R. Sharma, P. Davidar, N. Arumugam, A. Sedhupathy, J.-P. Puyravaud, K. M.Selvan, P.P.A. Rahim, S. Udayraj, J. Parida, D.K. Digal, R. Kanagaraj, K. Kakati, P. Nigam, A.C. Williams, B. Habib & S.P. Goyal

Pan-India population genetics signifies the importance of habitat connectivity for wild Asian elephant conservation

Global Ecology and Conserv. 32 (2021) e01888

Abstract. Asian elephants are endangered while they have faced ~70% population decline in India in the last 60 years. Climate change projections indicate exacerbation of ongoing habitat loss (>40%) by 2070, potentially impacting genetic structure of wild elephants across India. Therefore, we provide consolidated baseline data on genetic diversity and structure of elephants across four eco-regions of India, i.e., north-western (NW), north-eastern (NE), east-central (ECI), and southern India (SI), to identify populations at greater risk of further divergence. We genotyped 169 faecal samples across 14 microsatellites with 90.0% overall success rate. The genetic diversity levels were moderate and varied between the eco-regions (H_E = 0.57–0.74). Allelic richness was higher in NE (3.73–3.78) and SI (3.62–3.71). We observed a high inbreeding coefficient in NE (F_{IS} = 0.55–0.58) compared to the other elephant populations, probably due to the presence of related individuals in our samples. Genetic differentiation between populations using F_{ST} statistics (F_{ST} = 0.06–0.18) was significant. Bayesian and multivariate analyses identified three major genetic clusters in India – NW, NE, and combined ECI-SI, mostly consistent with their geographic distribution. We also observed an unexpected pattern of high genetic distance between adjacent populations. This fine-scale genetic structure suggests the presence of barriers (natural and anthropogenic) and complex social organisation. Additionally, incipient sub-structuring within NE and SI indicates potential genetic discontinuity. These results highlight the importance of maintaining genetic diversity, particularly of NE and ECI populations, by retaining habitat connectivity and ensuring gene flow for effective elephant conservation in India. © 2021 The Authors.

J.-M. Dubost, P. Kongchack, E. Deharo, P. Sysay, C. Her, L. Vichith, D. Sébastien & S. Krief

Zootherapeutic uses of animals excreta: The case of elephant dung and urine use in Sayaboury province, Laos

Journal of Ethnobiology and Ethnomedicine 17 (2021) e262

Abstract. Despite a widespread aversion towards faeces and urine, animal excreta are used in traditional medicine in many countries since centuries, but records are scattered and few therapeutic uses have been accurately documented while in the current context of emerging zoonoses such records may be of major interest. In this study, we investigated the therapeutic uses that mahouts in Xayaboury province, Lao PDR make of elephant urine and faeces as well as of the brood chamber that beetles (*Heliocopris dominus*) fashion from elephant dung. Semi-structured interviews were conducted with mahouts on elephant diet, health problems and responses to disease, andwhether they use elephant products. Data were supplemented by interviews with traditional healers. Seven respondents reported the use of elephant urine in ethnoveterinary care for elephants and in human medicine in case of diabetes and otitis. 25 respondents reported therapeutic use of elephant faeces (EF) and elephant dung beetle brood chambers. The major indications are gastrointestinal and skin problems. Macerations or decoctions are drunk or used externally as a lotion. The mahouts attribute the therapeutic effectiveness of EFs to their content which includes the remains of many species from the elephant diet which they consider to be medicinal. The indications of these uses are consistent with pharmacological and clinical studies highlighting the properties of different animals' urine and faeces and their curative potential tested in vivo. The acknowledgement by the mahouts of medicinal properties of elephant faecal bolus contrasts with the rare justifications of animal material use recorded in zootherapeutic studies, which falls within the symbolic domain. However, numerous studies highlight the preponderant role of the microbiota in physiological processes, raising the hypothesis of a curative action of EF, by rebalancing the user's microbiota. The therapeutic uses of EF preparations despite their possible curative properties are a potential source of zoonotic transmission from elephants to humans. In the current context of globalisation of trade which favours the emergence of zoonoses and in relation with the issue of One Health, it becomes crucial to further document the zootherapeutic practices to prevent emerging diseases. As elephants and local related ethnoethological knowledge are threatened, documenting them is urgent to contribute to their preservation. © 2021 The Authors.

K.L. Edwards, E.M. Latimer, J. Siegal-Willott, W. Kiso, L.R. Padilla, C.R. Sanchez, D. Schmitt & J.L. Brown

Patterns of serum immune biomarkers during elephant endotheliotropic herpesvirus viremia in Asian and African elephants

PLoS ONE 16 (2021) e0252175

Abstract. Hemorrhagic disease (HD) caused by a group of elephant endotheliotropic herpesviruses (EEHV) is one of the leading causes of death for young elephants in human care. These viruses are widespread and typically persist latently in adult elephants with no negative effects; however, in juvenile Asian and more recently young African elephants, the onset of disease can be rapid and the mortality rate high. Measuring biomarkers associated with the immune response could be beneficial to understanding underlying disease processes, as well as the management of infection and HD. The goal of this study was to measure acute phase proteins and cytokines in serum collected from elephants infected with EEHV (13 Asian and 1 African) and compare concentrations according to presence, severity and outcome of disease. Serum amyloid A (SAA) and haptoglobin (HP) were higher in elephants with EEHV viremia than those without; concentrations increased with increasing viral load, and were higher in fatal cases compared to those that survived. In Asian elephants, SAA was also higher during EEHV1 viremia compared to EEHV5. Cytokine concentrations were typically low, and no statistical differences existed between groups. However, in individuals with detectable levels, longitudinal profiles indicated changes in tumor necrosis factor alpha (TNF-α) and interleukin-2 (IL-2) that may reflect an immune response to EEHV infection. However, the overall low concentrations detected using previously validated assays do not support the presence of a 'cytokine storm' and suggest more work is needed to understand if sub-optimal immune responses could be involved in disease progression. These results highlight the potential benefit of measuring circulating biomarker concentrations, such as APPs and cytokines, to improve our understanding of EEHV viremia and HD, assist with monitoring the progression of disease and determining the impact of interventions.

P. Fernando & J. Pastorini

Whither the science in wildlife management? (Commentary)

Animal Conservation 24 (2021) 735-737

Abstract. none.

Adam Fish

Crash theory: Entrapments of conservation drones and endangered megafauna

Science, Technology & Human Values 46 (2021) 425-451

Abstract. Drones deployed to monitor endangered species often crash. These crashes teach us that using drones for conservation is a contingent practice ensnaring humans, technologies, and animals. This article advances a crash theory in which pilots, conservation drones, and endangered megafauna are relata, or related actants, that intra-act, cocreating each other and a mutually constituted phenomena. These phenomena are entangled, with either reciprocal dependencies or erosive entrapments. The crashing of conservation drones and endangered species requires an ethics of care, repair, or reworlding. Diffractions, disruptions that expose difference, result from crashes and reveal the precarious manner by which technologies, laws, and discourses bring nature and culture together. To support crash theory, this article presents three ethnographic cases. A drone crash in the United Kingdom near white rhinoceroses while building machine learning training data exhibits the involvement of the electromagnetic spectrum; the threat of crashes in the Pacific Northwest near Puget Sound orcas discloses the impacts of drone laws; and drone crashes in Sri Lanka among Asian elephants presents the problems of technoliberal ideals around programming natural worlds. Throughout the article, a methodology is developed, parallelism, which attends to the material similarities in lateral phenomena. © 2020 The Authors.

E. Fuchs, V.C. Beeck, A. Baotic & A.S. Stoeger
Acoustic structure and information content of trumpets in female Asian elephants (*Elephas maximus*)
PLoS ONE 16 (2021) e0260284
Abstract. Most studies on elephant vocal communication have focused on the low-frequency rumble, with less effort on other vocalization types such as the most characteristic elephant call, the trumpet. Yet, a better and more complete understanding of the elephant vocal system requires investigating other vocalization types and their functioning in more detail as well. We recorded adult female Asian elephants (*Elephas maximus*) at a private facility in Nepal and analyzed 206 trumpets from six individuals regarding their frequency, temporal and contour shape, and related acoustic parameters of the fundamental frequency. We also tested for information content regarding individuality and context. Finally, we recorded the occurrence of non-linear phenomena such as bifurcation, biphonation, subharmonics and deterministic chaos. We documented a mean fundamental frequency ± SD of 474 ± 70 Hz and a mean duration ± SD of 1.38 ± 1.46 s ($N_{indiv.} = 6$, $N_{calls} = 206$). Our study reveals that the contour of the fundamental frequency of trumpets encodes information about individuality, but we found no evidence for trumpet subtypes in greeting versus disturbance contexts. Non-linear phenomena prevailed and varied in abundance among individuals, suggesting that irregularities in trumpets might enhance the potential for individual recognition. We propose that trumpets in adult female Asian elephants serve to convey an individual's identity as well as to signal arousal and excitement to conspecifics. © 2021 The Authors.

S. Fuktong, P. Yuttasaen, V. Punyapornwithaya, J.L. Brown, C. Thitaram, N. Luevitoonvechakij & P. Bansiddhi
A survey of stereotypic behaviors in tourist camp elephants in Chiang Mai, Thailand
Applied Animal Behaviour Science 243 (2021) e105456
Abstract. Stereotypies are abnormal behaviors found in a wide range of animals that have been used as indicators of poor welfare. Elephants used in tourism have been reported to perform stereotypic behavior, but the occurrence has not been systematically assessed. The aims of this study were to ascertain the percentage of stereotypic behaviors exhibited by tourist camp elephants and relationship with demographic variables. This study surveyed 283 elephants from 20 elephant camps in Chiang Mai, Thailand. Amounts and types of stereotypic behavior were determined from 15-min direct observations. Additionally, demographic data and occurrence of stereotypic behavior (yes/no) were obtained from mahouts of 181 elephants using a questionnaire. Direct behavioral observations revealed that 57% (N = 161: 44 males and 117 females) of the elephants performed stereotypic behavior, while in mahout interviews, 58% were scored 'yes'. There were no differences in the least-squares mean score of stereotypic behaviors between males and females ($p = 0.32$), whereas there were differences among age groups ($p < 0.05$), with the highest in elephants 4–10 years of age, followed by 11–30 years of age, 31–50 years of age, > 50 years of age. Calves 0–3 years of age displayed the lowest rate of stereotypic behavior, when most were still with their mothers. The most common type of stereotypic behavior was swaying. Our results indicate that scores of stereotypic behaviors in elephants used in tourism differed among age categories. The next step will be to determine how management factors affect stereotypic behavior of elephants in this population and steps to mitigate it. © 2021 Reprinted with permission from Elsevier.

O. Hyvarinen, M.T. Beest, E. le Roux, G. Kerley, E. de Groot, R. Vinita & J.P.G.M. Cromsigt

Megaherbivore impacts on ecosystem and earth system functioning: The current state of the science

Ecography 11 (2021) 1579-1594

Abstract. Megaherbivores (adult body mass > 1000 kg) are suggested to disproportionately shape ecosystem and Earth system functioning. We systematically reviewed the empirical basis for this general thesis and for the more specific hypotheses that 1) megaherbivores have disproportionately larger effects on Earth system functioning than their smaller counterparts, 2) this is true for all extant megaherbivore species and 3) their effects vary along environmental gradients. We furthermore explored possible biases in our understanding of megaherbivore impacts. We found that there are too few studies to quantitatively evaluate the general thesis or any of the hypotheses for all but the African savanna elephant. Following this finding, we performed a qualitative vote counting analysis. Our synthesis of this analysis suggests that megaherbivores can elicit strong impacts on, for example, vegetation structure and biodiversity, and all the elephant species promote seed dispersal. We were, however, unable to evaluate whether these effects are disproportionate to smaller large herbivores. Although environmental conditions can mediate megaherbivore impact, few studies quantified the effect of rainfall or soil fertility on megaherbivore impacts, precluding prediction of megaherbivore effects on the Earth system, particularly under future climates. Moreover, our review highlights major taxonomic, thematic and geographic biases in our understanding of megaherbivore effects. Most of the studies focused on African savanna elephant impacts on vegetation structure and biodiversity, with other megaherbivores and Earth system functions comparatively neglected. Studies were also biased towards semi-arid and relatively fertile systems, with the arid, high-rainfall and/or nutrient-poor parts of the megaherbivores' distribution ranges largely unrepresented. Our findings highlight that the empirical basis of our understanding of the ecological effects of extant megaherbivores is still limited for all species, except the African savanna elephant, and that our current understanding is biased towards certain environmental and geographic areas. We further outline a detailed, urgently needed avenue for future research. © 2021 The Authors.

R. Joshi & K. Puri

Asian elephant in Appendix I of the Convention on Migratory Species: Strengthening the ecological connectivity for trans-boundary conservation

National Academy Science Letters 44 (2021) 427-431

Abstract. No permission to print abstract.

M.M. Keady, N. Prado, H.C. Lim, J. Brown, S. Paris & C.R. Muletz-Wolz

Clinical health issues, reproductive hormones, and metabolic hormones associated with gut microbiome structure in African and Asian elephants

Animal Microbiome 3 (2021) e85

Abstract. The gut microbiome is important to immune health, metabolism, and hormone regulation. Understanding host–microbiome relationships in captive animals may lead to mediating long term health issues common in captive animals. For instance, zoo managed elephants experience low reproductive rates, high body condition, and gastrointestinal (GI) issues. We leveraged an extensive collection of fecal samples and health records from the Elephant Welfare Study conducted across North American zoos in 2012 to examine the link between gut microbiota and clinical health issues, reproductive hormones, and metabolic hormones in captive elephants. We quantified gut microbiomes of 69 African and 48 Asian elephants from across 50 zoos using Illumina sequencing of the 16S rRNA bacterial gene. Elephant species differed in microbiome structure, with African elephants having lower bacterial richness and dissimilar bacterial composition from Asian elephants. In both species, bacterial composition was strongly influenced by zoo facility. Bacterial richness was lower in African elephants with recent GI issues, and richness was positively correlated with metabolic hormone total triiodothyronine (total T3) in Asian elephants. We found species-specific associations between gut microbiome composition and hormones: Asian elephant gut microbiome composition was linked to total T3 and free thyroxine (free T4), while fecal glucocorticoid metabolites (FGM) were linked to African elephant gut microbiome composition. We identified many relationships between bacterial relative abundances and hormone concentrations, including *Prevotella* spp., *Treponema* spp., and *Akkermansia* spp. We present a comprehensive assessment of relationships between the gut microbiome, host species, environment, clinical health issues, and the endocrine system in captive elephants. Our results highlight the combined significance of host species-specific regulation and environmental effects on the gut microbiome between two elephant species and across 50 zoo facilities. We provide evidence of clinical health issues, reproductive hormones, and metabolic hormones associated with the gut microbiome structure of captive elephants.

S. Kongsawasdi, K. Wantanajittikul, W. Langkaphin, B. Chuatrakoon, K. Namwongprom, P. Prupetkaew & T. Angkawanish

Optimal management to improve quality of life for an injured baby elephant: Thailand multidisciplinary care team

Kafkas Univ Vet Fak Derg 27 (2021) 655-659

Abstract. This article aimed to report the care, management, and monitoring of an injured female baby elephant. The collaboration among the multidisciplinary team included veterinary medicines, elephant handling, engineering, and physical therapy in the 3-year-old elephant with its left forelimb phalanges amputated through being caught in a snare trap. The management comprised medical wound care, nutrition and applying a prosthetic shoe. The kinematic parameters and vital sign monitoring were analysed. The results show that biomechanics gait analysis and physiological responses revealed promising benefit of the prosthetic shoe by reflecting a greater symmetrical gait pattern without dyspnea and no sign of exertion during daily life activity.

C.A. LaDue, I. Eranda, C. Jayasinghe & R.P.G. Vandercone

Mortality patterns of Asian elephants in a region of human–elephant conflict

Journal of Wildlife Management 85 (2021) 794-802

Abstract. Many wildlife species suffer from human–wildlife conflict, especially crop-raiding. Long-term analyses of mortality patterns are needed to assess the efficacy of management strategies that address this issue. We report mortality patterns from necropsies of 498 Asian elephants from 2009–2018 in an area of northwestern Sri Lanka. Deaths were lowest in July and highest in October, a period of peak crop availability. Most (about 70%) deaths were human-related, and males were killed in these incidents more frequently than females. As gunshot deaths decreased, other forms of human-related deaths increased. Additionally, causes of death differed between districts, with more intentional human-related mortality observed in the district with the highest percent of protected land. These results highlight the importance of understanding the long-term spatial and temporal variation in wildlife mortality to effectively address human-wildlife conflict.

J.A. Landolfi, P.M. Gaffney, R. McManamon, N.L. Gottdenker, A. E. Ellis, R.R. Rech, S. Han, L.J. Lowenstine, D. Agnew, M.M. Garner, D. McAloose, C. Hollinger, J. St. Leger, S.P. Terrell, M. Duncan & A.P. Pessier

Reproductive tract neoplasia in adult female Asian elephants (*Elephas maximus*)

Veterinary Pathology 58 (2021) 1131-1141

Abstract. Recent reports have highlighted a lower-than-expected prevalence of neoplasia in elephants and suggested mechanisms for cancer resistance. But despite infrequent reports in the literature, uterine neoplasia is common in managed Asian elephants (*Elephas maximus*). This study is an archival review of reproductive tract neoplasia in 80 adult female Asian elephant mortalities in managed care facilities in the United States from 1988 to 2019. Neoplasms occurred in 64/80 (80%) of cases. Most were in the uterus (63/64; 98%) with only a single case of ovarian neoplasia. Myometrial leiomyomas were present in 57/63 (90%) cases with uterine neoplasia. Uterine adenocarcinoma was present in 8/63 (13%) cases. Remaining cases included endometrial adenoma (2), focal carcinoma in situ in endometrial polyps (1), anaplastic carcinoma (1), endometrial hemangioma (1), primitive neuroectodermal tumor (PNET; 1), and angiosarcoma (1). One case with uterine adeno-

carcinoma had a separate pelvic mass histologically characterized as an anaplastic sarcoma. Distant metastases were documented in 5/8 (63%) cases of uterine adenocarcinoma, and in the uterine anaplastic carcinoma, PNET, and angiosarcoma. Four uterine adenocarcinomas and one carcinoma in situ were examined immunohistochemically for pan-cytokeratin, vimentin, and estrogen receptor. In all, neoplastic cells were pan-cytokeratin positive and vimentin negative, and in 2 cases were immunoreactive for estrogen receptor. Results show that female reproductive tract neoplasia, particularly of the uterus, is common in Asian elephants and is not limited to leiomyomas. Importantly, uterine neoplasms have the potential to impact fecundity and may represent obstacles to conservation in managed care. © 2021 The Authors.

M.-H. Lee, S.K.S.S. Nathan, L. Benedict, P. Nagalingam, E. Latimer, T. Hughes, D. Ramirez & J.R.A. Sukor

The first reported cases of elephant endotheliotropic herpesvirus infectious haemorrhagic disease in Malaysia: Case report

Virology Journal 18 (2021) e231

Abstract. Elephant endotheliotropic herpesvirus haemorrhagic disease (EEHV HD) is the leading cause of death in captive Asian elephant calves in Asia, North America, and Europe with a mortality rate of ~ 65% in calves that are under human care. Although EEHV HD was first found in elephant camps, more recently it was identified in wild populations which poses a greater threat to the elephant population. Deaths due to EEHV HD have been seen in wild elephants, but the in-situ prevalence and mortality rate is unknown. We report the first EEHV HD cases in Malaysia from 3 wild born endangered Bornean elephant calves from Sabah with known typical clinical signs. The first calf died within 24 h of the onset of clinical signs; the second calf died within 12 h of the onset of clinical signs. The third calf succumbed within 72 h. Necropsies revealed that all 3 calves had similar presentations of EEHV HD but in the third calf with less severity. We conducted conventional polymerase chain reaction (cPCR) assays and found EEHV DNA at all 7 loci in the 3 calves; it was identified as EEHV1A, the virus type that has been found in most other reported cases. Typical EEHV HD clinical signs and the molecular confirmation of EEHV by cPCR and sequencing point to EEHV as the cause of death. Further genetic investigation of the strain is in progress. © 2021 The Authors.

Y.M. Lekko, A. Che-Amati, P.T. Ooi, S. Omar, D.T. Mohd-Hamdan, L.S. Linazah, Z. Zakaria, S.Z. Ramanoon, M. Mazlan, F.F.A. Jesse, M.F.A. Abdul-Razak, S. Jasni & N. Abdul-Hamid

Detection of *Mycobacterium tuberculosis* complex antibodies in free-ranged wild boar and wild macaques in selected districts in Selangor and reevaluation of tuberculosis serodetection in captive Asian elephants in Pahang, Peninsular Malaysia

Journal of Veterinary Medical Science 83 (2021) 1702-1707

Abstract. Tuberculosis (TB) is a chronic inflammatory and zoonotic disease caused by *Mycobacterium tuberculosis* complex (MTBC) members, affecting several domestic animals, wildlife species and humans. The preliminary investigation was aimed to detect antibody against MTBC among indigenous wildlife which are free-ranged wild boar, free-ranged wild macaques and captive Asian elephants in selected areas of Selangor and elephant conservation centre in Pahang, respectively. The results indicate that MTBC serodetection rate in wild boar was 16.7% (7.3–33.5 at 95% confidence interval (CI)) using an in-house ELISA bPPD IgG and 10% (3.5–25.6 at 95% CI) by DPP®VetTB assay, while the wild macaques and Asian elephant were seronegative. The univariate analysis indicates no statistically significant difference in risk factors for sex and age of wild boar but there was a significant positive correlation ($P<0.05$) between bovine TB in dairy cattle and wild boar seropositivity in the Sepang district. © 2021 The Japanese Society of Veterinary Science.

L.-L. Li, J.M. Plotnik, S.-W. Xia, E. Meaux, & R.-C. Quan

Cooperating elephants mitigate competition until the stakes get too high

PLoS Biology 19 (2021) e3001391

Abstract. Cooperation is ubiquitous in the animal kingdom as it aims to maximize benefits through joint action. Selection, however, may also favor competitive behaviors that could violate cooperation. How animals mitigate competition is hotly debated, with particular interest in primates and little attention paid thus far to nonprimates. Using a loose-string pulling apparatus, we explored cooperative and competitive behavior, as well as mitigation of the latter, in semi-wild Asian elephants (*Elephas maximus*). Our results showed that elephants first maintained a very high cooperation rate (average = 80.8% across 45 sessions). Elephants applied "block," "fight back," "leave," "move side," and "submission" as mitigation strategies and adjusted these strategies according to their affiliation and rank difference with competition initiators. They usually applied a "fight back" mitigation strategy as a sanction when competition initiators were low ranking or when they had a close affiliation, but were submissive if the initiators were high ranking or when they were not closely affiliated. However, when the food reward was limited, the costly competitive behaviors ("monopoly" and "fight") increased significantly, leading to a rapid breakdown in cooperation. The instability of elephant cooperation as a result of benefit reduction mirrors that of human society, suggesting that similar fundamental principles may underlie the evolution of cooperation across species. © 2021 The Authors.

D.J. Liyanage, P. Fernando, P.N. Dayawansa, H.K. Janaka & J. Pastorini

The elephant at the dump: How does garbage consumption impact Asian elephants?

Mammalian Biology 101 (2021) 1089-1097

Abstract. We studied garbage consumption by Asian elephants at the Uddakandara garbage dump in southern Sri Lanka. Garbage at the dump was classified under six categories and quantified using a grid overlay. Elephants visiting the dump were individually identified by morphological criteria and items and quantities consumed by them were determined by focal animal sampling. Dung of elephants that did not consume garbage and those from the dump were compared quantitatively and dung constituents assessed by washing through three layered sieves. A total of 17 individual elephants visited the garbage dump during the study period, all of who were males. The observed sexual bias could be related to behavioural differences between the sexes. Elephants mostly consumed 'fruits and vegetables' and 'prepared food', possibly due to their higher palatability and nutritional value. Ingestion of polythene was incidental and associated with consuming prepared food. Proportions of the six categories in elephant diet and garbage piles were significantly different, indicating that elephants were highly selective when feeding. Elephant arrivals increased in response to unloading of garbage, suggesting attraction to fresh garbage. Dung analysis found that garbage consumption did not change the quantity and constituents of dung, except for the presence of anthropogenic items. As consumed anthropogenic items were regularly excreted, retention and obstruction of the alimentary tract are unlikely in elephants. Elephants feeding on garbage had better body condition than non-garbage consuming elephants, indicating that garbage provided better nutrition than natural food and was not detrimental to their health. © 2021 The Authors.

M. Mandal & N.D. Chatterjee

Geospatial approach-based delineation of elephant habitat suitability zones and its consequence in Mayurjharna Elephant Reserve, India

Environment, Development and Sustainability 23 (2021) 17788-17809

Abstract. No permission to print abstract.

G. Maurer, O. Gimenez, B. Mulot & N. Lescureux

Under pressure: How human-wild-captive elephant social-ecological system in Laos is teetering due to global forces and sociocultural changes

People and Nature 3 (2021) 1047-1063

Abstract. Few empirical studies have described social-ecological systems (SESs) in transition. Some studies focused on external drivers that impact the SES and communities' responses to adapt to changes, including economic, land and conservation policies. Others have considered the effect of social and cultural changes on communities' capacity to sustain their activities. While sociocultural changes are increasingly common through globalization and world-wide economic development, there is an urgent need to better understand and document how these changes affect individual and community agency to adapt or transform a system that is facing a combination of powerful internal and external forces. The human–Asian elephant relationship appears particularly illustrative of a complex SES because of the dual status of the elephant being wild or under human care, and the entanglement of ecological, cultural, social and economic dimensions. The ongoing and rapid political, socio-economic and environmental changes occurring in Laos for the last decades have strongly affected this relationship. We conducted an ethnological survey to assess how the SES has evolved in Laos and its consequences for human-wild-captive elephant interactions and elephant handling practices. We show that in the 1990s, the SES was based on the principles of common access to natural resources and social control over nature and spirits, and led to a form of elephant handling with close interactions between captive and wild elephants. Husbandry practices then could be likened to pastoralism as a mode of production associated with a mode of relation close to seasonal freedom. Since the turn of the present century, the commodification of nature and of increasingly divided access to natural resources led eventually to the segregation of wild elephants and captivity of their working conspecifics. With the intensification of workload, owners switched to a ranching-like economy, based on the accumulation of monetary capital from the employment of elephants in logging or tourism. We discuss how the combination of external drivers, such as economic liberalization, land and conservation policies, and internal drivers linked to sociocultural changes could affect a SES in transition, leading to a fading interest of the new generation in their family heritage. © 2021 The Authors.

F.M. Molenaar & P. Silvestre

Clinical approach to colic and collapse in an Asian elephant (*Elephas maximus*) with *Salmonella* saintpaul septicaemia and subsequent ileus

Vet Record Case Reports 10 (2022) e214

Abstract. An adult female Asian elephant (*Elephas maximus*) presented with clinical signs of colic unresponsive to analgesia, which progressed to hypothermia and collapse within 48 hours. Repeated sedations using butorphanol and detomidine were performed for initial diagnostic sampling, first aid and subsequent treatment. Initial haematology showed evidence of septicaemia and disseminated intravascular coagulation; urine analysis was consistent with metabolic acidosis. The initial treatment focused on rectal administration of enrofloxacin, metronidazole and fluids. By Day 7, the immune system was recovering as demonstrated by blood parameters but ileus had developed. Sedation interventions were discontinued and treatment consisted of oral ranitidine, fibre provision and rehydration. *Salmonella saintpaul* was cultured from the faeces and a disease risk analysis identified a possible infection route through food contamination. Serial haematology provided direction in clinical decision making throughout this challenging case. © 2021 British Veterinary Association.

R.P. Nair & E.A. Jayson

Estimation of economic loss and identifying the factors affecting the crop raiding behaviour of Asian elephant (*Elephas maximus*) in Nilambur part of the southern Western Ghats, Kerala, India

Current Science 121 (2021) 521-528

Abstract. The crop damage by the Asian elephant (*Elephas maximus*) on the livelihood of farmers is a major impediment to the conservation of the endangered mammals. The study was carried out in Malappuram district, Kerala, India from January 2013 to May 2016, to estimate the extent of crop damage by Asian elephants and to identify the factors affecting human-elephant conflict. To estimate the monetary loss, the method of running quadrats was employed. The major cash- crops destroyed by the Asian elephant were plantain (*Musa paradisiaca*), rubber (*Hevea brasiliensis*), areca nut (*Areca catechu*) and coconut (*Cocos nucifera*). A potential loss of Rs 5,076,827 (US$ 72,948) per annum (Rs 2,217,363 (US$ 31,861) (other crops) + Rs 2859,464 (US$ 41,087) (rubber)) was estimated. Fifty per cent of the encounters occurred at early midnight. The presence of areca nut cultivation and distance to the Reserve Forest were identified as the two factors affecting crop raiding. The damage to rubber trees by feeding on the bark has also been reported.

L. Natarajan, A. Kumar, Q. Qureshi, A.A. Desai & B. Pandav

Evaluation of wall-barriers to manage human conflict with Asian elephants in India
Wildlife Society Bulletin 45 (2021) 215-220
Abstract. The Terai Arc Landscape (TAL) in the foothills of the Himalayas is one of the four major elephant ranges in India. In response to the escalating problem of crop raiding by elephants, the State Forest Department of Uttarakhand (UKFD) has built walls along the forest boundary in several protected areas and multiple-use forest divisions. Given the high costs of constructing walls and the growing demand from farmers, the UKFD solicited an evaluation of wall efficacy. In response, we surveyed 98.4 km of walls in the TAL to assess frequency of breaches. We used generalized linear models to examine the influence of 7 explanatory variables on variation in breach frequencies between stretches of the wall. We observed 598 breaches and 87 weak spots in the 98.4 km of walls. Elephants caused 48% of the breaches, suggesting that walls in the TAL were not effective barriers against elephants. Explanatory variables of wall length, forest division, relative density of elephants, and land use along the wall stretches explained variation in wall breach frequencies. Based on our results, walls would only reduce elephant intrusion on 9 stretches (>1 km) totaling 11.8 km (approximately 12% of the wall stretches built in TAL). © 2021 The Wildlife Society.

L. Ni'am, S. Koot & J. Jongerden
Selling captive nature: Lively commodification, elephant encounters, and the production of value in Sumatran ecotourism, Indonesia
Geoforum 127 (2021) 162-170
Abstract. Ecotourism has become an increasingly important market-based practice in nature conservation. Several scholars and non-governmental organizations have discussed this as a commodification of nature in the context of capitalist expansion, but only a few have examined how value is produced in this process. Focusing on ecotourism in Tangkahan, in the Sumatra Island of Indonesia, this paper looks at how value is produced in human-elephant encounters. It builds on the concepts of lively commodities and encounter value to show how the incorporation of captive elephants in ecotourism generates value from two layers of interactions between humans and nonhumans. First, captive elephants are trained by mahouts for the encounters with tourists; then, the production of value takes place through tourists' encounters with the elephants in ecotourism activities (elephant bathing, elephant grazing, and trekking alongside the elephants). We argue that the expansion of the commodification of nature in some cases requires an understanding of the way this encounter value produces a 'captive nature': lively beings that are enclosed, managed, and employed to sell experiences. © 2021 The Authors.

L. Ong, A. Campos-Arceiz, V.P.W. Loke, P. bin Pura, C. Muhamad T. bin Tunil, H.S. A/L Din, R. bin Angah, N.A. binti Amirrudin, W.H. Tan, O. Lily, A. Solana-Mena & K.R. McConkey
Building ecological networks with local ecological knowledge in hyper-diverse and logistically challenging ecosystems
Methods in Ecology and Evolution 12 (2021) 2042-2053
Abstract. Collecting interaction data to build frugivory or seed dispersal networks is logistically challenging in ecosystems that have very high plant and animal diversity and/or where fieldwork is difficult or dangerous. Consequently, the majority of available networks are from ecosystems with low species diversity or they represent a subset of the community. Here, we propose an approach applying local ecological knowledge (LEK) of indigenous communities to build quantitative interaction databases and networks that would otherwise be difficult to achieve with direct observations. Indigenous communities live in many hyper-diverse ecosystems and the people within these communities often have detailed knowledge of ecological processes. Working in a Sundaland biodiversity hotspot – Royal Belum State Park, Peninsular Malaysia – we used visually oriented interviews with indigenous people (Orang Asli, in the Jahai and Temiar ethnic subgroups), field data and published records to collate interactions, and their estimated frequency of occurrence, of animal fruit consumption and seed dispersal. We documented 2,063 fruit consumption and 1,360 seed dispersal interactions among 164 plant species and 34 animal taxa, the latter representing groups of closely related species or

individual species. The majority of the interactions (97%) were identified by the LEK interviews, with the additional methods (field data and published records) used to support and marginally expand the interview data. The metrics for the networks we built reflect those of networks structured by biological mechanisms, supporting the validity of our novel approach. LEK is highly relevant for building detailed databases for ecological interactions in hyperdiverse and/or challenging ecosystems. Such ecosystems are among the most vulnerable on earth, harbouring ecological interactions that are often poorly documented at a community level. We show how LEK can broaden our knowledge of such sensitive ecosystems, but our approach is useful for any ecosystem in which people hold rich LEK.

M.R. Palombo, R. Carlini & S. Gippoliti

Critical inventory of *Loxodonta* and *Elephas* (Mammalia, Proboscidea) cranial remains in the collections of the Museo Civico di Zoologia of Rome (Italy)

Bollettino del Museo Civico di Storia Naturale di Verona, Botanica Zoologia 45 (2021) 17-60

Abstract. The osteological collection of the Museo Civico di Zoologia of Rome (MCZR) counts 2 complete skeletons, 4 skulls with mandible, 4 skulls, 5 mandibles, 1 molariform tooth, and 11 more or less complete tusks of extant elephants. This research aims to identify to which elephant among those that lived in captivity and died at the Zoological Garden of Rome (ZGR) the cranial material belongs. The results of the qualitative and quantitative analysis, the inferred sex and age estimates permit to assert that the elephant cranial remains of MCZR's osteological collections belong to at least four taxa (*Loxodonta africana*, *Loxodonta cyclotis*, *Elephas maximus maximus*, and *Elephas maximus sumatranus*). 4 Asian and 3 African among the 14 Asian and the 6 African elephants that died at the ZGR from 1910 to 2012 were identified, while for 2 Asian elephants the identification was doubtful or highly uncertain. In addition, we acknowledged the presence of a large cranium of an African bush male of unknown provenance, a skull of an African forest male that lived at the Zoo of Naples from 1952 to 1955, and of a skull of a very young Asian elephant of unknown origin.

S. Paudel, E.P. Brenner, S.A. Hadi, Y. Suzuki, C. Nakajima, T. Tsubota, K.P. Gairhe, B. Maharjan & S. Sreevatsan

Genome sequences of two *Mycobacterium tuberculosis* isolates from Asian elephants in Nepal

Microbiology Resource Announcement 10 (2021) e00614-21

Abstract. This report describes the genome sequences of two *Mycobacterium tuberculosis* isolates, S1 and S3, recovered from Asian elephants in Nepal. These genome sequences will enhance our understanding of the genomic epidemiology of *M. tuberculosis* in Asian elephants.

W.P.T.A. Perera, P.H.K.L.A. Prematilaka, M.H.A. Haseena, A.H.L.C.M. Athapaththu & M.R. Wijesinghe

Changes in habitat coverage from 2005 to 2019 in the Udawalawe National Park, Sri Lanka

Ceylon Journal of Science 50 (2021) 467-474

Abstract. In protected areas (PAs) designated for the conservation of biodiversity, temporal landscape changes do occur, driven by natural and anthropogenic factors. Such changes may impact on the conservation value of the PA. In a wildlife PA, changes in habitat extents could adversely affect some of the faunal species. Our objective was to assess temporal changes in the cover of three major habitat types in the Udawalawe National Park (UWNP) that have occurred over a short term. Based on the outcome, we aimed to determine the potential impacts such changes would have on the wildlife. Considering that UWNP was established primarily for conserving the nationally threatened and flagship species *Elephas maximus*, we carried out field studies and decided on three relevant habitat types - forest, scrub, and grassland. We used multi-temporal satellite images with ground truthing for assessing habitat extents in the years 2005, 2010, 2015, and 2019. Habitat cover maps were prepared using supervised classification and changes in the extents of the selected habitats were assessed. Between

2005 and 2019, the areas under forest and scrub had increased. The grassland has considerably decreased, mainly owing to invasion by scrub. Grassland depletion adversely impacts the elephant whose preferred food is grass and the high population of elephants in UWNP aggravates the situation. Depletion of food resources within the park would also lead to an increase in the human-elephant conflicts in border villages. Thus, in this study we highlight the importance of monitoring temporal changes in habitat cover in order to manage the PA and the inhabiting wild elephants.

J.-P. Puyravaud & P. Davidar

Wildlife managers ignore previous knowledge at great risk: The case of Rivaldo, the iconic wild Asian elephant *Elephas maximus* L. of the Sigur Region, Nilgiri Biosphere Reserve, India

J. of Threatened Taxa 13 (2021) 20249-20252

Abstract. Management of wildlife depends mostly on scientific data; ignoring this can lead to unintended consequences. We take the case study of the wild male Asian Elephant Rivaldo of the Sigur Region, who was translocated out of his range. Rivaldo returned to his home range within a few days, which could have been expected if scientific publications had been consulted. We suggest that a simple checklist of relevant publications can help park managers to decide on a proper management procedure. We also used a simple Bayesian framework to visually show how the probability of predicting a management outcome is increased by prior knowledge. The expensive and risky effort to relocate the elephant could have been avoided altogether if prior knowledge had been taken into consideration. © 2021 The Authors.

A.K. Ram, S. Mondol, N. Subedi, B.R. Lamichhane, H.S. Baral, L. Natarajan, R. Amin & B. Pandav

Patterns and determinants of elephant attacks on humans in Nepal

Ecology and Evolution 11 (2021) 11639-50

Abstract. Attacks on humans by Asian elephant (*Elephas maximus*) is an extreme form of human–elephant conflict. It is a serious issue in southern lowland Nepal where elephant-related human fatalities are higher than other wildlife. Detailed understanding of elephant attacks on humans in Nepal is still lacking, hindering to devising appropriate strategies for human–elephant conflict mitigation. This study documented spatiotemporal pattern of elephant attacks on humans, factors associated with the attacks, and human/elephant behavior contributing to deaths of victims when attacked. We compiled all the documented incidences of elephant attacks on humans in Nepal for last 20 years across Terai and Chure region of Nepal. We also visited and interviewed 412 victim families (274 fatalities and 138 injuries) on elephant attacks. Majority of the victims were males (87.86%) and had low level of education. One fourth of the elephant attacks occurred while chasing the elephants. Solitary bulls or group of subadult males were involved in most of the attack. We found higher number of attacks outside the protected area. People who were drunk and chasing elephants using firecrackers were more vulnerable to the fatalities. In contrast, chasing elephants using fire was negatively associated with the fatalities. Elephant attacks were concentrated in proximity of forests primarily affecting the socioeconomically marginalized communities. Integrated settlement, safe housing for marginalized community, and community grain house in the settlement should be promoted to reduce the confrontation between elephants and humans in entire landscape for their long-term survival. © 2021 The Authors.

M. Ranjini, P.M. Deepa, K. Vijayakumar, A. Janus & K. Karthyayini

Haemato-biochemical changes in tuberculosis infected and healthy Asian elephants (*Elephas maximus*) from South India

Journal of Veterinary and Animal Sciences 52 (2021) 345-349

Abstract. Tuberculosis is known to be a disease of elephants for the past 2000 years. The main causative agent isolated from reported tuberculosis (TB) cases were *Mycobacterium tuberculosis*. The study focuses on the haematological and serum biochemical changes in the blood of TB infected Asian elephants (*Elephas maximus*). Twelve apparently healthy elephants and twelve TB infected elephants (confirmed by trunk wash smear positive for acid fast bacilli) were selected for the study. Neonates, pregnant elephants and elephants in musth were not in-

cluded in the study. The study animals were subjected to haematological and serum biochemical evaluation. The data were analysed statistically. The results showed a significant increase in total leukocyte count, lymphocyte count, monocyte count, thrombocyte count and ESR in TB affected animals compared with apparently healthy animals. Serum creatinine, total bilirubin, direct bilirubin, globulin was significantly high in TB affected animals compared with healthy controls. Assessment of haematological and serum biochemical parameters in TB affected elephants aid in diagnosis and tracking of the infection. © 2021 The Authors.

L. Rutherford & L.E. Murray

Personality and behavioral changes in Asian elephants (*Elephas maximus*) following the death of herd members

Integrative Zoology 16 (2021) 170-188

Abstract. Elephants are highly social beings with complex individual personalities. We know that elephants have a general interest in death, investigating carcasses, not just limited to kin; however, research does not explore in depth whether individuals change their behavior or personality following traumatic events, such as the death of a conspecific. Within a captive herd of Asian elephants (*Elephas maximus*) housed at Chester Zoo, UK, we measured social behaviour and proximity and personality using the TIPI, and found age-related and relationship-related changes in both behavior and personality following the deaths of herd members. Overall, the herd spent less time socialising and engaging in affiliative behaviors following the death of the adult female when compared to baseline data, yet spent more time engaging in these behaviors after the death of two calves. The death of the central female had a dramatic impact on her infant calf, resulting in increasingly withdrawn behavior, yet had the opposite effect on her adult daughter, who subsequently established a more integrated role within the herd. Emotional Stability fell in the motherless calf but rose in an adult female, who had lost her adult daughter, but had a new calf to care for. We suggest that the greater impact on the behaviour and personality of surviving herd members following the deaths of calves, compared to an adult member, attests to the significance of the unifying role played by calves within an elephant herd. © 2020 International Society of Zoological Sciences.

N. Sahoo, S.K. Sahu, A.K. Das, D. Mohapatra, S.K. Panda, S.K. Gupta, B.K. Behera, A. Pahari & M. Dash

Elephant endotheliotropic herpesvirus hemorrhagic disease outbreak in an Indian zoo

Journal of Zoo and Wildlife Medicine 52 (2021) 1286-1297

Abstract. Elephant endotheliotropic herpesvirus hemorrhagic disease (EEHV HD) is an acute viral infection of growing Asian elephants (*Elephas maximus*). Four apparently healthy subadult Asian elephants aged between 6 and 10 yr at Nandankanan Zoological Park (NKZP), India, died of EEHV HD during August–September 2019. All four elephants were rescued from different reserved forests of Odisha state at less than 1 yr of age and hand reared in the NKZP. Elephants exhibited the clinical signs of lethargy, head swelling, fever, loss of appetite, abdominal distension, scant urination and defecation, signs of colic, lameness, trunk discharge, cyanosis/ulceration of tongue, erratic behavior, and recumbence before death. Period of illness varied between 28 and 42 h. Thrombocytopenia was the common significant hematological observation. No significant biochemical alterations were recorded except for higher creatinine concentrations. Analysis of blood samples in RT-PCR assay using two different sets of primers and probes that targeted terminase gene and major DNA-binding protein gene followed by cPCR and sequencing was positive for EEHV-1A in all four animals. Postmortem examination of all four carcasses showed hemorrhages in internal organs, including the hard palate, heart, lungs, stomach, mesenteric lymph nodes, mesentery, colon serosa, spleen, liver, kidney, and meninges. Histopathology showed congestion and/or hemorrhages in heart, lung, brain, kidney, and liver. There was presence of intranuclear inclusion bodies in the sinusoidal epithelial cells. The outbreak of EEHV HD that resulted in the acute death of four juvenile captive Asian elephants within <30 d, the first of its kind documented in India, is increasing the fear of similar outbreaks in the future. © 2021 American Association of Zoo Veterinarians.

N. Sathiandran, P.J. Vineesh & S.K. Thomas
Dung preference and trophic association of dung beetles (Coleoptera: Scarabaeidae) in the moist forests of the South-western Ghats of the Indian subcontinent
J. Asia-Pacific Entomology 24 (2021) 739-748
Abstract. First quantitative dung beetle-feeding trophic network analysis for the Oriental region is carried out by investigating trophic network interaction between dung beetles and mammal dung types in the moist forests of the Western Ghats a global biodiversity hot spot in south-western India. Dung-beetle assemblage associated with the dung of the prominent mammals, such as the macaque, boar, gaur, elephant and deer, showed differences in richness, abundance and composition among different dung types. Most dung beetles were generalists with low resource specificity and community-wide generalist feeding on herbivore and omnivore dung types. Dung beetles in the region displayed high species richness and abundance in boar dung. The high attraction and specificity of dung beetles towards the odoriferous boar dung indicate that the omnivore mammal *Sus scrofa* has a major role in maintaining the dung beetle community in the forests of the Western Ghats. Network interaction analysis shows that the vast majority in the assemblage are generalist species, and the few specialist species were all with low abundance. Low overall specialisation and low resource partitioning with high species richness is recorded in the assemblage. The assemblage's trophic level preference is reflected in the high dung specificity recorded in the omnivore and herbivore dung types. © 2021 Reprinted with permission from Elsevier.

M. Seewald, C. Gohl, M. Egerbacher, S. Handschuh & K. Witter
Endodontic treatment of a traumatic tusk fracture with exposed pulp in an Asian elephant (*Elephas maximus*)
J. of Veterinary Dentistry 38 (2021) 139-151
Abstract. Tusk fracture in elephants is a common incident often resulting in pulp exposure and pulpitis. Extensive lavage, endodontic therapy, direct pulp capping, or extraction are treatment options. In this report, the successful management of a broken tusk of a juvenile male Asian elephant (*Elephas maximus*) including morphological analysis of the tusk tip 2 years after surgery are presented. Treatment was carried out under barn conditions and included antimicrobial photodynamic therapy and partial pulpotomy with direct pulp capping. Immediate pain relief was reached. The fractured tusk was preserved and continued to grow. The therapeutic filling material remained intact for over 1 year but was absent 2 years after treatment. The former pulp cavity of the tusk tip was filled with reparative dentin, osteodentin, and bone, but the seal between these hard tissues and pulp chamber dentin was incomplete. Radiographs obtained 3 years after treatment showed no differences in pulp shape, pulp width, and secondary dentin formation between the treated right and the healthy left tusk. It can be concluded that in case of an emergency, the endodontic therapy of a broken elephant tusk can be attempted under improvised conditions with adequate success. Photodynamic therapy might contribute to prevent infection and inflammation of the pulp. The decision tree published by Steenkamp (2019) provides a valuable tool to make quick decisions regarding a suitable therapy of broken tusks. © 2021 The Authors.

Y. Shah & S. Paudel
Protect elephants from tuberculosis
Science 374 (2021) 832-833
Abstract. None.

W.H. Tan, A. Hii, A. Solana-Mena, E.P. Wong, V.P.W. Loke, A.S.L. Tan, A. Kromann-Clausen, N. Hii, P. bin Pura, M.T. bin Tunil, S.A.L. Din, C.F. Chin & A. Campos-Arceiz
Long-term monitoring of seed dispersal by Asian elephants in a Sundaland rainforest
Biotropica 53 (2021) 453-465
Abstract. Asian elephants (*Elephas maximus*) have inhabited almost all forests in tropical Asia until recently, yet little is known about their role in ecological processes, particularly in the Sundaic forests of South-East Asia. These forests are peculiar in their phenology, with supra-annual and highly irregular episodes of mast fruiting. Here, we present a long-term (6-year) monitoring of the seeds dispersed by elephants in dipterocarp forests of northern Peninsular Malaysia. We conducted monthly dung surveys at two mineral licks (11.3 km apart) frequently visited by elephants. Additionally, we recorded haphazard observations of seeds and

seedlings in elephant dung at other locations. We recorded a minimum of 48 morphospecies from at least 25 plant families dispersed by elephants. Elephant seed dispersal was very heterogenous in space, with only 30.3% of the morphospecies dispersed at both sites (Jaccard dissimilarity index = 0.48). Temporally, elephants dispersed seeds in sporadic pulses of abundance and diversity, without any apparent seasonality (seeds appeared in 19.1% of 1,284 dung piles and 57.1% of the 63 months in which we found dung) and with long periods without any seed being dispersed. Nearly half (48%) of the plants dispersed by elephants belong to a megafaunal dispersal syndrome. Our long-term approach allowed us to unravel an important aspect of Asian elephants' role and effectiveness in the seed dispersal cycle. Sundaland's forests are undergoing a rapid loss of their previously common megaherbivores (rhinos and elephants), with profound and long-term consequences for ecosystem functioning. © 2021 The Association for Tropical Biology and Conservation.

S. Terada

Building human-elephant relationships based on science and local ownership: A long-lasting issue in the era of sustainable development goals (Commentary)

Animal Conservation 24 (2021) 738-739

Abstract. None.

L. N. Tiller & H. F. Williams

The elephant in the farm: Long-term solutions are the key to coexistence (Commentary)

Animal Conservation 24 (2021) 733-734

Abstract. None.

J.A. de la Torre, E.P. Wong, A.M. Lechner, N. Zulaikha, A. Zawawi, P. Abdul-Patah, S. Saaban, B. Goossens & A. Campos-Arceiz

There will be conflict – agricultural landscapes are prime, rather than marginal, habitats for Asian elephants

Animal Conservation 24 (2021) 720-732

Abstract. Misconceptions about species' ecological preferences compromise conservation efforts. Whenever people and elephants share landscapes, human–elephant conflicts (HEC) occur in the form of crop raiding, elephant attacks on people and retaliatory actions from people on elephants. HEC is considered the main threat to the endangered Asian elephant *Elephas maximus*. Much of HEC mitigation in Asia is based on rescuing elephants from conflict areas and returning them to nature, for example, by means of 'problem elephant' translocation. Here, we used two independent and extensive datasets comprising elephant GPS telemetry and HEC incident reports to assess the relationship between elephant habitat preferences and the occurrence of HEC at a broad spatial scale in Peninsular Malaysia. Specifically, we assessed (a) the habitat suitability of agricultural landscapes where HEC incidents occur and (b) sexual differences in habitat preferences with implications for HEC mitigation and elephant conservation. We found strong differences in habitat use between females and males and that the locations of HEC incidents were areas of very high habitat suitability for elephants, especially for females. HEC reports suggest that in Peninsular Malaysia females are involved in more crop damage conflicts than males, whereas males are more prone to direct encounters with people. Our results show that human-dominated landscapes are prime elephant habitat, and not merely marginal areas that elephants use in the absence of other options. The high ecological overlap between elephants and people means that conflict will continue to happen when both species share landscapes. HEC mitigation strategies, therefore, cannot be based on elephant removal (e.g. translocation) and need to be holistic approaches that integrate both ecological and human social dimensions to promote tolerated human-elephant coexistence. © 2021 The Zoological Society of London.

D. Vasudev, V.R. Goswami, N. Srinivas, B.L.N. Syiem & A. Sarma

Identifying important connectivity areas for the wide-ranging Asian elephant across conservation landscapes of Northeast India

Diversity and Distributions 27 (2021) 2510-26

Abstract. Connectivity is increasingly important for landscape-scale conservation programmes. Yet there are obstacles to developing reliable connectivity maps, including paucity of data on animal use of the non-habitat matrix. Our aim was to identify important connectivity

areas for the endangered Asian elephant *Elephas maximus* across a 21,210 km^2 region using empirical data and recently developed animal movement models. We interviewed 1,184 respondents, primarily farmers, residing across our study region, to collect crowd-sourced data on elephant use of the matrix. We generated a classified land use/land cover map and collated remotely sensed data on environmental and anthropogenic covariates. We used logistic regression to estimate the influence of these covariates on resistance, based on elephant detections recorded via interviews. We modelled elephant movement within the randomised shortest path framework, which allows for scenarios ranging from optimal movement with complete information on the landscape to random movement with no information on the landscape. We calculated the passage of elephants through pixels in our study region, a parameter that denotes the expected number of elephant movements through a particular pixel across movement routes. We overlaid linear infrastructure sourced from secondary data, and human-elephant conflict hotspots generated from our interview data, on passage maps. Elephants preferred locations with high vegetation cover, close to forests and with low human population density. We mapped important connectivity areas across the study region, including in three important conservation landscapes. Whilst forests facilitated connectivity, the matrix also played an important contributory role to elephant dispersal. Incorporating information on environmental and anthropogenic drivers of elephant movement added value to connectivity predictions. Fine-scale mapping of connectivity, using empirical data and realistic movement models, such as the approach we use, can provide for informed and more effective landscape-scale conservation.

S.C. Vernes, B.P. Kriengwatana, V.C. Beeck, J. Fischer, P.L. Tyack, C. ten Cate & V.M. Janik

The multi-dimensional nature of vocal learning

Philosophical Transactions of the Royal Society B 376 (2021) e20200236

Abstract. How learning affects vocalizations is a key question in the study of animal communication and human language. Parallel efforts in birds and humans have taught us much about how vocal learning works on a behavioural and neurobiological level. Subsequent efforts have revealed a variety of cases among mammals in which experience also has a major influence on vocal repertoires. Janik and Slater (Anim. Behav.60, 1–11) introduced the distinction between vocal usage and production learning, providing a general framework to categorize how different types of learning influence vocalizations. This idea was built on by Petkov and Jarvis (Front. Evol. Neurosci.4, 12) to emphasize a more continuous distribution between limited and more complex vocal production learners. Yet, with more studies providing empirical data, the limits of the initial frameworks become apparent. We build on these frameworks to refine the categorization of vocal learning in light of advances made since their publication and widespread agreement that vocal learning is not a binary trait. We propose a novel classification system, based on the definitions by Janik and Slater, that deconstructs vocal learning into key dimensions to aid in understanding the mechanisms involved in this complex behaviour. We consider how vocalizations can change without learning, and a usage learning framework that considers context specificity and timing. We identify dimensions of vocal production learning, including the copying of auditory models (convergence/divergence on model sounds, accuracy of copying), the degree of change (type and breadth of learning) and timing (when learning takes place, the length of time it takes and how long it is retained). We consider grey areas of classification and current mechanistic understanding of these behaviours. Our framework identifies research needs and will help to inform neurobiological and evolutionary studies endeavouring to uncover the multi-dimensional nature of vocal learning.

H. Wang, P. Wang, X. Zhao, W. Zhang, J. Li, C. Xu & P. Xie

What triggered the Asian elephant's northward migration across southwestern Yunnan?

The Innovation 2 (2021) e100142

Abstract. None.

M.E. Weston, K.E. Mills & M.A.G. von Keyserlingk

Your happiness or mine: Influence of affective states and level of contact on public perceptions of elephant tourism

Animal Welfare 30 (2021) 279-293

Abstract. Many captive Asian elephants (*Elephas maximus*) in Thailand participate in the tourism industry at attractions known as 'elephant camps.' There has been significant criticism of low welfare venues, where the elephants may experience injuries, poor nutrition, unnatural social environments and aversive handling. Despite increasing concern for animal welfare, the general public often have difficulty identifying the welfare issues affecting captive animals. The aim of this study was to investigate participants' willingness to support an elephant attraction and their perceived emotional value from the experience, based on the affective state of the captive elephant and their level of contact with it. Participants (n = 590) from the United States were randomly assigned to one of four vignettes (using a 2×2 experimental design) that described an elephant attraction, varying the affective state of the elephant (feels excellent, feels terrible) and the level of contact they could have with the elephant (low, high). A mixed methods approach was used, where participants provided answers to Likert-type questions, followed by an open-ended response. Participants showed greater willingness to support the elephant attraction and greater perceived emotional value from the experience when the elephant felt excellent, as opposed to when the elephant felt terrible. There were no significant differences between low and high contact for the measures included in this study. Qualitative responses varied greatly, with participants making many assumptions about the elephant and the attraction, revealing potential misconceptions that they had regarding the welfare of captive elephants. This research may be used to encourage a shift in tourism preferences to venues that reflect positive elephant welfare. © 2021 Universities Federation for Animal Welfare.

E.P. Wong, A. Campos-Arceiz, N. Zulaikha, P. Chackrapani, A.G. Quilter, J.A. de la Torre, A. Solana-Mena, W.H. Tan, L. Ong, M.A. Rusli, S. Sinha, V. Ponnusamy, T.W. Lim, O.C. Or, A.F. Aziz, N. Hii, A.S.L. Tan, J. Wadey, V.P.W. Loke, A. Zawawi, M. M. Idris, P.A. Patah, M.T.A. Rahman & S. Saaban

Living with elephants: Evidence-based planning to conserve wild elephants in a megadiverse south east Asian country

Frontiers in Conservation Science 2 (2021) e682590

Abstract. Theory of Change (ToC) and Social Return of Investment (SROI) are planning tools that help projects craft strategic approaches in order to create the most impact. In 2018, the Management & Ecology of Malaysian Elephants (MEME) carried out planning exercises using these tools to develop an Asian elephant conservation project with agriculture communities. First, a problem tree was constructed together with stakeholders, with issues arranged along a cause-and-effect continuum. There were 17 main issues identified, ranging from habitat connectivity and fragmentation, to the lack of tolerance toward wild elephants. All issues ultimately stemmed from a human mindset that favors human-centric development. The stakeholders recognize the need to extend conservation efforts beyond protected areas and move toward coexistence with agriculture communities for the survival of the wild elephants. We mapped previous Human-Elephant Conflict (HEC) management methods and other governmental policies in Malaysia against the problem tree, and provided an overview of the different groups of stakeholders. The ToC was developed and adapted for each entity, while including Asian elephants as a stakeholder in the project. From the SROI estimation, we extrapolated the intrinsic value of the wild Asian elephant population in Johor, Malaysia, to be conservatively worth at least MYR 7.3 million (USD 1.8 million) per year. From the overall calculations, the potential SROI value of the project is 18.96 within 5 years, meaning for every ringgit invested in the project, it generates MYR 18.96 (USD 4.74) worth of social return value. There are caveats with using these value estimations outside of the SROI context, which was thoroughly discussed. The SROI provides projects with the ability to justify to funders the social return values of its activities, which we have adapted to include the intrinsic value of an endangered megafauna. Moreover, SROI encourages projects to consider unintended impacts (i.e., replacement, displacement, and deadweight), and acknowledge contributions from stakeholders. The development of the problem tree and ToC

via SROI approach, can help in clarifying priorities and encourage thinking out of the box. For this case study, we presented the thinking process, full framework and provided evidences to support the Theory of Change. © 2021 The Authors.

D. Yin, Z. Yuan, J. Li & H. Zhu
Mitigate human-wildlife conflict in China
Science 373 (2021) 500-501
Abstract. none.

Y. Yun, S. Sriphiboon, K. Pringproa, P. Chuammitri, V. Punyapornwithaya, K. Boonprasert, P. Tankaew, T. Angkawanish, K. Namwongprom, O. Arjkumpa, J.L. Brown & C. Thitaram
Clinical characteristics of elephant endotheliotropic herpesvirus (EEHV) cases in Asian elephants (*Elephas maximus*) in Thailand during 2006–2019
Veterinary Quarterly 41 (2021) 268-279
Abstract. Elephant endotheliotropic herpesvirus causes a hemorrhagic disease (EEHV-HD) that is a major cause of death in juvenile Asian elephants with EEHV1 and EEHV4 being the most prevalent. Aim: To perform a retrospective clinical data analysis. Records of a total of 103 cases in Thailand confirmed by polymerase chain reaction (PCR) on blood and/or tissue samples. The severity of clinical signs varied among EEHV subtypes. EEHV1A was the most prevalent with 58%, followed by EEHV4 with 34%, EEHV1B with 5.8% and EEHV1&4 co-infection with 1.9%. Overall case fatality rate was 66%. When compared among subtypes, 100% case fatality rate was associated with EEHV1&4 co-infection, 83% with EEHV1B, 75% with EEHV1A, and the lowest at 40% for EEHV4. Calves 2- to 4-year old were in the highest age risk group and exhibited more severe clinical signs with the highest mortality. Majority of cases were found in weaned or trained claves and higher number of cases were observed in rainy season. A gender predilection could not be demonstrated. Severely affected elephants presented with thrombocytopenia, depletion of monocytes, lymphocytes and heterophils, a monocyte:heterophil (M:H) ratio lower than 2.37, hypoproteinemia (both albumin and globulin), severe grade of heterophil toxicity, and low red blood cell counts and pack cell volumes. Survival was not affected by antiviral drug treatment in the severely compromised animals. Early detection by laboratory testing and aggressive application of therapies comprising of supportive and antiviral treatment can improve survival outcomes of this disease. © 2021 The Authors.

N. Zainol, T.M. Taher, S.N.A. Razak, N.A.I. Noh, N.A.M. Nazir, A.M. Shukor, A. Ibrahim & S.M. Nor
Wildlife crossings at Felda Aring - Tasik Kenyir road, Malaysia
Pertanika Journal of Tropical Agricultural Science 44 (2021) 401-427
The Felda Aring - Tasik Kenyir road was identified as one of the most threatening roads to wildlife in Malaysia. The present study was conducted to assess the road crossing activities involving the medium- to large-mammal species due to the problem stated. The objectives of this study were to (1) predict the suitability of the road and its surroundings as the roaming areas for the Asian elephant (*Elephas maximus*, n = 104) and Malayan tapir (*Tapirus indicus*, n = 66), (2) identify the mammalian species inhabiting the forest beside the road, (3) compare the forest's common species [photographic capture rate index (PCRI) > 10/ detection probability (P) ≥ 0.05] with the ones utilising the road crossing structures; the viaducts and the bridges, and (4) determine the most impacted species from traffic collisions. The road and its surroundings were classified as moderately suitable to the elephant and tapir (suitability values = 0.4 – 0.8). A total of 16 mammal species were recorded at the forest edges, in which the wild pig (PCRI = 118.96, P = 0.3719 ± 0.027), barking deer (PCRI = 68.89, P = 0.2219 ± 0.0232), sun bear (PCRI = 11.13, P = 0.0507 ± 0.0159), tapir (PCRI = 11.13, P = 0.0469 ± 0.0118), elephant (PCRI = 10.7, P = 0.0787 ± 0.0195), and Malayan porcupine (PCRI = 10.7, P = 0.103 ± 0.0252) were the common species utilising the crossing structures. In contrast, the Asian palm civet and leopard cat were the most frequently hit species on the road [$F(7,398) = 28.53$, $p < 0.0005$]. The present study found that large-mammal species were utilising the crossing structures at a higher frequency, whereas more medium-mammal species were involved in traffic collisions. © 2021 Universiti Putra Malaysia Press.

Instructions for Contributors

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Baskaran N & Desai AA (1996) Ranging behavior of the Asian elephant (*Elephas maximus*) in the Nilgiri biosphere reserve, South India. *Gajah* **15:** 41-57.

Olivier RCD (1978) *On the Ecology of the Asian Elephant*. Ph.D. thesis, University of Cambridge, Cambridge, UK.

Rajapaksha RC, Mendis GUSP & Wijesinghe CG (2004) Management of Pinnawela elephants in musth period. In: *Endangered Elephants, Past Present and Future*. Jayewardene J (ed) Biodiversity & Elephant Conservation Trust, Colombo, Sri Lanka. pp 182-183.

Sukumar R (1989) *The Asian Elephant: Ecology and Management*. Cambridge Univ. Press, Cambridge, UK.

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