GAJAH

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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

Gajah will be published as both a hard copy and an on-line version accessible from the AsESG web site (www.asesg.org/gajah.htm). If you would like to be informed when a new issue comes out, please provide your e-mail address. If you need to have a hardcopy, please send a request with your name and postal address by e-mail to <jenny@aim.uzh.ch>.

Cover

Tusker "Tenzing" in the Anamalai hills, southern India
Photo by Sreedhar Vijayakrishnan
(See article on page 39)

Layout and formatting by Dr. Jennifer Pastorini

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Editorial

Jennifer Pastorini (Editor)

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You are holding the 52nd issue of *Gajah* in your hands. You will find five research articles, one of them peer-reviewed, and one short communication on Asian elephants. Four articles are from India and the other two are from Thailand and Sri Lanka. This *Gajah* also includes two workshop reports and two Working Group summaries.

For the **Peer-Reviewed Research Article** Carleen Schwarz and co-authors studied the foraging behaviour of five semi-free elephants. They found that during 298.5 h of foraging the elephants fed on 165 different plant species.

For the first **Research Article** Jyoti Das *et al*. conducted line transects looking for elephant dung in Manas National Park to get an idea about population densities. They estimated that around 600 elephants are in the park. Rahul De and co-authors designed new primers for three regions of the mtDNA genome of elephants. As the amplified fragments are short it will also work for low quality DNA as in dung samples. Julee Jerang *et al*. looked at 100 facilities, each keeping 1–6 elephants, to evaluate the demography, care-taking and feeding habits of the captive elephant population in Eastern Arunachal Pradesh.

Sreedhar Vijayakrishnan *et al*. compiled a **Review Article** on how to survey elephants. They summarize direct and indirect count methods and discuss the importance of monitoring elephants for conservation.

In the **Short Communication** a very rare sighting of elephant twins in the wild is described and a brief overview of twinning in elephants is provided.

In **News and Briefs** we are informed about a workshop held in Thailand to discuss reintroduction of captive elephants to the wild. Another meeting was held by the Elephant Conservation Group in Sabah to exchange experiences and ideas between teams working on elephant conservation. As usual this *Gajah* presents abstracts from 48 recent scientific publications on Asian elephants and there are glimpses at 23 newspaper articles across Asia.

I am particularly pleased about the first two summaries of two AsESG **Working Groups** (see previous notes from the Chair of the AsESG) who have completed their tasks. The Working Group for "Guidelines for the rehabilitation of captive elephants as a possible restocking option for wild populations" came up with guidelines for the planning stage, the rehabilitation itself and also the post-release period. The Working Group dealing with "Management and care of captive Asian elephant bulls in musth" described the signs of musth in detail, discussed factors associated with musth and provided guidelines on how to deal with musth bulls, also listing options to diminish or suppress musth.

The **Chair** of the AsESG, Vivek Menon, gives us an update on the progress made by the Working Groups and informs us about the new elephant policies drafted in different countries. Most importantly he explains the proceedings for starting the next 4-year term of the AsESG, as the current term comes to an end in January 2021.

This *Gajah* would not have been possible without the hard work of the **Editorial Board** members and the generous funding of the **Wildlife Reserves Singapore Group**. I would like to thank the **authors** who not only submitted their manuscripts but also revised them willingly to make them much more interesting for the readers of *Gajah*. Four **reviewers** also helped *Gajah* by reviewing manuscripts.

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Notes from the Chair IUCN SSC Asian Elephant Specialist Group

Vivek Menon

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Dear Members

The current pandemic has created an unprecedented situation that has affected us all – our families, our work and our way of life. I hope you and your families are keeping well. Our hearts are with those who have been affected personally by the outbreak of corona virus and wish them speedy recovery. The current pandemic has, however, opened up new ways of working and communications and this has kept us all connected despite of the travel restrictions.

After a successful Asian Elephant Specialist Group (AsESG) members meeting in Sabah, Malaysia in December 2019 and based on the recommendations of AsESG meeting in Sabah, two new Working Groups have been formed; one on Borneo elephants to decide if this should be considered as subspecies and its Red-listing and the second for drafting the National Action Plan for conservation of elephants in Peninsular Malaysia. The Department of Wildlife & National Parks (DWNP), Peninsular Malaysia has planned to evaluate the implementation status of existing plan this month based on which the formulation of the new plan could be initiated early next year.

The Working Group documents that have already been submitted are being reviewed and will soon be available on the AsESG website. Summaries of two of these guidelines are being published in this volume of *Gajah*. Other Working Groups that have not completed their outcome document yet are requested to finalise them soon.

I am happy to inform that after the AsESG members meeting in Sabah last year, two new National Action Plans for elephant conservation (NECAP) were published. Both, the Asian Elephant Conservation Action Plan for Cambodia and the Borneo Elephant Action Plan for Sabah are available at <https://www.asesg.org/resources.php>. Lao PDR and India are also working to draft their NECAPs. Lao PDR has produced the draft plan which is being internally reviewed. India is currently having regional consultations with State Forest Department and elephant experts for threat analysis and proposed action points and intends to complete the consultation by mid October 2020, after which the technical committee formed by the Ministry will draft the plan.

As most of you are aware, *Elephas maximus indicus* was recently included in Appendix I of the Conservation of Migratory Species (CMS) at CMS CoP13 in February 2020 and the AsESG assisted in preparation of the proposal. This is the first international victory for the AsESG on a policy front and we must be happy in this being achieved. The AsESG along with the Ministry of Environment, Forest and Climate Change Government of India (MoEFCC), Wildlife Institute of India, CMS, IUCN Bangladesh and Wildlife Trust of India also organized a side event at CMS on 18th February 2020 to discuss "Elephant conservation beyond borders". It also partnered with Project Elephant Division, MoEFCC and Wildlife Institute of India for a discussion on "Asian elephant conservation: Prospects and challenges" on 20th February 2020.

The Elephant Reintroduction Foundation, in collaboration with the Department of National Park, Plant and Wildlife Conservation, the IUCN-SSC AsESG and the IUCN-SSC Conservation Translocation Specialist Group, Faculty of Veterinary Medicine, Chiang Mai University and National Elephant Institute conducted the Workshop on Open House Elephant Reintroduction Project Thailand in February 2020 in Bangkok, Thailand. The objectives of this workshop were to share and exchange the knowledge of elephant reintroduction, as well as evaluate and enhance the elephant reintroduction method. There were 70 participants from 8 nations including scientists, veterinarians, governmental and non-governmental staff, elephant camp owners etc. Our senior member, Dr Chatchote Thitaram took the lead in organizing the meeting.

Finally as this quadrennium draws to a close I wish to remind the AsESG members of the way forward. In all possibility, with the postponement yet again of the IUCN World Conservation Congress, the statutory bits will be done online in January. This means that the membership of this group for the AsESG closes with that and the process for a new membership starts of. Jon Paul, Chair of SSC is already confirmed to retain his place as he is unopposed to the post. He has asked me, if I wish to continue as Chair for the next term. I have replied that personally I will accept one more term, if all of you as members wish me to continue. With that I have requested Sandeep to circulate to all of you a questionnaire survey on Survey Monkey that will take a few minutes of your time. I would request you to fill that in, which will be an assessment of the last quadrennium and of the functioning of myself as Chair and Sandeep as Program Manager. Please be frank as we wish to get feedback from all of you on this idea of continuity of our positions, going forward for one more term and also the ways we can improve functioning if you feel that this is the right decision. If we receive reasonable consensus on that, I would also address all of you in the need to identify two new Deputy Chairs for the quadrennium going forward. This is essential for leadership succession as I don't intend in any case to run for a third term after this one if possible. Please assist me in this as well

At the end of this quadrennium, the AsESG would like to convey its sincere thanks to the editor and editorial board members of *Gajah* for all their efforts to ensure the journal is published in time and for maintaining its quality. I would also like to thank all the contributors of *Gajah* for sharing their research and conservation achievements and encourage others to publish their papers in *Gajah*. Our sincere thanks to our institutional partners, the Elephant Family and International Fund for Animal Welfare (IFAW), for their generous support to the AsESG and helping us to undertake the activities of the group and to the Chairs office in Caracas and the IUCN Secretariat staff at Gland for their manifold assistance and guidance.

Thank you once again. I wish you all health and happiness in the remaining part of 2020 and going forward.

Vivek Menon
Chair IUCN SSC AsESG

Tusker and termite mound Bandipur National Park

Foraging Ecology of Semi-Free-Roaming Asian Elephants in Northern Thailand

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Abstract. We observed the foraging behaviour of five semi-free-roaming elephants in Thailand from December 2016 to October 2019 using all occurrence focal sampling. The elephants consumed 165 species of plants representing 56 families. *Dendrocalamus* sp. (bamboo), accounted for 40.3% of the elephants' foraging time. The elephants spent significantly more time browsing than grazing. A significant increase in grazing during the cold season may be attributed to increased access to cultivated fields. Despite this increase, bamboo remained the principle component of the elephants' diet across seasons. This study provides baseline information regarding foraging by semi-free ranging elephants in a previously undescribed area.

Introduction

Asian elephants (*Elephas maximus*) are one of the few extant megaherbivores. They spend between 12–18 hours per day feeding and consume 1.5–2.5% of their body weight in dry fodder daily (Sukumar 2003). Elephant diet is variable depending on habitat, geographic region, season, and availability (Sukumar 2003). They are known to switch between browse and graze depending on environmental conditions, especially in areas with strong seasonality (Sukumar 2006). Their dietary composition is also highly variable on a local scale within a geographic region (Himmelsbach *et al*. 2006). Although Asian elephants are generalized herbivores, their food selection is influenced by factors such as nutrient requirements and plant palatability, texture and phenophase (Sivaganesan & Johnsingh 1995; Sukumar 2003). Studies in India, China, Nepal, Sri Lanka and Myanmar have demonstrated that elephants consume a diverse array of fodder (Sukumar 1990; Chen *et al*. 2006; Himmelsbach *et al*. 2006; Samansiri & Weerakoon 2007; Roy & Chowdhury 2014; Koirala *et al*. 2016), and studies in Thailand have detailed the limited diet of captive elephants (Bansiddhi *et al*. 2018). However no comparable work has been done on free-foraging elephants in Thailand. Considering the notable population of elephants in Thailand and the geo-spatial influences on elephant diet, it is important to address this knowledge deficit.

There are approximately 3100–3600 wild elephants in Thailand, and a captive population of over 3700 (AsERSM 2017). Of the captive population, 75% reside in 'Elephant Camps' established for tourism in the northern provinces (Kontogeorgopoulos 2009). These camp elephants are usually fed an insufficient variety of food and their staple fodder is of unbalanced nutritional composition, including supplements such as fruit (Kontogeorgopoulos 2009). Unnatural conditions of camps make them inadequate environments to study the foraging habits of Asian elephants, while low population density and poor visibility in forests makes studying foraging by wild elephants challenging in some areas (Campos-Arceiz *et al*. 2008). Knowledge of feeding behaviour and ecology is crucial to managing wild elephants, mitigating human-elephant conflict, and improving husbandry of captive elephants (Chen *et al*. 2006; Sukumar 2006; Campos-Arceiz *et al*. 2008; Koirala *et al*. 2016).

The objectives of this study were to document the main fodder species of semi-free-roaming elephants in a mixed-use landscape in northern Thailand; and to identify seasonal changes in consumption. This study was part of ongoing research into Asian elephant behaviour and ecology in mountainous tropical rainforest ecosystems.

Materials and methods

Study site

Northern Thailand is characterized by mountain ranges and dense forests. Located 180 km southwest of Chiang Mai in the Mae Chaem district, Kindred Spirit Elephant Foundation and Sanctuary (KSES) is situated in a small Karen hill-tribe village called Ban Naklang with a population of about 500 people. The village was adjacent to approximately 4000 ha of land, comprised of mixed use agricultural fields (predominately rice and corn), old growth forests and various stages of successional forests (Fig. 1). The elevation ranges from 700–1100 m.

This mountain tropical ecosystem consists of a variety of habitats including sphagnum bog, moist and dense evergreen cloud-forest, dry evergreen, pine, mixed deciduous, teak and dipterocarp forests (Gale & Hammer 2018). The area is distinctly seasonal and can be divided into a cold dry season (November – February), a hot dry season (March – June), and a wet season (July – October) under the influence of the southwest monsoon.

KSES was established in May 2016 and is currently home to five elephants, females Too Meh (age 58) and Mae Doom (age 25), and males Gen Thong (age 7), Boon Rott (age 14) and Dodo (age 14). Too Meh, Mae Doom, Gen Thong, and Boon Rott have resided at KSES since it was established, and Dodo joined in September 2018. Before coming to KSES, these elephants were working in tourist camps in Northern Thailand, performing tricks, giving rides and serving as photo props. At KSES they are not worked but instead are free-roaming throughout the day. The elephants had access to approximately 4000 ha around Ban Naklang. They have free choice to forage, associate, and behave as they please with restrictions regarding use of agricultural fields, roads, and neighboring villages. The elephants all have mahouts (elephant caretakers) that ensure they stay away from restricted areas and in the forests with enough natural fodder. Mahouts followed the free roaming elephants for 12 hours a day on average, enforced land restrictions and prevented crop raiding via verbal commands. Land restrictions were relaxed after harvesting, allowing the elephants limited access to agricultural fields during the cold season. The elephants chose the plant species they consumed and the amount of time they spent foraging on the selected plants. The only exception to this was during the hot dry season when food was not abundant in the forests, when the mahouts provided grass to supplement the elephants' diets as needed. Throughout the day and during observational periods the elephants were not restricted to a location, allowing for a unique opportunity to study the foraging behaviour of semi-free-roaming elephants. The elephants were confined in place at night using long chains

Figure 1. Map of northern Thailand and study area.

in the forest to ensure their and the community's safety. Where they spent the night changed daily depending on where they roamed during the day.

Data collection

Data was collected from December 2016 through October 2019 on four elephants (Too Meh, Mae Doom, Gen Thong, and Boon Rott) with the addition of one elephant in October 2018 (Dodo). Observation periods lasted 1.5 hours and commenced between 9:00 and 10:00 am depending on the location of the elephants.

Data was collected via all-occurrence focal sampling, following Roy & Chowdhury (2014). In order to determine the amount of time the elephants' spent foraging on plant species, the observer focused on one elephant at a time to record plant species consumed (identified by the mahout with the name in local language), the length of time the elephant fed on said plant species, functional group, and part(s) of the plant consumed. The functional groups identified were trees, shrubs, herbs, grasses, and climbers. Parts of the plants consumed were classified as bark, fruit, leaf, root, twig, stem or whole (plant eaten in entirety). Samples of all novel species the elephants consumed were collected, photographed, the common name recorded if known, and scientifically identified by a botanist in Chiang Mai, thus establishing a database of elephant food plants.

Data analysis

Trees, shrubs, herbs, climbers, and bamboo were classified as browse and grasses as graze. Despite being botanically classified as a grass, bamboo was categorized as browse because of its growth characteristics and following other feeding studies of elephants (i.e. Sukumar 1990; Himmelsbach *et al*. 2006; Chen *et al*. 2006).

A two-tailed Z-test with a significance level of $p = 0.05$ was used to test for seasonal differences in time spent grazing and browsing. Differences in time spent foraging on different functional groups between the three seasons, were tested for significance by One Way ANOVA. Tukey's Honestly Significant Difference (HSD) post-hoc test was used to compare differences in the type of plants consumed between seasons. One elephant, Dodo, was excluded from the seasonal analysis because less than a year of data was collected on him.

Results

Dietary richness

The elephants were observed foraging for a total of 17,912 min. Of which, 4,546 minutes were in the cold season, 5,337 minutes in the hot season and 8,029 minutes in the wet season. A total of 165 identified plant species from 56 families were consumed. Of these, 155 were directly observed and 10 were observed by mahouts. Over 58% of the species were from 11 families, consisting of Fabaceae (30 species), Poaceae (19), Moraceae (10), Rubiaceae (6), Anacardiaceae (6), Fagaceae (5), Lythraceae (4), Apocynaceae (4), Phyllanthaceae (4), Euphorbiaceae (4), and Vitaceae (4) (See Appendix for species). Another 24 samples were not identified and consisted of one climber, two grasses, one shrub, 19 trees, and one herb.

Of the 165 identified species, trees accounted for 49.1% of the species consumed, climbers 21.2%, grasses 12.1%, shrubs 10.3%, herbs 6.1% and bamboo 1.2%. Although bamboo represented 1.2% of the species, the elephants spent 44.0% of their time consuming bamboo. The remaining time was spent feeding on trees (29.1%), grasses (12.4%), climbers (12.4%), shrubs (1.4%) and herbs (0.8%). The elephants spent significantly more time browsing than grazing (browse 87.6%, graze 12.4%, $z = 142.257$, Fig. 2).

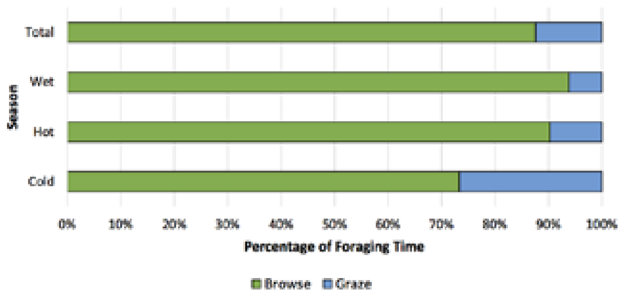

Figure 2. Time elephants spent browsing and grazing during the year and seasonally.

In assessing feeding time by species, *Dendrocalamus* sp. (bamboo), accounted for 40.3%, *Zea mays* (grass) 7.9%, *Sphatolobus* sp. 1 (climber) 6.2%, *Bambusa* sp. (bamboo) 3.7%, *Radermachera* sp. 1 (tree) 3.6%, and *Pachyrhizus* sp. 1 (climber) 2.3%. Other species accounted for less than 2.0% each (see Appendix).

Four crop species were consumed, *Zea mays* (corn), *Pennisetum purpureum* (Napier grass), *Mussa* sp. (banana) and *Oryza sativa* (rice). Crop consumption was from leftover harvest and diet supplementation and not crop raiding. The elephants had limited access to corn and rice fields post-harvest, aligning with the cold season. All four crops were used for diet supplementation when needed.

The parts of plants consumed varied by functional groups. For trees, leaves were the most commonly consumed (80.0% of species), followed by stems (49.0%), bark (47.0%), and twigs (41.0%). To a lesser extent the roots (16.0%), shoots (7.0%), and fruits (5.0%) were eaten, and some trees were eaten whole (12.0%). Mainly leaves (80.0%) and stems (74.0%) of climbers were consumed. Some climbers were consumed whole (26.0%), or the twigs (11.0%), bark (9.0%), and one fruit (3.0%). Leaves were also the most consumed portions of shrubs (53.0%), while many were also consumed whole (35.0%). Additionally, the twigs and stems were consumed (24.0% each), as well as the roots (18.0%), and one fruit (6.0%). Bamboo was consumed whole (100.0%), although the leaves, twigs, stems, and shoots were also selected for (100.0% each). Herbs were most commonly consumed whole (70.0%), but leaves (50.0%) and stems (30.0%) were also consumed. Grasses were also dominantly consumed whole (100.0%), while the fruit, leaves, and stems of one species (*Zea mays*) were also selected for.

When feeding on trees, in 31.0% of species only one part was consumed, in 22.0% two parts, in 11.0% three, and in 36.0% four or more parts. When only one plant part was consumed, the elephants most commonly chose the leaves (68.0% of species), and to a lesser extent bark (three species), roots (two), and stems, twigs, or fruit (one each). When feeding on climbers, in 20.0% of species only one plant part was consumed, in 46.0% two parts, in 20.0% three, and 14.0% four or more parts. From the shrubs, 47.0% were fed on selectively for one part, 12.0% for two parts, 12.0% for three, and 29.0% for four or more parts.

Seasonal comparison

The elephants spent significantly more time consuming bamboo in the wet season than in the cold season ($F = 4.790$, $p = 0.038$). Differences in bamboo consumption between wet and hot seasons and between cold and hot seasons were not significant ($F = 1.06$, $p = 0.342$, $F = 3.120$, $p = 0.128$, respectively). The elephants spent significantly more time consuming grasses in the cold season than in hot and wet seasons ($F = 20.067$, $p = 4.818 \times 10^{-4}$). There were no significant differences in time spent consuming climbers ($F = 0.134$, $p = 0.871$), herbs ($F = 0.088$, $p = 0.916$), shrubs ($F = 3.190$, $p = 0.897$), or trees ($F = 0.789$, $p = 0.483$) between the cold, hot, and wet seasons (Fig. 3).

The elephants spent significantly more time feeding on browse than graze species year-round. The elephants spent the largest percentage of time consuming browse species during the wet season at 94.0% ($z = 111.159$), compared to 90.0% browse in hot season ($z = 83.189$) and 73.0% in cold season ($z = 44.548$, Fig. 2).

Discussion

The total of 165 plant species from 56 families consumed by the elephants in our study exceeds that recorded for Asian elephants in other

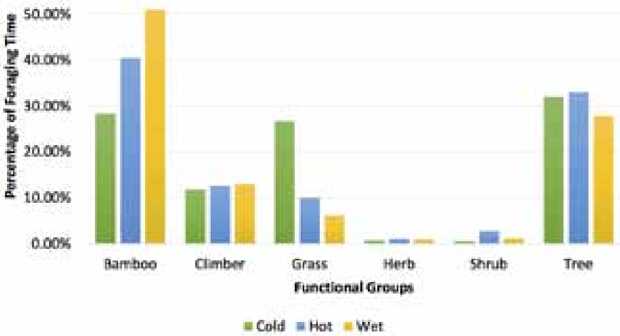

Figure 3. Foraging times on different functional groups of plants by elephants by season.

geographic areas. For example 57 species from 25 families in Nepal (Koirala *et al*. 2016), 67 species from 28 families in West Bengal, India (Roy & Chowdhury 2014), 106 species from 27 families in China (Chen *et al*. 2006), 112 species in India (Sukumar 1990), 116 species from 35 families in Sri Lanka (Samansiri & Weerakoon 2007), and 124 species from 27 families in Myanmar (Himmelsbach *et al*. 2006).

Of the 165 plant species consumed, six species accounted for 64% of the elephants' foraging time. This selective feeding behaviour with a few species comprising the main portion of their diet is consistent with studies done in India and Myanmar (Sukumar 1990; Himmelsbach *et al*. 2006). Elephants may use easily consumable fodder such as bamboo to fulfil their high intake requirements of up to 10% of bodyweight in fresh biomass, while a diverse diet is required to ensure elephants still obtain essential nutrients found in time-intensive species, such as trees (Sukumar 1989; Karunaratne & Ranawana 1999). For example, bark contains important minerals including calcium (Sukumar 2006). Our elephants selectively fed on the bark of 47% of observed tree species (see Appendix). Thus, despite access to an abundance of easily consumable fodder, the elephants spent time and energy consuming selected plant parts.

In southern India, Sukumar (1990) found 85% of the elephants diet consisted of species from the families Leguminosae (Fabaceae), Arecaceae, Cyperaceae and Poaceae (formerly Gramineae). With the exception of Cyperaceae, all these families were represented in the diet of elephants in our study. The elephants in this study spent about 56% of their time consuming plants of the family Poaceae. However as grasses encompassed only about 12% of their foraging time, the majority of this was due to consumption of bamboo. Notably, almost 44% of their time was spent consuming two species of bamboo (Fig. 4). Our findings are similar to that of a study in Myanmar, where bamboo comprised 57% and 85% of elephants' diet at two sites (Himmelsbach *et al*. 2006). In contrast, bamboo formed a much smaller portion of the diet, and was only consumed by elephants at three of five study sites in southern India (Sukumar 1990). A study in China found elephants consumed mostly browse species, however bamboo accounted for only about 4.5% of their diet (Chen *et al*. 2006). Bamboo comprising a variable proportion of elephants' diet in different locations may be due to its natural absence or rarity in some geographic areas. Availability may also differ due to overfeeding, decreased regeneration and extraction by people (Joshi & Singh 2008).

When analyzing seasonal patterns in foraging, we found that more time was spent consuming bamboo in the wet season than the cold season. In the cold season, there is an increase in grass consumption time. This may be due to seasonal differences in agricultural field access, including rice (*Oryza sativa*) and corn (*Zea mays*), that are restricted during hot and wet seasons while the fields are in use. Grass is considered an important component of elephants' diet because it has a high protein content, especially while young, and few toxic secondary compounds (McKay 1973; Sukumar 1989). We found that the proportion of grass in the elephants' diet decreased as the seasons shifted from cold to hot, then wet. This is likely due to the increased access to fields during the cold season, the lack of available grasses in the hot season, followed by restricted access to the fields in the wet season. A study in Sri

Figure 4. Elephant consuming bamboo.

Lanka found a similar pattern, where fields were cultivated seasonally and wild elephants were able to feed on grass only for a brief period of time (Pastorini *et al*. 2013). This indicates that graze may be a significant but transitory fodder in the diet of some elephants (Pastorini *et al*. 2013).

The elephants in this study demonstrated a year round preference for browse over graze. Our results differ from findings in India where grasses comprised the majority of the elephants' diet in the wet season (Sukumar 1989) and dominated the diet in deciduous forests (Baskaran *et al*. 2010; Sivaganesan & Johnsingh 1995). Our findings are consistent with a study in China that showed browsing species accounted for a larger proportion of the elephants' diet (77 spp. taking 91% vs. 6 spp. taking 9%; Chen *et al*. 2006). These findings may indicate that grasses contribute a smaller portion to Asian elephant diet in Southeast Asia than in the Indian subcontinent (Chen *et al*. 2006; Himmelsbach *et al*. 2006; Campos-Arceiz *et al*. 2008). However a study from West Bengal, India reported 56% of elephants' bite counts were browse species (Roy & Chowdhury 2014). Therefore elephants may vary in their use of grass and browse geographically, possibly due to differences in availability.

Frequency and foraging time are not the only indicators of importance in the elephants' diet, and even rarely used plants may have important roles (Himmelsbach *et al*. 2006). In fact, elephants might be very particular about how much they consume of specific plant types or parts in order to balance nutritional requirements while limiting consumption of potentially toxic plant compounds (Campos-Arceiz *et al*. 2008). Large herbivores such as elephants may require a more diverse diet than smaller herbivores due to slower metabolic processes and detoxification rates (Freeland 1991).

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Thank you to Kindred Spirit Elephant Foundation and Sanctuary for the logistical support in organizing field work, Talia Gale for establishing and overseeing the research project for 20 months, and the mahouts of the five elephants for their extensive knowledge of local flora. We would like to thank all interns and Biosphere Expeditions for their help in data collection and continuous support. Plant identification would not have been possible without the work of botanist Parchaya Srisanga.

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Appendix. List of all plants recorded in this study organized by family, including number of species documented in each family (N), percentage of time the elephants spent foraging on each species out of the total of 17,912 minutes (% Time), the plant type and parts consumed (B = bark, F = fruit, L = leaf, R = root, T = twig, St = stem, Sh = shoot, WP = whole plant).

				%	Plant part(s) consumed							
Family	N	Latin name	Type	Time	B	F	L	R	T	St	Sh	WP
Adoxaceae	1	*Viburnum* sp.	Tree	0.01	X					X		
Amaranthaceae	1	*Amaranthus viridis*	Herb	0.04								X
Anacardiaceae	6	*Buchanania lanzan*	Tree	1.19	X		X	X	X	X		
		Gluta obovata	Tree	0.40	X					X		
		Gluta usitata	Tree	1.40	X		X	X	X	X		
		Mangifera sp.	Tree	0.51	X	X	X					
		Spondias pinnata	Tree	0.82			X					
		Anacardiaceae sp.	Tree	0.03	X							

Family	N	Latin name	Type	% Time	Plant part(s) consumed							
					B	F	L	R	T	St	Sh	WP
Annonaceae	1	Annonaceae sp.	Tree	0.32	X		X					
Apocynaceae	4	*Horrharena pubescen*	Tree	0.10	X		X		X	X		
		Wrightia arborea	Tree	0.12	X	X	X		X			
		Apocynaceae sp. 1	Climber	0.01			X			X		
		Apocynaceae sp. 2	Tree	0.94	X		X		X	X		X
Araliaceae	1	*Radermachera* sp.	Tree	3.63	X		X	X	X	X	X	
Arecaceae	1	*Phoenix loureiroi*	Tree	0.47	X		X		X	X		X
Asparagaceae	1	*Asparagus filicinus*	Herb	0.01			X			X		
Asteraceae	3	*Ageratum conyzoides*	Herb	0.02								X
		Crassocephalum crepidioides	Herb	0.21			X					X
		Asteraceae sp.	Climber	0.01			X			X		
Capparaceae	1	*Capparis* sp.	Tree	0.08			X					
Celastraceae	1	*Celastrus paniculatus*	Climber	0.12			X		X	X		
Clusiaceae	1	*Cratoxylum formosum*	Tree	0.44	X		X	X	X			
Commelinaceae	2	*Commelina paludosa*	Herb	0.01								X
		Commelinaceae sp.	Grass	0.01								X
Convolvulaceae	2	*Ipomea hederifolia*	Climber	0.02			X			X		
		Convolvulaceae sp.	Climber	0.15								X
Costaceae	1	*Cheilocostus speciosus*	Herb	0.01			X			X		
Cucurbitaceae	1	*Cucurbita maxima*	Climber	0.02		X	X			X		
Dilleniaceae	1	*Dillenia* sp.	Tree	0.63	X	X						
Dioscoreaceae	3	*Dioscorea* sp. 1	Climber	0.01			X			X		
		Dioscorea sp. 2	Climber	0.01			X			X		
		Dioscorea sp. 3	Climber	0.25			X			X		X
Dipterocarpaceae	3	*Dipterocarpus tuberculatus*	Tree	0.05			X					
		Pentacme siamensis	Tree	0.13	X		X	X		X		
		Shorea obtusa	Tree	1.70	X		X	X	X	X		
Equisetaceae	1	*Equisetum ramosissimum*	Herb	0.10								X
Euphorbiaceae	3	*Macaranga denticulata*	Tree	0.11					X			
		Mallotus philippensis	Tree	0.59	X		X		X	X		
		Euphorbiaceae sp.	Climber	0.01						X		
Fabaceae	28	*Acacia megaladena*	Climber	0.15	X		X					
		Acacia sp.	Tree	0.88			X		X	X		
		Albizia odoratissima	Tree	0.03			X		X			
		Albizia sp.	Tree	0.83			X		X	X		X
		Archidendron sp.	Tree	0.37			X		X	X		
		Bauhinia sp.	Tree	0.09			X					
		Cassia fistula	Tree	0.01			X		X			
		Dalbergia sp. 1	Tree	0.01			X			X	X	
		Dalbergia sp. 2	Tree	0.41	X		X			X		

				%	Plant part(s) consumed							
Family	N	Latin name	Type	Time	B	F	L	R	T	St	Sh	WP
		Entada rheedii	Climber	1.33			X		X	X		X
		Erythrina variegata	Tree	0.03			X			X		
		Mimosa pigra	Shrub	0.23			X		X			X
		Mimosa pudica	Herb	0.11								X
		Mucuna sp.	Climber	0.15			X			X		X
		Pachyrhizus sp.	Climber	2.28	X		X			X		X
		Phylacium majus	Climber	0.05						X		
		Pueraria sp. 1	Climber	0.02	X					X		
		Pueraria sp. 2	Climber	0.12			X					
		Sphatolobus sp.	Climber	6.20			X			X		X
		Tamarindus indica	Tree	0.12			X		X			
		Xylia xylocarpa	Tree	0.22	X		X			X		X
		Fabaceae sp. 1	Climber	0.06			X			X		
		Fabaceae sp. 2	Climber	0.08			X			X		
		Fabaceae sp. 3	Climber	0.01			X					
		Fabaceae sp. 4	Climber	0.04			X			X		
		Fabaceae sp. 5	Tree	0.06			X					
		Fabaceae sp. 6	Climber	0.09			X			X		
		Fabaceae sp. 7	Shrub	0.07			X	X	X			
Fagaceae	4	*Lithocarpus* sp.	Tree	0.01			X			X		
		Quercus kerrii	Tree	0.56	X		X	X	X	X		X
		Quercus sp. 1	Tree	0.09			X					
		Quercus sp. 2	Tree	0.03			X					
Lamiaceae	3	*Tectona grandis*	Tree	1.01	X		X		X	X		
		Vitex sp. 1	Tree	0.01						X		
		Vitex sp. 2	Tree	0.03			X			X		
Lecythidaceae	1	*Careya arborea*	Tree	0.11		X						
Loganiaceae	1	*Strychnos nux-blanda*	Tree	0.03			X			X		
Lythraceae	4	*Lagerstroemia* sp. 1	Shrub	0.02			X					
		Lagerstroemia sp. 2	Tree	0.07			X		X			
		Lagerstroemia speciosa	Tree	0.11	X					X		
		Lagerstroemia villosa	Tree	0.01			X					
Malvaceae	3	*Grewia laevigata*	Tree	0.03	X							
		Grewia sp.	Tree	0.37	X		X			X		
		Sterculia foetida	Tree	0.35	X					X		
Menispermaceae	3	*Tinospora crispa*	Climber	0.17			X			X		
		Tinospora sp.	Climber	0.05			X			X		
		Menispermaceae sp.	Climber	0.03			X					
Moraceae	9	*Broussonetia papyrifera*	Tree	0.03			X					
		Ficus hispida	Tree	0.13			X					

Family	N	Latin name	Type	% Time	Plant part(s) consumed							
					B	F	L	R	T	St	Sh	WP
		Ficus racemosa/fistulosa	Tree	1.35	X		X	X	X	X		X
		Ficus religiosa	Climber	0.12			X		X			
		Ficus semicordata	Tree	0.03			X		X			
		Ficus sp. 1	Tree	0.27			X		X	X	X	
		Ficus sp. 2	Tree	0.02			X					
		Ficus sp. 3	Tree	0.01			X					
		Ficus sp. 4	Tree	0.01			X		X			
Musaceae	1	*Musa* spp.	Tree	1.32			X			X	X	X
Myrsinaceae	2	*Ardisia* sp.	Tree	0.34			X	X	X	X		
		Embelia sp.	Tree	0.01			X					
Myrtaceae	1	*Syzgium* sp.	Tree	0.17	X		X		X		X	
Oleaceae	1	*Olea salicifolia*	Tree	0.01			X			X		
Orchidaceae	2	*Dendrobium* sp.	Shrub	0.06								X
		Orchidaceae sp.	Shrub	0.01			X					
Pandanaceae	1	*Pandanus* sp.	Shrub	0.02			X					
Passifloraceae	1	*Passiflora edulis*	Climber	0.16			X			X		X
Phyllanthaceae	4	*Antidesma* sp.	Tree	0.01			X					
		Aporosa sp.	Tree	0.11	X		X	X	X	X		
		Aporosa villosa	Tree	0.03				X				
		Phyllanthus emblica	Tree	0.01								X
Piperaceae	1	*Piper* sp.	Climber	0.01			X			X		
Poaceae	16	*Apluda mutica*	Grass	0.06								X
		Arundinella setosa	Grass	0.01								X
		Bambusa sp.	Bamboo	3.68			X		X	X	X	X
		Cyrtococcum accrescens	Grass	0.07								X
		Dendrocalamus sp.	Bamboo	40.27			X		X	X	X	X
		Imperata cylindrica	Grass	0.10								X
		Microstegium vagans	Grass	0.15								X
		Oryza sativa	Grass	0.27								X
		Panicum notatum	Grass	0.03								X
		Pennisetum purpureum	Grass	1.34								X
		Thysanolaena latifolia	Grass	0.03								X
		Zea mays	Grass	7.93		X	X			X		X
		Poaceae sp. 1	Grass	0.24								X
		Poaceae sp. 2	Grass	0.03								X
		Poaceae sp. 3	Grass	0.74								X
		Poaceae sp. 4	Grass	1.14								X
Polygalaceae	1	*Xanthophyllum* sp.	Tree	0.01			X					
Primulaceae	2	*Ardisia crenata*	Shrub	0.03			X					
		Embelia sp.	Tree	0.41	X		X		X	X		

				%	Plant part(s) consumed							
Family	N	Latin name	Type	Time	B	F	L	R	T	St	Sh	WP
Rosaceae	2	*Rubus* sp. 1	Shrub	0.08								X
		Rubus sp. 2	Shrub	0.01								X
Rubiaceae	6	*Gardenia sootepensis*	Tree	1.11	X		X	X	X	X	X	
		Hymenodictyon orixense	Tree	0.07	X		X		X			
		Paederia foetida	Climber	0.51			X		X	X		
		Rubiaceae sp. 1	Tree	0.14	X		X			X		
		Rubiaceae sp. 2	Tree	0.24	X		X		X	X		
		Rubiaceae sp. 3	Tree	0.08	X							
Rutaceae	3	*Clausena* sp.	Tree	0.01			X					
		Toddalia asiatica	Climber	0.04								X
		Rutaceae sp.	Shrub	0.03				X	X			
Sapindaceae	1	*Dimocarpus longan*	Tree	0.47	X		X		X	X		
Smilacaceae	1	*Smilax ovalifolia*	Climber	0.03			X			X		
Solanaceae	2	*Solanum erianthum*	Shrub	0.09								X
		Solanum torvum	Shrub	0.70		X	X		X	X		X
Tectariaceae	1	Tectaria sp.	Shrub	0.04						X		
Tiliaceae	2	*Grewia eriocarpa*	Tree	1.22	X		X			X		
		Tiliaceae sp.	Tree	0.53	X		X		X	X		
Ulmaceae	1	*Holoptelea integrifolia*	Tree	0.02								X
Urticaceae	1	*Boehmeria* sp.	Herb	0.01			X			X		
Vitaceae	4	*Cayratia* sp.	Shrub	0.01			X					
		Cissus sp.	Climber	0.04								X
		Vitaceae sp. 1	Shrub	0.01				X				
		Vitaceae sp. 2	Shrub	0.02			X			X		
Zingiberaceae	3	Zingiberaceae sp. 1	Grass	0.03								X
		Zingiberaceae sp. 2	Grass	0.01								X
		Zingiberaceae sp. 3	Herb	0.32			X					X
Identified by Mahouts												
Euphorbiaceae	1	*Manihot esculenta*	Shrub							X		
Fabaceae	2	*Albizia chinensis*	Tree				X					
		Fabaceae sp. 8	Climber				X					
Fagaceae	1	*Castanopsis* sp.	Tree					X				
Gnetaceae	1	Gnetum sp.	Climber							X		
Hypoxidaceae	1	*Curculigo* sp.	Tree									X
Moraceae	1	*Ficus* sp. 5	Tree		X		X					
Poaceae	3	*Pennisetum polystachyon*	Grass									X
		Saccharum sp.	Grass									X
		Poaceae sp. 5	Grass									X
Unidentified	24	unknown species		1.58								
Total	189			100								

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Population Estimation of Asian Elephants in a Tropical Forest of Northeast India

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Abstract. The long history of armed conflict in Manas National Park has resulted in the decline of wildlife populations. With the attainment of peace, knowledge of extant animal population sizes became crucial for making informed conservation decisions. The present study estimated the population of Asian elephants within a distance sampling framework using dung counts along 92 line transects. The population size was estimated to be 601 (95%, CI 454–797), with the highest density in mixed moist deciduous forest (1.57 elephants/km^2). This serves as the baseline information and also discusses the accuracy of the dung count method and possible shortcomings of our estimates.

Introduction

Assessment of large mammal population sizes becomes crucial for the management of protected areas (Waltert *et al*. 2008). Effective management practice can only be possible with a reliable estimate of population size and structure. The Asian elephant (*Elephas maximus*) is facing a severe threat to its survival from large-scale habitat loss and degradation, negative interaction between humans and elephants, and poaching across its range. The contiguous forests along the Himalayan foothills from northern West Bengal, eastward through Assam along southern Bhutan and Arunachal Pradesh, are considered to be vital for elephant conservation, with approximately 6000 elephants believed to range across the landscape (Santiapillai & Jackson 1990; Sukumar & Santiapillai 1996). The Manas National Park is a key protected area in the landscape and a primary habitat for elephants. Manas witnessed intense armed conflict from the mid-1980s to 2003, which resulted in habitat degradation, declining wildlife populations and smothering of conservation and management interventions (Goswami & Ganesh 2014). The social upheaval was put to halt with the formation of Bodoland Territorial Council (BTC) in 2003 and conservation actions were implemented. In the context of the armed conflict and resumption of conservation efforts, it was important that the elephant population in Manas be reliably estimated.

Traditionally, elephants have been censused in Manas with the help of the total count method conducted at five-year intervals. Although there is a lack of elephant population estimates from the park prior to 1980, it was believed that Manas still supported a good population of elephants, despite the turmoil. But it was important to corroborate this belief by obtaining a reliable estimate of elephant population size or density. Albeit the task of accurately estimating the elephant population in Manas is critical for implementing rational conservation measures, it is not an easy exercise and needed to be carried out with sufficient scientific rigour.

The line transect method involving distance sampling (Burnham *et al*. 1980) has been extensively used for estimating animal densities for a variety of taxa in various habitats (Karanth & Sunquist 1992; Varman & Sukumar 1995; Biswas & Sankar 2002; Jathanna *et al*. 2003; Wegge & Storass 2009; Wang 2010; Goswami & Ganesh 2014; Sinha *et al*. 2019). The direct count approach (i.e., counting the animal itself rather than its dung) is recommended in areas of good visibility and high elephant density (Jathanna

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et al. 2015). In areas of low elephant density, the indirect count method relying on elephant dung can be more feasible. Elephant densities have been estimated using line transect method either through direct counts (Karanth & Sunquist 1992; Jathanna *et al*. 2015) or indirect counts (Sale *et al*. 1990). The use of dung counts as a survey method to assess elephant populations, primarily those living in forest environments in low density, is well established (Barnes 1993, 1996; Barnes *et al*. 1997; Hedges & Lawson 2006). However, it is important to recognise that dung counts conducted along line transects under a distance sampling framework can accurately estimate the density of dung, but rely on two additional parameters to translate them to animal densities: dung decay rate and defecation rate. The variance in defecation and decay rates can have a strong influence on estimated animal density. Nevertheless, it is suggested that these variances, even when combined with the variance in dung density, can yield fairly modest variance in the final estimate of elephant density (Hedges & Lawson 2006). In Manas where dung piles are more readily detectable than elephants, the dung count method was more feasible to implement.

To determine the elephant population numbers and density in different forest habitats of Manas National Park, detailed line transect surveys were conducted during 2009–2010. This study is the first effort to estimate elephant density and population size in Manas using a systematic line transect survey involving long-term monitoring of dung decay rates.

Methods

Study area

Our survey was conducted in three different administrative ranges of Manas National Park (26°35'–26°50' N, 90°45'–91°15' E) situated in the north-eastern state of Assam in India (Fig. 1). These ranges were namely Panbari Range (western), Bansbari Range (central) and Bhuyapara Range (eastern). These three ranges span both sides of the Manas River and are limited in the north by the international border of Bhutan, to the south by villages, and to the east and west by reserve forests. Altitude ranges from 50 m MSL on the southern boundary to 200 m MSL along the Bhutan hills (Sarma *et al*., 2008).

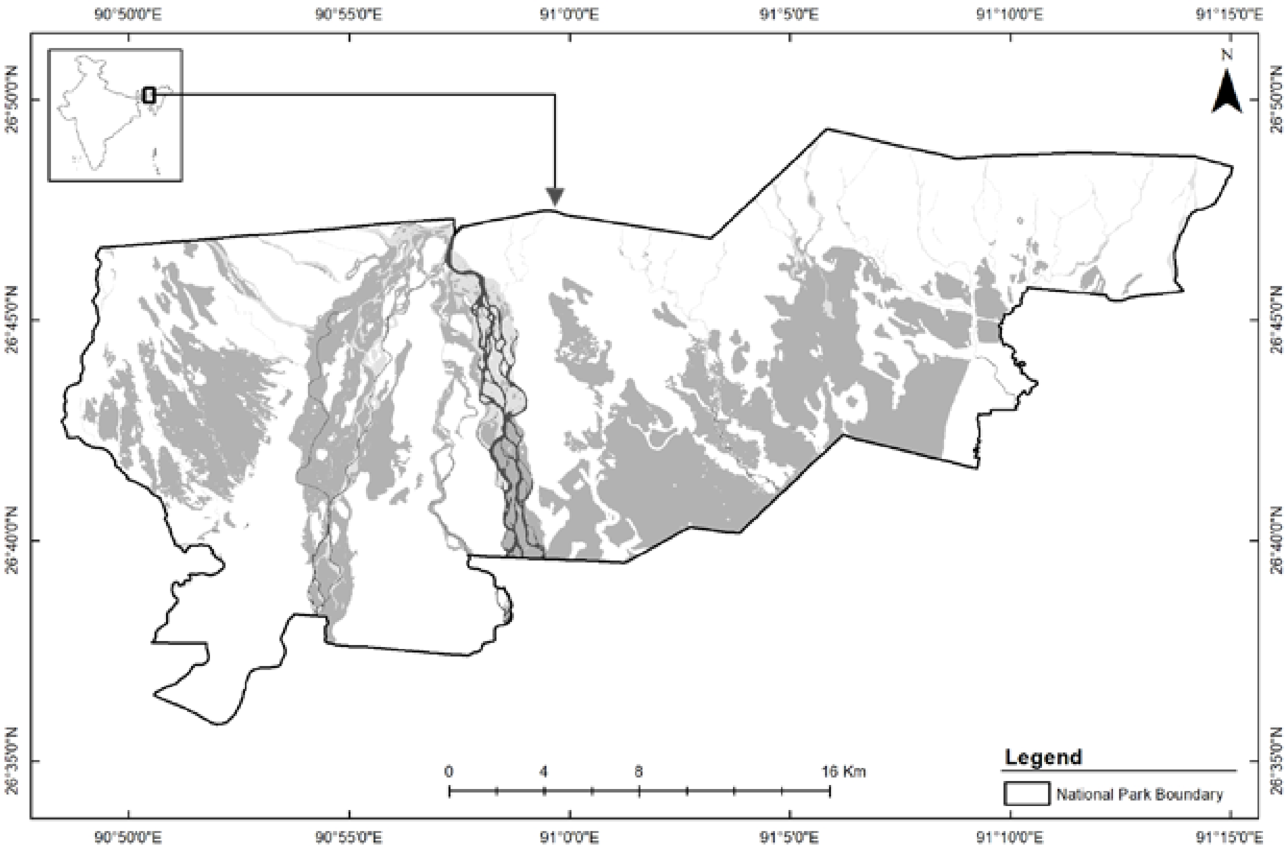

Figure 1. Map showing the location of Manas National Park in Assam. The grey areas represent the grasslands and the white areas represent woodlands. The dark waterbody is the river Beki.

The National Park occupies an area of 519 km^2 (Sarma *et al*. 2008), which forms the core area of the Manas Tiger Reserve (2837 km^2). There are three main types of vegetation: sub-Himalayan alluvial semi-evergreen forest, east-Himalayan mixed moist and dry deciduous forests and grasslands. Much of the riverine dry deciduous forest is an early successional stage, which is replaced by moist deciduous forest away from the water courses, and eventually succeeded by the semi-evergreen climax forests in the northern part of the Park.

The area under three different forest covers in Manas National Park is described in Table 1. based on Sarma *et al*. (2008).

Estimating elephant density using dung counts

The dung count method involving line transect surveys within a distance sampling framework requires a translation of dung density to elephant density. To achieve this, dung density needs to be calibrated by dung decay rates as well as defecation rates. Therefore, to estimate elephant numbers and density in Manas, the following data were collected in a stratified random manner: number of dung-piles encountered per km of transect walked, defecation rate of elephants, mean rate of dung decay; combining these three parameters, elephant numbers and density were estimated.

Table 1. Description of the three major habitats in Manas. The sampling was conducted in these three habitats.

Habitat type	Area (km^2)	Major plants
Semi ever-green	177.0	*Pterospermum acerifolium* *Dysoxylum binectariferum* *Phoebe goalparensis* *Amoora wallichi* *Sterospermum personatum* *Chukrassia tabularis* *Duabanga grandiflora* *Michelia champaca* *Linnea coromandelica* *Sterculia villosa*
Mixed moist deciduous	65.6	*Bombax ceiba* *Lagerstroemia flosreginae* *Careya arborea* *Terminalia bellerica* *Gmelina arborea*
Grasslands	206.5	*Narenga porphyrocoma* *Imperata cylindrica* *Phragmites karka* *Arundo donax* *Saccharum spontaneum* *Themeda arundinacea* *Saccharum procerum* *Vetiveria zizaanioides*
Total	449.1	

Number of dung piles per km

Habitat-based stratification was adopted to lay line transects ranging from 0.8 to 1.3 km across the study area. A total of 92 line transects, with a total length of 100.65 km were walked during the survey in two seasons: dry season (October – April) and wet season (May – September) (Table 2). All the transects had a random start location, with a fixed perpendicular orientation to roads and the major rivers of the park. Transects were oriented as such, to cut across the major drainage so as to maximise habitat representativeness of each transect (minimise probability of individual transects running entirely within or outside routes favoured by elephants).

All the transects were strictly maintained to be a straight line, and were spaced 2 km apart from each other. All transects were walked only once. Once on the transect, only those dung piles seen from the transect centre-line were recorded.

Estimation of defecation rate of elephants

Defecation rate/day is considered as one of the most important components in line transect surveys involving dung counts. However, the defecation rate may vary with habitat, season and individuals. Dung defecation rate of elephants depends on the elephant's diet, which in turn depends on the habitat type and the season (Dawson 1992). Obtaining data on defecation rates of wild elephants was not possible due to the difficulty of tracking elephants for long periods of time especially at night, which is potentially dangerous. This exercise can also be done by observing domestic animals if they

Table 2. Summary of number of transects (N) and their average, maximum and minimum surveyed lengths and effective strip widths (ESW).

Survey habitat	N	Transect length [km]				ESW [m]
		Average	Min	Max	Total	
Mixed moist deciduous forest	36	1.0	1.0	1.0	36.0	2.52
Semi evergreen forest	17	1.1	0.8	1.2	17.9	2.76
Grassland	39	1.2	0.9	1.3	46.8	2.66

are semi-wild and free ranging (Varma 2006). However, ecologists have a serious concern on this "borrowed defecation rate" as factors such as diet can play a major role in determining it.

Hedges and Lawson (2006) conducted a study in Way Kambas National Park in Sumatra (Indonesia) during 2000–2001 where they estimated an overall mean defecation of 18.07 times/day with 95% CI of 17.93–18.20 and a standard error of 0.0689. This estimate is considered as the standard estimate by 'Monitoring of Illegal Killing of Elephants', a CITES body in 2004. Hence, this defecation rate was used in our study in the absence of location specific data.

Estimation of mean rate of dung decay

The rate of dung decay depends on a combination of several factors that include the action of dung beetles, exposure to climatic factors and composition of the dung itself (Alfred *et al.* 2010). To estimate the rate of dung decay in the study area, 41 fresh dung piles were marked in forests of three different vegetation types following Laing *et al.* (2003), including: (i) semi evergreen forest (forest canopy ranged between 80–100%, which normally represents undisturbed forest); (ii) mixed moist deciduous forest (forest canopy ranged between 40–80%, which normally represents secondary forest); and (iii) grasslands (forest canopy ranged between 0–30%, which represents treeless areas).

The dung decay observations were carried out between September 2009 and November 2010, simultaneously with the transect surveys. Each fresh marked dung pile was relocated using the GPS and compass, and its state of decay was recorded at an interval of every 15 days.

Dung decay rates observed were 74.46 days in mixed moist deciduous forest, 98.44 days in semi evergreen forest and 89.52 days in grasslands. Differences in decay rates among the three habitats were not significant (Kruskal-Wallis test: $K = 4.01$, $df = 2$). Hence, we combined the decay rate data for the different habitats under dry and wet season categories. Out of the 41 dung piles, 25 fresh dung piles were marked in the dry season and 16 in the wet season. We found no significant difference in the mean decay rate of dung-piles between the seasons (Independent t-test: $t = 0.49$, $df = 39$, $p = 0.98$). Therefore, the data were pooled and used to calculate the mean number of days for decay, which was estimated as 86.7 ± 8.19 ($n = 41$) (Table 3).

Estimation of elephant density

We used the program DISTANCE v6.2 to analyse the data, which allows the selection of different models and also includes a range of different options (Burnham *et al.* 1980). In the software, we first included the dung count data (the perpendicular distance from the observer), defecation rate and decay rate. The probability of detection was estimated using six models recommended by Buckland *et al.* (2001) combining probability density function (uniform, half normal and hazard-rate) with adjustments (cosines, simple and hermite polynomials). The model with the lowest Akaike's Information Criterion (AIC) was selected for each sampling zone unit. The program automatically calculates

Table 3. Decay rate [days] of dung piles in three different habitat types irrespective of seasons.

Habitat	N	Mean	SE
Grassland	17	89.52	13.29
MMD	15	74.46	13.42
Semi evergreen	9	98.44	19.87

the F(0) from the perpendicular distance data. This is an estimate of the reciprocal of the 'Effective Strip Width' (ESW).

The density of dung-piles (D) is then calculated by the following formula:

$$D = n \times F(0) / 2L$$

Where:

n = number of dung piles

L = total length of the transects in which they were recorded

Variance of D and the confidence limits are estimated following Burnham *et al*. (1980). F(0) is the probability density function of detected distances from the line, evaluated at zero distances (Alfred *et al*. 2010). Further, dung density (D) was estimated for each habitat type and the population size (N) was computed based on the size of the habitat area. Often an encounter rate (n/L) is computed as an index for sample size considerations or even as a crude relative density index (Alfred *et al*. 2010).

The data were stratified based on habitat types to detect separate detection functions for each habitat and the global density was estimated by using the mean of each habitat weighted by the habitat area. We ran the program with various combinations of the key and adjustment functions that provide flexibility in modelling the detection function g(x). The models recommended in this computation are likely to perform reasonably well, since the AIC generated by each model is used as a selection guideline. The model that generated the lowest AIC is considered as a reasonable density. In the trial analysis, the model fit was poor based on goodness-of-fit tests, due to observations far from the line and

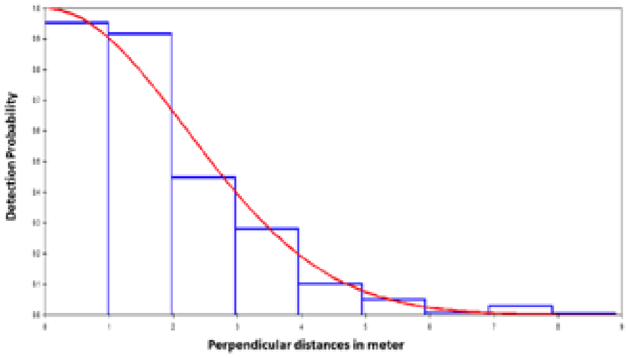

Figure 2. A typical visibility curve of recorded dung piles with no data truncation.

some significant outliers. Hence, the data were truncated at the distance where g(x) = 0.15 and analysed further after truncation.

Results

A total of 1068 dung-piles were recorded in 92 line transects. No dung-piles were recorded beyond a distance of 8 m from the centre-line of the transects (Fig. 2). The density estimates in six different models, as recommended by Buckland *et al*. (2001) are summarised in Table 4. Hazard rate function with cosine adjustment term was selected as the best model based on the lowest AIC value. The estimated overall density of elephants was found to be 1.33 km^2 (CV 14.22%, 95% CI: 1.01–1.77). However, different densities of elephants were found to occur in the three different habitats (Table 5). The population of elephants in Manas National Park was estimated as 601 (CV: 14.22 %, 95% CI: 454–797).

The grasslands had the highest estimated number of elephants with a population of 269 ± 39 (95% CI: 201–358), followed by semi evergreen forest with a population of 230 ± 48 (95 % CI: 151–349). The lowest estimate was in the mixed moist

Table. 4. Summary of the global density of elephants per km^2 in all six models recommended by Buckland *et al*. (2001).

Model	Density	CV %	Upper CL	Lower CL	AIC
Uniform + cosine	1.36	14.09	1.80	1.03	3481.0
Uniform + simple polynomial	1.23	14.14	1.63	0.93	3510.1
Half normal + cosine	1.40	14.23	1.86	1.05	3471.9
Half normal + hermite polynomial	1.28	14.17	1.70	0.97	3523.2
Hazard rate + cosine	1.33	14.22	1.77	1.01	3470.6
Hazard rate + simple polynomial	1.28	14.37	1.70	0.96	3478.5

Table 5. Density and population estimates in three habitats.

Habitat type	Density parameter (elephants/km^2)			Number parameter (# elephants)		
	Point estimate	SE	% Coef. of Variation	Point estimate	SE	95% CI
Mixed moist deciduous	1.57	0.25	15.97	103	16.45	75–142
Semi evergreen forest	1.29	0.27	20.82	230	47.88	151–349
Grassland	1.30	0.18	14.53	269	39.07	201–358

deciduous type of forests with a population of 103 ± 16 (95% CI: 75–142). However, in terms of elephant density, the mixed moist deciduous forest had the highest density of elephants with 1.57 ± 0.25 individuals per km^2 (95 % CI: 1.14–2.15) followed by grasslands with 1.30 ± 0.18 individuals per km^2 (95 % CI: 0.97–1.73). The lowest density was estimated in the semi evergreen forests (1.29 ± 0.27 individuals per km^2 (95% CI: 0.85–1.97).

Discussion

Estimation of mean rate of dung decay

Dung decay rates can be highly site specific (Hedges & Lawson 2006). Factors like the diet of elephants, vegetation cover, prevailing weather conditions and rainfall patterns may influence the decay rate of a fresh dung pile. The presence of ground feeding birds such as jungle fowl, partridges, and quail can also accelerate the deterioration rate of elephant dung piles (Wanghongsa & Boonkird 2004).

Though the dung decay rates were different in the three habitat types, they were not significant. Moreover, there was no seasonal difference in dung decay rate during the study period unlike that observed in some other studies (e.g., Wanghongsa & Boonkird 2004). The effect of the weather on decay rate thus seemed to have a minimal effect in our case. In contrast, Wanghongsa and Boonkird (2004) found that weather conditions had a significant effect on dung decay rates, with dung piles decaying 2.14 times faster in the wet season. This is probably due to the high activity of insects in the wet season (Alfred *et al*. 2010). Wanghongsa and Boonkird (2004) recorded about 29 families of insects to have influenced dung pile decay from 100 dung piles.

Figure 3. Elephant herd visiting the Burhaburi camp in Manas. Photo by Abhijit Boruah.

Estimates of elephant population

The population estimate of the present study (601 elephants, 1.33 elephants/km^2) is not comparable with an earlier estimate of the department (780 elephants, 1.68 elephants/km^2) obtained in 2008 (Census Report 2009) because different sampling methods were used. Although there is reluctance to use the dung count method to estimate elephant population size, available evidence indicates that it can give good estimates with reasonable confidence limits (Jachmann 1991; Barnes 2001, 2002; Eggert *et al*. 2003). The dung count method is used extensively for estimating elephant numbers in forested areas, yet there is considerable scepticism concerning its accuracy (Barnes 2001). Published accounts of dung counts show that they give estimates similar to those from other methods for vertebrates ranging in size from lizards to elephants (Todd *et al*. 2008). Thus, dung counts are as accurate or inaccurate as other methods for estimating vertebrate numbers including elephants (Barnes 2001).

Detectability plays a key role in estimating dung densities and ignoring this may lead to erroneous outcomes in estimating the population size. Different habitat types may have different detection probability and in the present study, the detection probability in the three habitats varied from 0.40 in mixed moist deciduous forests and 0.43 in grasslands to 0.50 in semi evergreen forests. In absolute terms, these estimates of detection probability suggest that nearly half of the elephant population could be missed during surveys in Manas, irrespective of habitat type, if detection probability was not accounted for. In addition, there could be habitat-specific variation in detection probability, as evident in this study, because of differences in vegetation types and thickness of the forest. The grasslands in Manas tend to be thicker and denser during peak monsoon and post monsoon, which limits visibility and thereby detection probability to a great extent. Inaccessibility in a large habitat like Manas may also limit sampling intensity. The difficulty of travel and observation in forests sometimes means that the amount of data that can be collected per unit effort is low (Walsh *et al*. 2001). The dung count method is considered to be more cost effective than the more sophisticated dung DNA method (Hedges *et al*. 2013). Considering all these factors, we applied the line-transect based dung count method to elephant population estimation, which is well suited to the prevailing vegetation in Manas.

We found that the density of elephants was highest in mixed moist deciduous forests than in the other two habitats during the study period. This can be due to availability of more diverse forage in mixed moist forests than in reasonably homogenous grasslands. Some of the fodder plants, including *Dillenia indica*, were observed more in the mixed moist forests, which may attract elephants. While examining dung piles, *Dillenia* fruit parts were recorded to a great extent. Sukumar *et al*. (2003) recorded the same from Buxa Tiger Reserve.

Besides, the Forest Department's population census data, there are no other empirical data on elephant population size and density in Manas to compare with. Historical estimates are doubtful

and mainly educated guesses. Therefore, this result provides a new baseline for population size with scientific methods. The population in Manas has always drawn attention because of its international importance as a park. Since it is part of a transboundary landscape the park is significantly utilized by migrating elephants during both seasons. This 'open' population gains added importance as it is likely to contribute to maintaining better genetic diversity across the larger landscape. The increased human–elephant conflict in the fringe areas of the park (Nath *et al*. 2009) and considerable change in the land-cover types in the study area (Sarma *et al*. 2008) lead to potential threats to the long-term existence of elephants in the region. The larger landscape of the Ripu Chirang Elephant Reserve, of which the Manas National Park is a part, has witnessed extensive deforestation during the last decade or so. This has led to fragmentation of the otherwise contiguous forested landscape that facilitates the movement of elephants across the region. This deforestation has caused loss of prime habitats mostly in parts of Kachugaon and Holtugaon forest divisions. Unfragmented habitat is essential for long-term conservation of Asian elephants, as the species depends on entire landscapes rather than a few habitat patches (Leimgruber *et al*. 2003). The study shows that for populations such as the one in Manas, estimates from the low-cost dung count method are feasible to obtain and have scientific validity.

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Research Article Gajah 52 (2020) 24-29

Multi-Gene mtDNA Primers for Use with Non-invasive Sampling of Asian Elephants

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Abstract. Understanding population genetic structure and phylogeography can be useful in framing conservation strategies for the Asian elephant. Non-invasive genetic sampling allows for such information to be obtained. However, amplifying long fragments from poor-quality faecal DNA is challenging. Therefore, we developed primers to amplify 270–474 bp fragments to cover ≈2 kb of the Asian elephant mtDNA genome across ATP8-ATP6, ND5 and D-loop regions. We obtained a 1978-bp sequence (in six fragments) from up to two-week-old faecal samples with a success rate of 79.8%. These primers would provide fine resolution phylogeography for the Asian elephant, and population-specific SNPs would aid in forensic tracking.

Introduction

The Asian elephant (*Elephas maximus*) has been obliterated from 95% of its historical range, whereas, in India, its geographic distribution has shrunk by 70% since the 1960s (Sukumar 2006). The only surviving Proboscidean species in Asia is enlisted as 'Endangered' by IUCN, is placed on 'Appendix I' of CITES and is a 'Schedule I' species as per the Wildlife (Protection) Act, 1972 of India. Once widespread in India, the species has retreated to four general areas: north-eastern, central, north-western and southern India with a total population of ≈27,000 individuals (PED-MoEFCC 2017).

Thorough information on population genetic structure and the distinctiveness of populations are imperative for management of a threatened animal species (Avise 1995). Genetic tools are useful in delineating population units of conservation importance (Crandall *et al*. 2000; Fraser & Bernatchez 2001; Vidya *et al*. 2005a, b) in addition to understanding behaviour, evolution, and planning conservation strategies for large social animals like elephants (Fernando & Lande 2000; Fernando *et al*. 2003; Vidya & Sukumar 2005).

There has been considerable interest in understanding the phylogeography of the Asian elephant (Fernando *et al*. 2000, 2003; Fleischer *et al*. 2001; Vidya *et al*. 2009) ever since early studies showed differences between mainland and Sri Lankan populations (Nozawa & Shotake 1990; Hartl *et al*. 1995) and the presence of two divergent clades of mitochondrial DNA (Hartl *et al*. 1996). A majority of the studies on the phylogeography or population genetic structure of the Asian elephant focus on using mitochondrial DNA (mtDNA) (Fernando *et al*. 2000; Vidya *et al*. 2009; Zhang *et al*. 2015), although some studies have additionally examined nuclear markers (Fernando *et al*. 2003; Vidya *et al*. 2005a, b; Ahlering *et al*. 2011). Almost all studies based on mtDNA have used the non-coding D-loop region. Exceptions include studies by Hartl *et al*. (1996) and Fleischer *et al*. (2001) that used cytochrome b (Cyt b), and by Vandebona *et al*. (2002) using NADH dehydrogenase subunit 5 (ND5). Most of these studies have been limited to the use of sequences that were 400–700 bp long, covering a single locus whereas improved insight of the Asian elephant phylogeography may be obtained with longer sequences across multiple genes.

Molecular techniques involving non-invasive genetic sampling using dung or faecal matter

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have been used successfully to examine evolutionary radiation, gene flow and sub-structures of elephant populations (Fernando *et al*. 2000; Vidya *et al*. 2005a, b; Ahlering *et al*. 2011; Zhang *et al*. 2015). However, if the dung samples collected are old, the faecal DNA may be sheared and degraded. The most widely used mtDNA primers for Asian elephants amplifying the D-loop region are over 600 bp long (Fernando & Lande 2000) and may be challenging to amplify from poor quality source material. Designing primers with robust annealing to yield amplicons that are 200–500 bp long could facilitate amplification from non-invasive faecal DNA and allow long stretches of mtDNA to be assembled from the shorter fragments. There were a few published primers targeting regions other than the D-loop, but they had been tested only in the African elephants (e.g. Finch *et al*. 2014) or were universal mammalian primers having the risk of human cross-amplification (Vandebona *et al*. 2002). Therefore, we aimed to design and optimize suitable multi-gene primers for amplification of the published polymorphic regions of the ATP synthase, ND5 and D-loop regions of mtDNA from faecal DNA of varying quality for better understanding of evolutionary radiation in Asian elephants.

Material and methods

DNA extraction from faecal samples

We collected elephant faecal samples, ranging from fresh to approximately two weeks old, from the Rajaji Tiger Reserve and the adjoining Forest Divisions in Uttarakhand, India, opportunistically while surveying the area on foot. The samples were placed in sterile 50 ml screw-cap containers with silica gel immediately after collection to prevent moisture-induced degradation. We oven-dried the samples at 50°C at the laboratory before storage at room temperature up to one year before DNA extraction.

We scraped the top layer from the faecal samples containing sloughed-off intestinal epithelial cells using a sterile blade into sterile 2.0 ml polypropylene tubes. We followed the standard DNA extraction protocol suggested by the manufacturer using column-based QIAGEN QIAamp DNA Stool Mini Kit after overnight digestion with stool lysis buffer at 56°C in a water bath. The eluted DNA was stored at -20°C until further use. We used a negative control during all the extraction batches to check for contamination.

Designing the mtDNA primers

Though the Asian and the African elephants diverged approximately 6.8 million years ago (Roca *et al*. 2015), conserved sequences are present and primers are known to cross-amplify. Therefore, we aimed to amplify parts of the mtDNA genome displaying polymorphism in different populations of Asian and African elephants as represented in the public domain database of NCBI GenBank. We found polymorphism at ATP synthase F0 subunits 8 (ATP8) and 6 (ATP6) (Finch *et al*. 2014), ND5 (Vandebona *et al*. 2002), and the D-Loop region (Fernando & Lande 2000; Sulandari & Zein 2012; Vidya *et al*. 2009), which were suitable for further investigation.

Therefore, we decided to redesign one set of ATP8-ATP6 primers having 84 bp overlap with an existing set of primers (Finch *et al*. 2014) using a published Asian elephant complete mtDNA genome (GenBank Accession no. NC_005129.2) as reference. The primers now amplify a fragment including partial COX2, tRNA-Lys, ATP8, and partial ATP6. We also designed two similar sets of primers compatible with an existing study (Vandebona *et al*. 2002) for the ND5 region, with 84 bp overlap to facilitate contig building. The widely used D-loop primers for elephants (MDL5-MDL3; Fernando & Lande 2000) amplify a product of ≈630 bp, including partial Cyt b, tRNA-Thr, tRNA-Pro and partial D-loop, for which we observed a success rate of <30% from degraded faecal DNA (Goyal *et al*. unpublished). Fernando et al. (2003) proposed a set of internal primers (MDLseq-1 and MDLseq-2) for the D-loop region corresponding to the primer set MDL5-MDL3, but these also generate products close to 600 bp. Therefore, we decided to design internal primers with shorter amplicons (ranging from 270 to 474 bp) to use with the existing D-loop primers, producing two amplicons with 104 bp overlap. Redesigning of the existing primers was done manually by aligning the primers to the complete mtDNA genome of the Asian elephant and modifying the nucleotides as necessary. We used Primer3web v4.1.0 (Koressaar & Remm 2007; Untergasser *et al*. 2012) to design the novel primers.

Standardization of amplification conditions

To optimize the annealing temperature, we subjected all six sets of primers (Table 1) to a broad temperature gradient of 50°C to 64°C. The reactions consisted of Thermo 2X Maxima Hot Start Green PCR Master Mix, 1.5 μg bovine serum albumin, 3 pmoles of each of the forward and reverse primers, 3 μl genomic DNA of variable concentration and RNase free water to bring the reaction volume up to 15 μl. The thermocycler profile was as follows: initial denaturation (95°C for 5 min), followed by 40 cycles of denaturation (95°C for 30 sec), annealing (varying temperature as per experimental gradient for 40 sec) and extension (72°C for 40 sec) followed by a final extension at 72°C for 10 min before the 4°C hold. All PCR reactions contained a negative as well as a positive control. The resulting amplicons were directly loaded into SYBR green stained 2% w/v agarose gels and run using TAE buffer before visualizing in an ultraviolet light-based gel documentation system. A 100 bp DNA ladder was run with each round of electrophoresis for recording the presence/absence of desired bands of predicted length.

Species confirmation from the amplicons

The successful amplicons were purified of excess primers and nucleotides by enzymatic hydrolyzation using Exonuclease I and Shrimp Alkaline Phosphatase. We subjected the resultant products to Sanger sequencing using BigDye Terminator v3.1 Cycle Sequencing Kit (Applied Biosystems). We used the ethanol precipitation method to clean up the sequencing products. We then dissolved them in HiDi Formamide (Applied Biosystems) prior to capillary injection in an ABI 3530 XL Genetic Analyser. The data were compared with the sequence repository of NCBI GenBank for species confirmation.

Results and discussion

We observed positive amplification of predicted lengths in all six sets of primers with no bands in negative controls of extractions or PCRs (Fig. 1).

Optimal annealing temperature

The optimal annealing temperature (Ta) for all the primers selected (Table 1) for this study for producing sharp bands varied between 52°C and 58°C (Table 2). We did not observe the presence of any non-specific bands or smearing at the optimized Ta for any of the fragments. The presence of primer-dimers was also minimal.

Amplification success rates

After determining the optimal Ta, we tested the primers with several faecal DNA extracts (n = 11 to 82) to record proportions of positive amplification. The overall success rate with faecal DNA in all the primers varied between 68.8% and 93.9% (mean = 79.8%, Table 2). We observed >90% success rates in amplifying the ND5 fragment using the primer pair EmND5_2F-EmND5_2R and the D-loop fragment amplified by MDL3mF-MDL3. Lowest success (68.8%)

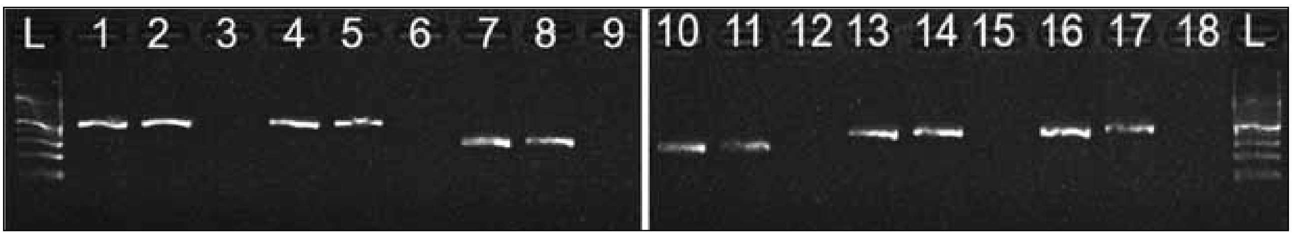

Figure 1. Agarose gel electrophoresis of representative amplicons produced by the primers used. Lane key: L: 100 bp ladder, 1-18: PCR products of MT24mF and MT24mR (1-3), MT25F and MT25R (4-6), EmND5_1F and EmND5_1R (7-9), EmND5_2F and EmND5_2R (10-12), MDL5 and MDL5mR (13-15), MDL3mF and MDL3 (16-18). Lanes 3, 6, 9, 12 and 18 contain the negative PCR controls.

Table 1. Primer sequences.

Primer	Primer sequence (5' – 3')
MT24mF	AGTCTCATCAGAAGATGTTCTCC
MT24mR	GGATAGTTCTTCGTTCACTTCT
MT25F	TCGCCTTCTTTTCCCAATCT
MT25R	GGTGTTCCTTGTGGGAGAA
EmND5_1F	CGTATTGGCGATATAGGCTTC
EmND5_1R	AGTGGGTAAAAGCGGATGAG
EmND5_2F	AGGCCCTACCCCAGTATCAG
EmND5_2R	TGGGTAAAGGCTAGATGTGGTT
MDL5	TTACATGAATTGGCAGCCAACCAG
MDL5mR	GGGTAAATAATGTGATGCACGATT
MDL3mF	CCCTGCAAGTAAACCAATCCGCT ATGT
MDL3	CCCACAATTAATGGGCCCGGAGCG

was observed in the first fragment of the ND5 (EmND5_1F-EmND5_1R).

Species confirmation

All positive amplifications produced high-quality sequences with sharp discernible peaks in the chromatograms and the Q value for each base was >20 with no 'dye blobs'. The comparison of the sequences we generated with the NCBI GenBank data repository confirmed that 100% of the sequences generated during this study belonged to the Asian elephant and the desired mtDNA fragment.

Our results show that it is possible to generate ≈2.0 kb high-quality mtDNA sequence data from non-invasively collected faecal DNA of the Asian elephant with high to moderate success rates from fresh to two-week-old dung samples. The primers described in this study all encompass polymorphic regions of the mtDNA, and hence, screening samples across the geographic range of the species would provide valuable information on the phylogeographic characteristics.

In the recent past, regional studies have shown the presence of new haplotypes in different parts of the mtDNA genome in the Asian elephant (Vandebona *et al*. 2002; Thitaram *et al*. 2015) highlighting the need of a range-wide, multi-gene study. Besides, location-specific single nucleotide polymorphisms (SNPs) fixed at the population level have been used in wildlife forensics (Ogden & Linacre 2015; Kumar *et al*. 2016). Hence, identifying an array of SNPs in Asian elephants could aid forensic researchers in tracking poaching cases to the origin of the samples, thereby contributing to the conservation of Asian elephants. In addition, evidence of positive selection at the genes responsible for the oxidative phosphorylation pathway has been observed in African forest and savannah elephants, probably to adapt to the harsh climatic conditions they face (Finch *et al*. 2014). As the Asian elephant also occupies a variety of temperature regimes, studies on such protein-

Table 2. Details of the mtDNA primers designed and tested to amplify a total of 1978 bp.

Fragment	Size (bp)	Primer	Status	Amplicon		Ta	Success rate
				Position*	Size (bp)	(°C)	(%)
ATP8-ATP6	845	MT24mF	Modified	7477 – 7950	474	58	72.7 (n=11)
		MT24mR	Modified				
		MT25F	Finch *et al*. (2014)	7867 – 8321	455	52	70.6 (n=17)
		MT25R	Finch *et al*. (2014)				
ND5	458	EmND5_1F	Designed	12,262 – 12,533	272	56	68.8 (n=16)
		EmND5_1R	Designed				
		EmND5_2F	Designed	12,450 – 12,719	270	58	93.8 (n=16)
		EmND5_2R	Designed				
D-loop	675	MDL5	Fernando & Lande (2000)	15,151 – 15,548	398	56	78.9 (n=19)
		MDL5mR	Designed				
		MDL3mF	Designed	15,418 – 15,825	408	56	93.9 (n=82)
		MDL3	Fernando & Lande (2000)				

* Based on complete mitochondrial genome of *Elephas maximus* (Accession number: NC_005129.2).

coding regions (ATP synthase and NADH dehydrogenase) using our new primers may also reveal interesting spatial variations in such genes.

Conclusion

We aimed to design primers to amplify polymorphic regions (ca. 2.0 kb) of Asian elephant mtDNA based on published literature. This included partial fragments of the ATP8-ATP6 complex (ca. 850 bp), ND5 (ca. 450 bp) and D-loop (ca. 630 bp) regions from non-invasive samples. We designed 8 novel oligos to obtain 270–474 bp-fragments. We were successful in amplifying a total of 1978 bp in three contigs from non-invasive faecal DNA with a mean success rate of 79.8%. Therefore, these primers would be useful in generating data from across the range of the Asian elephant to study multi-gene phylogeography and genetic variation.

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Research Article

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Demography, Feeding and Keeper Status of Captive Asian Elephants in Eastern Arunachal Pradesh, North-eastern India

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Abstract. To understand the population viability of captive elephants in eastern Arunachal Pradesh, India, we documented the demographic parameters, food and feeding of captive elephants and their keepers' status in private and forest department systems during 2016–2017. The two systems together managed 135 elephants, with 84% being adults and a male bias in younger age-classes. Fecundity was 0.04 calves/adult female/year and mortality was 2.2%, which were lower than in southern India. Given the observed demographic parameters, we recommend, the Arunachal Forest Department to gradually increase its captive stock through effective management and use them in patrolling and eco-tourism for long-term sustainability.

Introduction

The Asian elephant (*Elephas maximus*), listed as an 'endangered' species (IUCN Red List 2017), exists in fragmented populations in south and southeast Asia with 36,000–52,000 distributed among 13 countries (Riddle *et al*. 2010). It is an integral part of the cultural ethos and mythology of Asia. A third of the Asian elephant population is currently in captivity, and so they deserve greater attention both in terms of management and research. In India, captive elephants, numbering 3467–3667, are distributed among 23 states and union territories, including the Andaman and Nicobar Islands (AsESGM 2017), with the majority found in the north-eastern (55%) and southern (25%) states. In the northeast, they are found in larger number in the states of Assam (~1300) and Arunachal Pradesh (560–580) (MoEF 2018). Most studies on captive Asian elephants are from southern India and deal with timber camp elephants (Sukumar *et al*. 1988; Krishnamurthy & Wemmer 1993; Sukumar *et al*. 1997). More recently there have also been studies on captive elephants in private and Hindu temple systems (eg. Vanitha 2007; Vanitha *et al*. 2008, 2009, 2010a, 2010b).

The Asian elephant in spite of its long history in captivity has not been bred sustainably in most captive places. There are hardly any records of captive elephant births in Indian temples, as reproduction in temple premises is considered inauspicious. Private owners do not encourage breeding as maintenance of pregnant and lactating cows is expensive (Krishnamurthy 1998). However, a significant number of privately owned elephants breed in captivity in the north-eastern states of Assam and Arunachal Pradesh, as they are managed close to forested areas, where captive cows come in contact with wild bulls. In north-eastern India interest among private owners for managing elephants is waning due to the loss of demand for them in forestry operations owing to the ban on logging (Bist *et al*. 2002). Thus, in the future captive breeding among privately owned elephants in the north-eastern states could decline. The captive populations of Asian elephants in western zoos (Wiese 2000), Myanmar (Leimgruber *et al*. 2008) and southern Indian timber camps (Vanitha 2007; Vanitha *et al*. 2010a, 2012) are also in reproductive decline. An assessment of the demographic parameters of the captive elephants of north-eastern India may provide insights into their likely future.

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Captive elephants in general are not fed in accordance with their nutritional requirements and natural food preferences, which is especially true in relation to elephants managed in zoos (Crandall 1964), Hindu temples (Krishnamurthy 1998; Vanitha 2007; Vanitha *et al*. 2008) and private systems (Vanitha 2007; Vanitha *et al*. 2008). Some captive facilities offer monotonous fodder round the year without seasonal change and in some cases in inadequate quantities (Vanitha 2007; Vanitha *et al*. 2008, 2010a). In contrast wild elephants feed on a wide range of food plants according to seasons (McKay 1973; Olivier 1978; Baskaran 1998; Roy *et al*. 2006). Captive elephants, especially those managed privately and temples, unlike the ones managed by the Forest Department in a semi-wild condition, are totally dependent on the food provided. Hence, there is a need to evaluate the food and feeding practices prevailing in captive facilities.

Elephant-keepers manage the captive elephants on a day-to-day basis, and their living standards and well-being has declined over the years with the dwindling of the importance of the elephant in daily life. This could result in human casualties also, as elephants might attack keepers lacking compassion towards them, while handling or owing to stress due to workload (Vanitha *et al*. 2009).

Methods

Study area

The study was carried out between November 2016 and April 2017 in eastern Arunachal Pradesh, which includes 12 districts (Longding, Tirap, Changlang, Anjaw, Lohit, Namsai, Lower Dibang Valley, Dibang Valley, Upper Siang, Siang, East Siang and West Siang). The state has 62% of its area under forest cover and ranks second highest in India.

The state uses a large number of captive elephants for timber extraction and there was a minimum of 550 elephants in 2002 (Bist *et al*. 2002), which is the third largest captive population in India. The majority (89%) are under private control. Almost all the elephants in the state are used for logging operations in private or community forests, or for work in saw mills. It is the only state to use elephants for agricultural operations (Bist *et al*. 2002). Details about holdings and captive elephants under the forest department are listed in Table 1.

The state's economy is largely agrarian, based on the terraced farming of rice and cultivation of crops, such as maize, millet, wheat, pulses, sugarcane, ginger, oilseeds, cereals, potato, and pineapple (IBEF 2018). A high proportion of

Table 1. Details of captive elephant holdings and elephants in eastern Arunachal Pradesh.

Detail	Private	Forest Department
Facility	Individual owners	Dibang Forest Division & Namdapha National Park
Number of facilities	98	2
Mean number of elephants per facility	1.3 (range 1–4)	4 (range 2–6)
Number of facilities with one elephant	67	None
Nature of work	Logging	Joy ride and patrolling
Duration of work	6 h/day	4 h/day
Time of work	7:00–11:00 & 16:00–8:00	7:00–9:00 & 16:00–18:00
Bathing frequency	Once a week for 2 h	Twice a week for 2 h
Periodic veterinary check-up	Absent	Present (once per year)
Recruitment	Captive birth Purchase from private facilities of other states	Captive birth Confiscation from private Wild orphan rescue
Breeding	Present	Present

the population in the state is below the poverty line (37%) with an average income is Rs. 40/day (equals to US$ ~0.5) (together from urban and rural) and has a relatively low literacy rate (65%) (Konwar 2015).

To assess the population size and structure, a list of captive elephants was prepared using government records and enquiries with private authorities, veterinarians and NGOs. Subsequently, field visits were carried out to each captive elephant location and details verified. The age and sex were recorded for each elephant by enquiring from the keepers, and verified with the stud book/register of records available with each facility. Shoulder height (from dorsal edge of the scapula to the bottom of the front foot) and tusk and tush length and circumference at the lip were measured. Age was verified by shoulder height, and in addition by considering tusk parameters in case of tusked males (Sukumar *et al*. 1988). The age was corrected for one adult female elephant, as its age was not comparable with shoulder height measurements as per Sukumar *et al*. (1988). Elephants were categorized into four age classes, viz. calf (<1-year old; 90–120 cm height), juvenile (≥1 to <5 years; 121–180 cm), subadult (≥5 to 15 years; 181–210 cm for female and 181–240 cm for male), and adult (≥15 years; >210 cm for female and >240 cm for male) based on shoulder height (Sukumar *et al*. 1988).

Natality and mortality

Data on population growth and mortality of elephants during 2013–2017 were obtained from registers of records and by enquiring from keepers. Population growth included births and immigration of individuals through purchase/confiscation/wild rescues, mostly orphans. Fecundity was calculated by dividing the total number of calves born during the study period by the total number of sexually mature female elephant-years, following Sukumar *et al*. (1997). Elephant-years refer to the summation of all individual elephants multiplied by their number of year(s) representation/survival in a given system for a particular period. For example, if out of 25 different elephants managed in a given system over a two-year period, 20 were there for two years and the remaining five only for one year, the number of elephant-years is 20 x 2 + 5 x 1 = 45. Age-specific mortality was computed by dividing the total number of individuals that died within a given age-class by the total number of elephant-years in that class (Sukumar *et al*. 1997).

Assessment of food and feeding

Food supplied was assessed from November 2016 to April 2017 by inquiring about food items including cooked ration and cut fodder provided to each elephant. Additionally, time and period of supply were obtained from records available at the facilities and enquiry.

Keeper's salary

Salary paid and the number of keepers per elephant was determined from interviews and examining the records of expenses maintained by elephant owners and forest department.

Data analysis

The trend in population size from 2013 to 2017 was tested using linear regression. Differences in supplementary food supplied among age-classes (adult, subadult and juvenile) and between sexes were tested for significance using Kruskal-Wallis and Mann-Whitney U tests, respectively, in SPSS Version 23.

Results

Population size

Private and forest department systems together managed 134 elephants during 2016 and 135 elephants in 2017 (until April). Of the 135 elephants managed during 2017, nine belonged to the forest department. A comparison of data on population size since 2013 shows a negative trend (Fig. 1).

Age structure and sex ratio

Data on age structure has shown that the adult class constituting over two-thirds (84%) of the

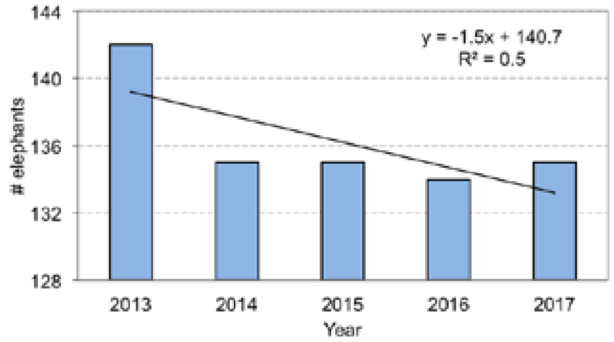

Figure 1. Population size of captive elephants during 2013–2017.

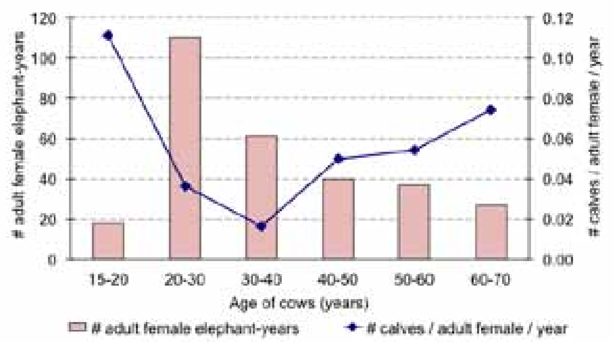

Figure 2. Age-specific fecundity rate of captive elephants during 2013-2017.

total population size in the two captive systems (Table 2) and younger age-classes, such as subadult, juvenile and calf, constitute only 16%. Further, data on age-sex composition during the last five years has shown that the population composed almost of equal number of males and females, both at adult segment and overall. However, at subadult and juvenile segments, it was males biased. The sex ratio has shown female bias at calf level (Table 2).

Natality

There were 61 sexually mature females in the age-class 15–70 years during 2013 to 2017, amounting to 293 female-elephant years. There were 13 births in the period, giving a total of 0.04 calves/adult female/year. Age specific fecundity is given in Figure 2. The age group 30–40, had the lowest fecundity.

Mortality

Of the 141 individual elephants (132 with private owners and nine with the forest department) in 2013–2017 constituting 681 elephant-years over the five-year period, 15 died, 14 in the private system and one in the forest department system, with a mean annual mortality rate of 2.2% for both the systems (Table 3). Of these 15, adults have accounted for 6 individuals or 1%, followed by calves at 9 individuals or 47%. Overall, mortality among females was higher (2.7%; 9/339 elephants) than males (1.8%; 6/342 elephants).

Food and feeding

The elephants' food consisted of: (i) cut fodder - green grass and browse as stall feeding, (ii) supplementary diet of soaked rice and gram inside a bundle of grass and (iii) natural feeding. Quantity of supplementary diet fed were significantly higher for adult class than the younger age-classes (Table 4). Between genders, males were fed a significantly larger quantity of rice and gram compared to females (Table 5).

Status of the keeper: Each elephant above 5 years was managed by two persons, a keeper and an assistant keeper. In the forest department, both keeper and the assistant were employed, whereas in the private system, the owner acted as the keeper and a hired person assisted him. Keepers are paid 111.9 ± 6.09 US$/month by the forest department and 112.4 ± 1.72 US$/month by the private system (Table 6).

Table 2. Age-sex composition of captive elephants in eastern Arunachal Pradesh during 2013–2017.

Age class	Percentage (number in 2017)			Sex ratio (male : female)
	Male	Female	Total	
Adult	41.1 ± 0.55 (57)	43.0 ± 0.41 (60)	84.2 ± 0.74	1.0 : 1.0
Subadult	6.2 ± 0.37 (0)	3.1 ± 0.25 (1)	9.3 ± 0.22	1.0 : 0.5
Juvenile	2.1 ± 0.24 (2)	1.8 ± 0.38 (2)	3.8 ± 0.54	1.0 : 0.9
Calf	0.9 ± 0.37 (10)	1.9 ± 0.84 (3)	2.7 ± 1.08	1.0 : 2.2
Total	50.2 ± 0.63 (69)	49.8 ± 0.63 (66)	100	1.0 : 1.0

Table 3. Age-specific annual mortality of captive elephants during 2013-2017.

Age-class	Female		Male		Overall	
	Mortality rate (%)	n*	Mortality rate (%)	n*	Mortality rate (%)	n*
0–1	23.1	13	100.0	6	47.4	19
1–5	0.0	12	0.0	14	0.0	26
5–10	0.0	8	0.0	22	0.0	30
10–20	0.0	31	0.0	42	0.0	73
20–40	0.0	171	0.0	177	0.0	348
40–60	6.5	77	0.0	71	3.4	148
60–80	3.7	27	0.0	10	2.7	37
Total	2.7	339	1.8	342	2.2	681

n* = number of individuals at risk (of death) expressed as the number of elephant-years over the age-class interval.

Discussion

Population demography

Population size: Of 135 captive elephants we documented, the majority were owned privately. The actual numbers are probably higher as some elephants were not covered due to being away from their holdings during our survey. The central government records show that Arunachal Pradesh has 560–580 captive elephants (Project Elephant 2004), but records of the State Forest Department of Arunachal Pradesh (2001) show that Namsai District alone had 253 captive elephants in 2001 (State Forest Department, Namsai District Captive Elephant Register 2001). Therefore, the Central government records greatly underestimated the elephant numbers. The present estimate of 135 captive elephants for eastern Arunachal, which includes 11 more districts apart from Namsai, indicate that there was a significant decline in elephant numbers in the region. Our study also showed that this decline continued up to 2017.

The adult segment (82.4%) recorded in the captive elephants of eastern Arunachal Pradesh is higher than that of the captive population in Tamil Nadu (76%) (Vanitha *et al*. 2010a, 2012), and wild populations of Mudumalai Wildlife Sanctuary (42%) (Baskaran *et al*. 2010) and Anamalai hill ranges of Western Ghats (45%) (Baskaran *et al*. 2013). Though the captive population in north-eastern India was known for a moderate level of breeding in the past (Krishnamurthy 1998; Bist *et al*. 2002), its current age structure indicates either high mortality or disposal of elephants in subadult and juvenile segments. The male-biased sex ratio at subadult and juvenile segments further supports the above statement. Of the 253 captive elephants in Namsai District, as shown by state government record, 48 were sold to other states of India – three each to Rajasthan and

Table 4. Quantity of food supplied and natural feeding duration (NFD) provided to different age-classes of captive elephants.

Age-class	Supplementary diet		NFD (h)
	Rice (kg)	Gram (kg)	
Adult	6.0 ± 0.22	3.4 ± 0.09	13.7 ± 0.19
Subadult	3.4 ± 0.14	1.6 ± 0.14	13.7 ± 1.24
Juvenile	2.2 ± 0.25	1.00 ± 0.00	14.7 ± 0.25
Kruskal-Wallis χ^2	41.74	48.51	5.81
p value	0.000	0.000	0.055

Table 5. Quantity of food supplied and natural feeding duration (NFD) provided in relation to sex of captive elephants.

Sex	Supplementary diet		NFD (h)
	Rice (kg)	Gram (kg)	
Female	5.1 ± 0.27	2.9 ± 0.13	13.8 ± 0.32
Male	6.1 ± 0.31	3.3 ± 0.15	13.6 ± 0.31
Total	5.6 ± 0.21	3.1 ± 0.10	13.7 ± 0.22
Mann-Whitney U	169.5	143.0	522.5
p value	0.000	0.000	0.670

Table 6. Salary details in US$ (@ Rs.65/US$) of keepers managing different age-classes of elephants.

Age class	N	Salary/month
Adult	113	112 ± 1.8
Subadult	13	114 ± 5.7
Juvenile	4	104 ± 10.6
Overall	131	112 ± 1.7
Kruskal-Wallis χ^2		0.725
p value		0.696

Karnataka, 17 each to Bihar and Kerala, and eight to Uttar Pradesh indicating disposal of elephants from eastern Arunachal Pradesh (State Forest Department, Namsai District Captive Elephant Register 2001). Private and Hindu temple systems in Tamil Nadu, which prefer female elephants, have elephants originating from north-eastern states of Arunachal Pradesh and Assam (Vanitha 2007; Vanitha *et al.* 2010a, 2012). Therefore, the high adult segment observed in eastern Arunachal is likely due to the selective disposal of female elephants to other states of India. Thus, the sex-ratio bias towards males in the subadult and juvenile segments is unusual, as the elephant is a polygynous species, whose population is supposed to be female biased gradually from younger to older age-class (i.e. juvenile to subadult and adult). Given the present scenario of aged population trend with male-biased sex ratio in younger age-classes, the population does not promise a healthy trend of growth or recovery even in the future. The high variation observed in the number of calves between years could be attributed to inter-annual variation in natality. In elephants, the long inter-calving interval results in only a small and varying percentage of females calving in any given year. A high calving rate in any year is usually followed by a lower rate in the subsequent years, as there will be fewer females remaining to calve in the population (Baskaran *et al.* 2010).

Natality: The mean fecundity rate of 0.04 estimated in the present study is considerably lower than that reported for the captive population of southern India (0.155 during 1969–1989, Sukumar *et al.* 1997, and 0.065, during 1996–2005 Vanitha 2007; Vanitha *et al.* 2010a, 2012). Privately owned captive elephants are continuously worked, and owners consider pregnancy and calving as an impediment to work, expensive and a burden (Bist *et al.* 2002) considering the 18–22-month pregnancy period (Sukumar 1989). Age-specific fecundity data shows that middle-aged cows (30–40 age segment) had lower fecundity (0.02 calves/adult female/year) than younger (15–30 years) and older classes (≥0.04 calves/adult female/year), which may be due to the middle age-class bearing a greater workload resulting in lower fecundity.

Mortality: The present study estimated a mean annual mortality of 2.2%, which is comparable to the mortality rate in wild elephants in southern India of 3% (Daniel *et al.* 1995). The present estimate is also comparable with the 1.9% mortality estimated for the timber camp population in Tamil Nadu (Sukumar *et al.* 1997), but lower than the 3.9% reported for the captive populations from private, Hindu temple and forest department systems in Tamil Nadu (Vanitha *et al.* 2010a). The elephant is a polygynous species, in which males experience greater mortality than females (Trivers 1985), the observed higher mortality of females than males in the present study could be ascribed to greater workload. In general, calves are more susceptible to mortality than other age-classes. The observed calf mortality of 47.4% is comparable with that for the captive population in southern India of 39% (Sukumar *et al.* 1997). The lower overall mean annual mortality rate observed in the present study (2.2%) further reveals that sale/gift of elephants is the reason for the aged population and skewed sex ratio trend than higher mortality.

Food and feeding

Asian elephants in the wild feed on a wide variety of food plants (McKay 1973; Olivier 1978; Daniel *et al.* 1995; Baskaran 1998; Roy *et al.* 2006). Their natural diet includes twigs, stems, leaves, bark, fruits and roots of herbs, shrubs and trees, although the main fodder is grass (Baskaran 1998). Since the captive elephants under both private and forest department systems were allowed 13 h a day of natural feeding, their nutritional needs could be met by shifting from grass consumption during the wet season to browse during the dry season. They could also consume a wide variety of food plants in the natural habitats. Timber camp elephants in southern India also had similar feeding opportunities (Vanitha 2007; Vanitha *et al*. 2008).

The intake rate of food by elephants has been estimated as 5% of their body weight per day on wet-matter (Sukumar 1989). On an average, to consume fresh fodder equalling 5% of body weight, a cow elephant requires as much as 150–175 kg and a bull 200–275 kg per day (Vanitha *et al*. 2008). The present estimate of the mean quantity of supplementary diet supplied per day for adult class (9 kg) is significantly lower than that reported for the timber camp elephants from southern India (Vanitha 2007; Vanitha *et al*. 2008). Although the captive elephants in the study area are let out for 13 h of natural feeding, whether they get the required quantum of green fodder on a day-to-day basis is doubtful, considering that they are let out into the same area throughout the year (JJ and NB pers. obs.), leading to decreased availability of food. The captive elephants in eastern Arunachal Pradesh work mostly in logging, which usually is of longer duration and is more strenuous than other work like eco-tourism, going in processions and patrolling. Thus, an adequate supplementary diet is essential to maintain their health and for sustainable breeding.

Keepers' welfare

Keepers' welfare is related to the elephant's well-being. Our study has shown that elephant-keepers are paid US$ 112/month, which is low compared to the salary prescribed by Project Elephant Experts Committee which is ~US$ 185/month in 2004 (MoEF 2004). Due to low wages, the traditional keepers abandon their jobs (MoEF 2004) and the elephants are left to the care of non-traditional, lesser compassionate and inexperienced keepers. Such situations contribute to attacks by elephants leading to manslaughter and injuries, as reported in southern India (Krishnamurthy 1998; Vanitha *et al*. 2010b). In such cases, the chances of human-elephant conflict with captive elephants are higher; as observed in 2011, when a bull named Dafaa Babu from Namdhapa National Park killed its keeper, and in 2013 Hary Prasad from Namsai District killed its owner.

Conclusions and recommendations

Sustaining the captive elephant population

The present captive population may not be sustainable in the long run considering the (i) aged population, and (ii) low fecundity. To overcome these problems, the private system has to improve captive breeding by providing adequate quantity and quality of supplementary diet. Arunachal State Forest Department in the eastern part of the state is managing very few captive elephants (n = 9) at present, as compared to the private system (n = 125). For captive breeding of elephants, unlike zoos for other species, forested areas like national parks, sanctuaries and territorial forest divisions are ideal locations. Thus, the Arunachal Forest Department should gradually increase its captive stock in forested areas of the eastern parts of the state, through improved captive breeding by better management of existing stocks and with addition of orphans, which could also be used for patrolling and eco-tourism.

Feeding

The study shows that a considerable number of captive elephants in private and forest department systems get a low quantity of supplementary diet compared to captive elephants managed at the timber camps in southern India. Also, the supplementary diet is soaked in water and fed to the elephants inside a bundle of grass. The quantity of supplementary food fed to elephants managed in private and forest department should be based on the veterinarians' prescription as per age, sex, work nature and reproductive status of the elephants, as is practiced in southern India (Krishnamurthy 1998; Vanitha 2007; Vanitha *et al*. 2008). Cooked supplementary diet would enhance the assimilation rate of nutrients (Krishnamurthy & Wemmer 1995; Baskaran *et al*. 2009). As elephants have low digestive efficiency (Benedict 1936), the forest department and the private systems should consider introducing cooked rice and pulses, as practiced in Tamil Nadu, instead of feeding them only grain soaked in water.

Keepers' status

Unlike in the past, where mohuotry was a proud profession of a specialized class of people, now it has lost its charm due to lack of comparable economic benefits and poor welfare owing to the dwindling importance of captive elephants. Many private facilities cannot afford to pay the right amount of salary (MoEF 2004; Vanitha *et al*. 2010b). Therefore, the art of elephant-keeping is dying at a faster rate and effective steps must be taken urgently to improve the economic status of the keepers and care for their welfare through better pay, risk allowance, insurance and family accommodation, as suggested by Project Elephant Expert Committee, Government of India (MoEF 2004). All facilities should strictly adhere to the norms of the state Forest Department regarding the number of keepers per elephant.

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The Elephant in the Room: Methods, Challenges and Concerns in the Monitoring of Asian Elephant Populations

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Abstract. Increasing anthropogenic pressures has led to the fragmentation of Asian elephant habitats, affecting their numbers, demography and ranging patterns across their range. Baseline information on the demography and population dynamics of free-ranging Asian elephants is often unavailable. Population monitoring at the landscape level has many constraints, including those of visibility, habitat, terrain and field logistics, among several others. While knowing elephant numbers may be important for managing local populations, demographic parameters and distribution patterns are perhaps more crucial to ascertain long-term trends for conservation.

Introduction

The Asian elephant (*Elephas maximus*) is classified as endangered by the IUCN (Choudhury *et al*. 2008). Persistent poaching across several landscapes contributes to selective removal of males (Blake & Hedges 2004) while recent reports of poaching for skin suggests additional emerging threats. Asian elephant landscapes are increasingly encroached upon, leading to extensive habitat loss and fragmentation (Leimgruber *et al*. 2003). Habitat availability for the species has, in fact, almost halved over the past few decades (Choudhury *et al*. 2008).

In highly populated countries like India and Sri Lanka, around 60–70% of elephants share space with humans, mostly in modified landscapes (Madhusudan *et al*. 2015; Fernando *et al*. in press). This has resulted in increased encounters and interactions, most of which tends to be negative. Thus, conservation efforts need to extend beyond protected areas and into human-dominated landscapes that are increasingly becoming critically important for the conservation of Asian elephants (Madhusudan *et al*. 2015).

Despite decades of research on Asian elephants, information on their distribution, numbers, demography and behaviour remain unavailable across most landscapes (Blake & Hedges 2004; Gray *et al*. 2014; Madhusudan *et al*. 2015). Such information is, however, vital for the long-term conservation of the species, especially in two of its major strongholds: India and Sri Lanka (de Silva *et al*. 2011; Jathanna *et al*. 2015). The paucity of information is primarily due to visibility constraints in most Asian elephant landscapes, which, unlike the African savannahs, are often densely vegetated with deciduous to evergreen forests. Problems in detectability can significantly downgrade density estimates (Karanth & Nichols 1998) and affect observational studies on elephant populations.

As conservation interventions depend heavily on effective monitoring techniques, there is an urgent need to develop reliable techniques and evaluate their applicability across landscapes and vegetation types. Although population-monitoring techniques have improved in recent years, there continues to be a reliance on a few direct methods and on dung counts, primarily

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owing to the unavailability of trained personnel and logistical constraints associated with other techniques, described later in this paper. Moreover, while these traditional methods are usually applicable across a wide range of landscapes, newer methods, such as photographic cataloguing that effectively estimates numbers of elephants (Goswami *et al*. 2019), or alternate approaches, such as assessing elephant distribution through questionnaire surveys (Fernando *et al*. in press), may have wider applications.

In this perspective paper, we outline some of the more important challenges that confront the currently employed elephant population evaluation techniques. We believe that acknowledging some of these constraints may allow for more effectively designed population-monitoring exercises, which could contribute to informed decisions on the management and conservation of elephant populations in the future.

Censusing elephants

The counting of elephants is an exercise widely prioritised across elephant range states. Routine population monitoring, however, is limited by the feasibility of large-scale surveys and methodological sampling constraints in obtaining reliably comprehensive estimates. Depending on whether the counts are made based on direct sightings of the animals and recording their numbers or estimating the same from animal signs, population estimation techniques have been classified as direct and indirect respectively. The direct methods that have been improvised and implemented for elephant population monitoring include line-transect surveys (Jathanna *et al*. 2003; Kumara *et al*. 2012), total block counts, waterhole counts, simultaneous observer counts (foot counts) and vehicle road counts while the indirect sign-based abundance estimations include dung counts (Kumaraguru *et al*. 2010; Baskaran *et al*. 2013) and DNA-based capture-recapture surveys (Chakraborty *et al*. 2014; Gray *et al*. 2014).

Direct sighting methods

The direct methods commonly deployed include line-transect surveys, block counts, waterhole counts, and photographic cataloguing-based capture-recapture surveys. These are primarily adopted in areas where vegetation is relatively sparse, allowing better sighting of animals. Most direct sighting techniques are labour-intensive, however, and require trained personnel. Some of the more commonly adopted direct survey methods are discussed here.

Line transects

Line-transect surveys continue to be one of the most widely accepted and reliable methods for population monitoring of elephants across their range (Varman & Sukumar 1995; Buckland *et al*. 2001; Kumara *et al*. 2012). Synchronised elephant surveys, carried out at the national level by the Project Elephant in India, for instance, rely primarily on this technique (MoEF & CC 2017). Line-transect surveys involve two or more surveyors walking along paths of fixed length, recording species sightings, along with other parameters, such as sighting angle and distance, to arrive at the perpendicular distance of the animal from the surveyor (Varman & Sukumar 1995; Kumara *et al*. 2012).

Although the method provides reliable estimates of distribution and population characteristics (Jathanna *et al*. 2015), it requires the involvement of large groups of trained volunteers to ensure large spatial coverage. The management and coordination of high numbers of volunteers could, however, pose logistic difficulties. While this particular method is fairly robust, it is difficult to execute in undulating and hilly terrains or in habitats with closed vegetation, where the laying of linear transects is a challenge. Poor visibility and detection problems could further bias estimates. To arrive at robust estimates, a minimum of 60‑80 detections is usually required (Buckland *et al*. 2001) and this may be difficult to achieve in many tropical habitats, especially evergreen forests with dense vegetation and low densities of elephants.

Block counts

In the block-count method, surveyors typically walk in a zigzag manner and record all elephant sightings within a sampling unit, called a block; these are often defined and demarcated a priori by the surveyors themselves. While the method assumes perfect detectability, not all individuals within a block get detected during surveys, thereby violating its underlying assumption (Jathanna *et al*. 2015). This method is logistically convenient, especially for government forest departments, owing to their familiarity with an area but such surveys in habitats, without systematic stratification, could significantly bias estimates (Kumara *et al*. 2012). For instance, blocks may not even spatially cover the different habitat types across particular landscapes, owing to improper placement of the sampling units.

Waterhole counts

Waterhole counts, where surveyors remain stationary near water bodies counting all elephants that visit the area, reflect an inherent bias in its sampling approach. Many dry habitats across elephant ranges are today dotted with numerous human-made water sources, leading to enhanced congregations of elephants (Dzinotizei *et al*. 2019) and enhanced estimates of their densities. Moreover, waterhole counts are often practised in areas where natural water sources, such as streams, are aplenty and elephants do not necessarily frequent waterholes. In fact, elephants are known to preferentially use natural water bodies, such as streams or rivers, in dry forests (Pastorini *et al*. 2010; Lakshminarayanan *et al*. 2015) or dry streambeds to access subsoil moisture (Sukumar 1989). The failure to take these behavioural strategies into account while planning surveys thus leads to the appearance of systematic biases in waterhole counts.

Photo-based capture-mark-recapture surveys

Photographing elephants to build a database and assessing their population size through capture-recapture techniques have increasingly gained momentum in recent years (Goswami *et al*. 2007, 2019; de Silva *et al*. 2011). This method helps obtain robust estimates, provided there is adequate spatial coverage of the landscape and the various assumptions of the capture-recapture models are verified and accounted for. Considering the large-scale distribution of elephants in closed habitats across tropical Asia, however, the applicability of this method is restricted only to certain areas, where individual elephants can be conveniently photographed, within typically expansive elephant habitats.

Indirect counting methods

In the wake of difficulties encountered with direct sighting-based methods, indirect sign-based surveys have often been adopted to estimate elephant counts. The most widely used of these methods include dung count surveys, DNA-based capture-recapture techniques and camera-trap-based monitoring exercises.

Dung count surveys

Dung surveys are one of the most commonly adopted techniques across tropical Asia, typically in areas constrained by direct visibility of elephants and characterised by low-density populations. Dung-based density estimates rely primarily on three components: dung encounter rates, defecation rates and dung decay rates. Dung encounter rates are primarily determined by dung deposition rates and the disintegration of dung piles. A range of abiotic and biotic factors, such as temperature, rainfall, humidity, shade, animal activity and various anthropogenic disturbances influence dung encounter rates (Dawson 1993; Barnes 2001; Nchanji & Plumptre 2001; Breuer & Hockemba 2007; Pastorini *et al*. 2007; Baskaran *et al*. 2013). Single-site estimations of dung decay rates, used in population estimations, can affect density estimates (Nchanji & Plumptre 2001), warranting site-specific assessments. Additionally, the standardisation of the method by using defecation rates of captive elephants rather than from those in the field could influence the final estimates. Similarly, dung production, defecation rates and dung decay characteristics in a particular landscape are all strongly dependent on seasonality, type of diet, representative age classes of the elephants, their overall health as well as on certain abiotic factors, such as water availability in the area (Nchanji *et al*. 2008). Theuerkauf & Gula (2010) discuss how seasonality and rainfall can be accounted for by extensive sampling in the dry season, although there could well be seasonal influences on the use of certain habitats by elephants.

DNA-based capture-recapture surveys

DNA-based estimations of elephant population characteristics involve dung sample collection and individual identification in a capture-recapture framework (Hedges *et al*. 2013; Chakraborty *et al*. 2014; Gray *et al*. 2014). While this method usually generates reliable estimates once dedicated laboratories with skilled technicians are able to standardise the molecular techniques, it is largely applicable to small elephant populations and areas with low animal densities. It is usually difficult to implement over large areas with high elephant densities, primarily owing to the costs involved. The other constraints typically involve the logistics of collection, handling and storage of dung in the field, which would ensure the availability of non-degraded, uncontaminated faecal samples for sound laboratory analyses.

Camera-trap-based monitoring

Varma *et al*. (2006) discuss the use of camera traps for large-scale population monitoring of elephants. This method has also been used to understand crop-raiding patterns, demography of populations in human-use areas and social behaviour (Ranjeewa *et al*. 2015; Smit *et al*. 2019; Srinivasaiah *et al*. 2019). A critical aspect of camera-trap surveys is the right placement of the units to get usable pictures (Varma *et al*. 2006). This is evident from the large number of generally uninformative elephant images that are produced by camera traps that monitor other sympatric species across protected areas. The rather elaborate process involved in its execution, its labour-intensive nature and often the low-capture rates obtained, accompanied by the high costs involved, could limit the application of this method to relatively restricted areas and small elephant populations. Camera traps can, however, be useful in areas with extremely low animal densities and difficult terrains (Moolman *et al*. 2019).

Population monitoring: Size, structure or dynamics?

One of the primary objectives of elephant population estimation, routinely carried out across range countries, is to understand how the populations are responding to increasing anthropogenic pressures and to understand their changing ranging patterns (Nichols & Karanth 2012; Jathanna *et al*. 2015; MoEF & CC 2017). The loss of elephants to threats such as poaching for ivory or the recent increase in the demand for elephant skin in southeast Asia (Sampson *et al*. 2018) warrant regular monitoring. Poaching for ivory has also led to skewed sex ratios (Sukumar *et al*. 1998) and increase in numbers of tuskless males in certain populations (Sukumar 2003). Baskaran *et al*. (2013) have also reported a significant female bias amongst individuals in the older age classes in the Anamalai landscape of the Western Ghats, indicating a possibly targeted removal of males in the past, as has been described from other landscapes as well (Kumara *et al*. 2012).

In addition to population estimates, therefore, it may also be vital to evaluate the demographic responses of populations to various ecological pressures, as changes in certain demographic parameters allow for the prediction of population fluctuations, including the possibilities of local extinction (Caswell 2000; González *et al*. 2013). Although, globally, various studies have demonstrated the behavioural plasticity of different species populations (Hockings *et al*. 2015), including those of Asian elephants (Srinivasaiah *et al*. 2019), which may allow them to successfully adapt to current anthropogenic regimes, their long-term survival appears to be bleak. Demographic declines have already been documented in several taxa, ranging from insects (Habel *et al*. 2019; Janzen & Hallwachs 2019), amphibians and reptiles (Falaschi *et al*. 2019; Hill *et al*. 2019) to birds (Lee & Bond 2015; Haché *et al*. 2016) and large mammals (Hervieux *et al*. 2013; Hockings *et al*. 2015). Such declines, unfortunately, remain unknown for large-bodied species like Asian elephants, in which demographic changes can be further pronounced due to relatively longer life-history processes.

Abundance estimates: Is just counting elephants enough?

Issues with extrapolation

Population estimation exercises typically provide density estimates for the sampling areas alone and not exact numbers of elephants, which require further extrapolation. The landscape features and distribution patterns of elephants, however, confound such estimations (Baskaran *et al.* 2013). Issues of extrapolation thus constitute an important concern when population estimations are conducted. Similarly, a unified approach in estimating critically important population parameters is still to be arrived at, although synchronised surveys are regularly conducted across elephant range countries. The differences in spatial scales at which surveys are generally executed and the varying methodologies adopted thus often make comparative analyses difficult, as, for example, in the case of the Anamalai elephant populations, for which variable estimates have been obtained by different studies (Sukumar *et al.* 1998; Leimgruber *et al.* 2003; Baskaran *et al.* 2013). Elephant distributions at the landscape level often tend to be non-uniform, especially in large, contiguous, often heterogeneous landscapes, such as those in the Western Ghats, with elephants not using several of its mountainous slopes and human-populated valleys. These problems thus need to be addressed by conducting rigorous surveys that would first effectively establish the distribution patterns of the concerned elephant populations across their range.

Understanding fine-scale distribution patterns of elephants

Although one of the most studied of all mammalian species, our understanding of the fine-scale distribution patterns of Asian elephants still remains limited. The available information on elephant distribution patterns across Asian countries have predominantly been located within protected areas, largely ignoring groups or individuals outside parks (Baskaran *et al.* 2013; Fernando & Pastorini 2011). Several recent studies have, however, considered wide-ranging elephant groups or individuals that often use the matrix of human-dominated areas outside parks while mapping their distribution (Madhusudan *et al.* 2015; Fernando *et al.* in press). The human-dominated Valparai plateau, which forms part of the Anamalai Tiger Reserve in the Anamalai hills of southern India, for example, supports about 100-120 elephants annually (Kumar *et al.* 2010) but is typically ignored during the annual population estimation exercise in the reserve; about 5% of the resident elephant population of the region is thus never evaluated. Mapping such populations is nevertheless crucial, as the prevailing human-elephant conflict could significantly threaten the persistence of some of these unaccounted groups in the long term. Long-term monitoring and reliable mapping exercises could also reveal potential range expansion or reduction over time, as has been observed in certain populations in Sri Lanka (Fernando *et al.* in press).

Conclusions

Asian elephant populations are subject to a wide range of influences that threaten their very survival across their distribution range. These could be direct threats like poaching and conflict-related mortalities, or more indirect ones, such as certain management measures, including drives and captures. Indiscriminate drives, followed by the subsequent confinement of individuals in protected areas, leading to increased competition and eventual mortality of large numbers of elephants, as has happened in Sri Lanka, is an example of such persecution (Fernando 2015). In India, population control measures, including immunocontraception, are now being suggested to attempt the mitigation of rapidly rising negative interactions between elephants and humans across their shared habitats. These practices are reminiscent of those being implemented in African elephant populations that are now largely being maintained within private game reserves with their numbers managed through selective culling and immunocontraception (Pimm & van Aarde 2001).

Reliable countrywide estimates should be made available prior to consideration of such strategies.

There is also no conclusive evidence that increased instances of human-elephant conflict are related to an increase in elephant numbers. Increase in conflict instances is possibly more a reflection of changing distribution and ranging patterns of the species.

Given that certain management interventions have direct bearing on elephant populations, their long-term monitoring becomes crucially important, particularly to take informed decisions in conservation policies. Our own personal observations and a review of the existing literature indicate that there is no single method that can be reliably applied across landscapes while stand-alone survey techniques may not work as well, even at finer landscape levels. Madhusudan *et al*. (2015), on the other hand, ably demonstrate how data from various sources, ranging from systematic surveys to newspaper or other informal reports, can be used to successfully map elephant distributions over large regions. Camera-trap- or sign-based abundance estimates and distribution mapping could similarly be coupled with questionnaire surveys (Fernando et al. *in press*), especially outside protected areas. Different sources of information, therefore, collectively contribute to our knowledge of elephant populations across large swathes of particular landscapes.

With the rapid growth of serious public interest in the survival threats being faced by wildlife in many habitat countries, citizen-science initiatives need to be urgently harnessed to acquire functional information as well as formulate participatory conservation strategies for many threatened taxa and their populations (SoIB 2020). In the case of Asian elephants, such citizen-sourced information could aid the long-term tracking of individual elephants across local habitats and also contribute to the building up of behavioural databases on individual elephants that interact with human communities over the larger landscape.

We also strongly believe that setting up of long-term scientific monitoring stations/groups in critical and important areas across elephant ranges may help better understand the structure and dynamics of local populations in the long term. Finally, informal observation networks can cumulatively produce meaningful group-level data that can be used to understand the structure and dynamics of elephant populations across entire landscapes (Araujo *et al*. 2017).

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Wild Asian Elephant Twins in Sri Lanka

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Introduction

We report on the sighting of twin calves born to a wild Asian elephant (*Elephas maximus*) in Sri Lanka (Fig. 1). We failed to find any previous published reports of twinning in free-ranging Asian elephants, hence assume this to be the first such communication.

The twins were identified in the Minneriya National Park, which is famous as the site of the 'elephant gathering'. The central feature of the Minneriya National Park is a large artificial lake, which dates back more than a thousand years, having been built in the time of the ancient kings of Sri Lanka. The lake was created for irrigated paddy cultivation and continues to be used for the purpose. It fills up during the northeast monsoon from October to January. Annually, when the water is let out for paddy cultivation in the dry season that falls from May to September, the exposed lakebed turns into a lush grassland. Hundreds of elephants gather there to feast on the fresh grass during this period and aggregations of up to a 100 elephants maybe commonly observed, with over 300 elephants sighted in a single 'safari' at times. Minneriya is part of a large protected area system that allows free movement of elephants and includes the Kaudulla and Anganmadilla National Parks (also with large reservoirs), Giritale Sanctuary, Hurulu Eco-Park and Forest Reserve and Gal Oya Forest Reserve.

The Minneriya twins

When the gathering commenced this year, two newborn babies suckling together on either side of the same female were observed by SP. The twins were first seen on 3rd July 2020. As the park was closed for over three months from mid March to 1st July 2020 due to covid-19 safety measures, the exact time of birth is not known. We estimate the twins to be born some time in June 2020. As one is a female and the other a male, they are non-identical or fraternal twins, which means they originate from two eggs (dizygotic). Therefore genetically they are the same as full siblings and on average would share 50% of their genes, but as twins they had the same gestational experience.

Sometimes elephant babies are known to suckle from other females in the herd, a phenomenon referred to as 'allomothering' (Lee 1987). However, during continuous observations for 4 h on 6th July and another 2 h on 12th July 2020, the two calves suckled exclusively from a single female and followed her very closely everywhere (Fig. 2). The behaviour and the similarity in size of the babies make it almost certain that they are twins.

The elephants in Minneriya and the adjacent protected areas are being studied through the Cinnamon Elephant Project. The project

Figure 1. Female 'Bernadine' with her twins at Minneriya National Park, Sri Lanka.

individually identifies and catalogues the elephants that are observed. Currently over 400 elephants have received ID cards and the numbers do not show any sign of levelling off yet. The mother of the twins is a female known as Bernadine. She is also accompanied by her previous offspring Bubba, who is now about four years old. The twins have been named Bhathiya and Bhagya by the Wildlife Department. Big brother Bubba does not seem to be too interested in the twins but their cousin Bonnie, who is a female about six years old, is very concerned about them and is always with them.

Twinning in elephants

Twin births are rare among elephants. In wild African elephant populations, the frequency of twin births was observed to be 0.07% at Amboseli (Moss *et al*. 2018) and 2.46% in Tarangire National Park (Foley 2002). At Amboseli only 2 sets of twins (both opposite sex) were recorded out of 2687 births (Moss *et al*. 2018). At Tarangire National Park 7 sets of twins were born in 284 pregnancies (Foley 2002). Five of them were male-female and the other two were twin females. Notably one female gave birth to twins three times in a row and another female in the same herd also had twins (Foley 2002). This may indicate a genetic propensity for twinning in particular females and also explains the high twinning rate at Tarangire National Park with 4 of the 7 sets of twins being born in just one herd.

The only previously published records of twin births in Asian elephants appear to have been of those in captivity. In European zoos 5 of 551 (0.91%) Asian elephant births were twins and none of the 10 calves survived the birth (EEG 2020). The studbook of Myanmar's timber elephants, reaching back to 1875, lists 3053 births, 17 (0.56%) of which were twins (Mar 2002). The Forest Department of Tamil Nadu (India) recorded 3 twin births in 258 pregnancies (1.16%) in its elephant camps (Sukumar *et al*. 1997).

Figure 2. Both twins suckling.

In 1920 twins were born in an elephant camp in Myanmar (Hundley 1920). The male and female survived and became working elephants (Stockley 1926; Hundley 1927). Yin (1962) reports on a twin birth in Myanmar in 1961. The male and female calves were born 3.5 h apart.

In 1971 male twins were born in an elephant camp in Theppakadu, Tamil Nadu, India. Interestingly the mother first kicked the second calf, born only 15 min after the first. But the caretakers intervened and finally she accepted both calves (Davidar 1971). Female twins were born at an elephant-camp in Orang National Park, Assam in 2010 (Jayawardene 2010). The birth took place in the night when the mother was foraging in the forest.

Nepal recorded its first twin birth in 2008 at the Breeding Center in Chitwan National Park (Thapa 2009). The two males were born 4 h apart during the night. Their father was a wild bull called 'Romeo' who used to visit the camp at night.

In Thailand two sets of same sex twins were born in captivity in 2010 consisting of two females in the Chiang Mai Province and two males in the Surin Province (Jayawardene 2010).

There is also a record of a birth of male triplets in 1913. However, one calf was stillborn and the other two survived less than two weeks, mainly because the mother did not accept them (Macfie 1916).

Elephants have a gestation period of 22 months, the longest of any animal. Therefore carrying two foetuses to full-term is a challenge. Consequently twins are often stillborn or born prematurely. This may be one reason why twin births in the wild have not been previously reported in Asian elephants. If one or both die at birth due to complications, or the mother rejects one, it is unlikely to be known. Additionally, Asian elephants mostly live in low visibility forests and actively avoid humans and it would be very hard to identify twins in brief encounters of elephant herds. The situation in Minneriya is exceptional as elephants spend long periods of time out in the open grassland and are habituated to tourists, which facilitates their observation.

Outlook

Bernadine has come through the first hurdle of birthing live twins. Feeding two calves is her next challenge, as elephant babies are mostly dependent on the mother's milk for the first two years. Since Bernadine is a young female in good health, and the large protected area system under the Wildlife and Forest Departments provides good fodder year round, there is hope that the twins will survive this critical period and make it to adulthood.

Sri Lanka is arguably the best place in the world to see wild Asian elephants, as it is the country with the highest elephant density (Fernando & Pastorini 2011). With this record of twins in the wild, Sri Lanka chalks up another elephantine first, adding to the only 'dwarf elephant' (Wijesinha *et al*. 2013) and the only known free ranging 'white elephant' in the world, both of whom call Sri Lanka their home.

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Report on the Workshop Open House Elephant Reintroduction project Thailand

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Background

Since 1957, the number of wild and domestic Asian elephants (*Elephas maximus*) in Thailand has dramatically declined from about 100,000 to 5,000. This situation has raised awareness of the plight of elephants in Thailand, among the general public and non-governmental organizations. As a result a reintroduction program to preserve and increase elephant numbers in the wild was initiated.

The program was started in January 1997 when the HRH Queen Sirikit of Thailand released three female elephants to the Doi Phamuang Wildlife Sanctuary. To date (2020), 108 elephants have been released into 3 protected areas, the Sublungka Wildlife Sanctuary (Lopburi Province, central Thailand), Doi Phamuang Wildlife Sanctuary (Lampang-Lamphun Province, northern Thailand) and Phu Phan National Park (Sakon Nakorn Province, northeastern Thailand) (Angkawanish & Thitaram 2012; Thitaram *et al*. 2018). Thirty-six calves have been produced through natural mating by released bulls. The aim of the project was to restore and conserve the natural habitat through the released elephants, as well as to create self-sustaining wild elephant populations in the protected areas.

Releasing captive elephants back to the wild has been suggested in Lao PDR (Sims K & Pinto C 2019; Elephant Conservation Center 2020) and Myanmar (Hedges *et al*. 2018).

Workshop

Having more than 20 years of experience in releasing captive elephants back to the wild, the Elephant Reintroduction Foundation, in cooperation with the Department of National Park, Plant and Wildlife Conservation, the IUCN-SSC Asian Elephant Specialist Group, the IUCN-SSC Conservation Translocation Specialist Group, the Faculty of Veterinary Medicine, Chiang Mai University and the National Elephant Institute, conducted the Workshop on Open House Elephant Reintroduction Project Thailand. It was held from 5th–7th February 2020 at the Miracle Grand Hotel in Bangkok (Fig. 1) and in the Sublanka Wildlife Sanctuary, Lopburi, Thailand. The objectives of this workshop were to share and exchange the knowledge of elephant reintroduction, as well as evaluate and improve elephant reintroduction methods. There were 70 participants from 8 countries, representing various organizations and roles (scientists, veterinarians, governmental and non-governmental staff, elephant camp owners etc.), attending the workshop.

Figure 1. The speakers and the Elephant Reintroduction Foundation committee.

The program comprised of lectures on Asian elephant conservation status, animal reintroduction, behavioural consideration in elephant reintroduction, releasing both orphaned wild elephants and captive elephants back to the wild in India, Sri Lanka and Thailand, as well as re-wilding programs in Laos, Myanmar and Sabah, Malaysia.

On the 2nd day, a field visit was conducted to search for released elephants at the Sublanka Wildlife Sanctuary (Fig. 2). After a briefing on the geography of the sanctuary, the participants travelled by truck to the forest and trekked to find the elephants. After 3 hours of searching, two adult females with their two wild born female calves were found. Their behaviour was different to that prior to release as they were not tame like captive elephants but avoided humans. However, aggression towards people was not as much as by wild elephants, and the mahouts were able to get close to them.

Discussions were held on the demography, rehabilitation, the releasing process, consequences of release, and the future of these elephants on day 3 of the workshop. Opinions were expressed from both wild and captive elephant perspectives. The necessity of rehabilitating and releasing captive elephants to the wild was the first issue debated, as it depends on the area available for release and situations in each country. Several issues such as the number of captive and wild elephants, health and behaviour of elephants, ecology, attitudes of people, possible human-elephant conflict, budget, and socio-economics were identified as important. The methods of reintroduction included planning and management of recipient areas, recruitment and rehabilitation of elephants, suitable age and number of elephants and monitoring of released elephants. In the long term, planning of management, regulation of the activity, assessing the ecology of released elephants, social engagement and communication were identified as being important.

Figure 2. Visit to Sublanka Wildlife Sanctuary.

The participants got knowledge that elephants raised under human care could survive in the wild. Both Thai and international participants shared their knowledge and experiences with the participants who may consider undertaking similar work in their own countries.

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Report of the Seventh Elephant Conservation Group Workshop

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Background

As Gajah's readers know too well, Asian elephants (*Elephas maximus*) are endangered, and taking effective actions for their conservation is difficult, very difficult. The human-elephant conflict (HEC), Asian elephants' main threat, is a wicked problem; this is, a problem difficult or impossible to solve because of incomplete, contradictory, and changing requirements that are often difficult to recognize (https://en.wikipedia.org/wiki/Wicked_problem).

Despite considerable efforts being made across the species range, the progresses in mitigating the negative effects of HEC on people and elephants are, at best, modest. In this context, knowledge exchange among stakeholders, particularly among conservationists working on the same issues in different geographical, ecological, and sociopolitical contexts, can help improve our capacity to address the wicked issues of Asian elephant conservation and HEC mitigation. Here we report on the 7th meeting of the Elephant Conservation Group (ECG) that took place in Kota Kinabalu, Sabah, Malaysian Borneo, on 1.–3. December 2019.

ECG is an informal network of Asian elephant conservation researchers and practitioners that began operating in 2011 with the main objective of generating peer-to-peer knowledge exchange about Asian elephant conservation issues in different countries, landscapes, and socio-ecological contexts (https://elephantconservationgroup.wordpress.com). ECG members gather regularly (every 1–2 years, generally in a range country) and spend 3–4 days discussing different aspects of our work, concerns, and things we would like to learn from each other. ECG's meetings are run on a budget — generally renting a big house in which we stay in shared rooms and conduct presentations and discussions in the living room. The essence of ECG meetings is the quality of the discussions, the openness and comfort of the exchanges, and the opportunity to develop personal relationships among members.

ECG had already met six times since 2011. This 7th meeting in 2019 was attended by 19 people, representing 12 organizations from 9 range countries. The participants included representatives from Cambodia (FFI), China (ZSL-China), India (NCF), Indonesia (Indonesia

Elephant Conservation Association), Malaysia (MEME, Seratu Aatai, WWF-Malaysia), Myanmar (WWF-Myanmar), Nepal (IUCN-Nepal), Sri Lanka (CCR), Thailand, UK (Elephant Family) and the USA (WWF-US). Some individuals and organizations have attended all seven meetings, while for a few this was their first ECG meeting.

Below we present a very succinct summary of the activities and discussion topics, as well as three consensus statements that were agreed upon on the course of the discussions.

Group reports

The first half of the meeting was allocated to group reports in which each organization delivered a short presentation describing progress and new ideas since the previous meeting in April 2018.

Among this session's highlights, Prithiviraj Fernando (CCR) presented on the controversy around wild elephant feeding by the public in Sri Lanka. While some people consider this situation problematic for elephant conservation, he argued that elephant feeding can be managed in a positive way for both wild elephants and people.

Paing Soe, from WWF-Myanmar, reported on the recent skin-related poaching crisis in Myanmar and how WWF's conservation initiatives seem to have been effective at curbing elephant killing in recent months and years.

Ananda Kumar, from India's NCF shared the perception that, in the landscape where they work (Hassan), for each problem elephant removed (e.g. killed or translocated) more problem elephants seem to appear. Whether this is actually

happening, and the underlying mechanisms, definitely merit further investigation. He also shared an anecdote about a massive bull walking tamely among people without seemingly posing any threat to people. Why would this big male behave in such a docile way while other individuals are so aggressive? Similar cases of extremely tame elephants have been reported from the Lower Kinabatangan, in Sabah. On the other hand, Becky Shu Chen from ZSL-China showed us a movie of very aggressive elephants, walking through villages chasing people they encounter.

Sreedhar Vijayakrishnan, also from NCF, reported how in their long-term elephant monitoring in Valparai, they have recorded home range shifts in some family groups, confirming that such shifts do occur in Asia.

Nurzhafarina Othman, from Sabah's Seratu Aatai, presented a booklet on elephant behaviour that her team has developed, especially to promote safety among villagers and plantation staff in HEC-affected areas.

Thematic discussions

We allocated the second half of the meeting to discussion sessions whereby we addressed topics previously proposed by ECG members. The discussion topics included: (1) the role of habitat enrichment on HEC mitigation, (2) can HEC mitigation lead to more habitat encroachment by people?, (3) palm oil plantations and their attitude towards elephants, (4) effect of infrastructure on elephant habitat connectivity, (5) how to use behavioural science for elephant conservation, and (6) decision-making in elephant translocation.

Consensus statements

In this ECG meeting, we tried for the first time to produce consensus statements on some of the issues discussed. Due to the complexity of the topics, we did not attempt to reach consensus on all topics. On the topic of habitat enrichment, we reached the following two consensuses:

1. **Habitat enrichment can be used to concentrate Asian elephant presence or certain activities and behaviours in specific areas**. For example, if we want to attract elephants to a road underpass, we can use preferred food plants to attract them there.

2. **There is no evidence on whether habitat enrichment can reduce HEC**. Although habitat enrichment is frequently considered as one of the options to mitigate HEC throughout Asia, we think there is no evidence of such an approach being used effectively at the moment. We agreed that it is appropriate to test its effectiveness as long as it is properly monitored and we can learn from the experience.

Furthermore, we did not reach a clear consensus on whether habitat enrichment can be used to increase elephant populations. In any case, we agreed that manipulating natural vegetation (e.g. tropical forests) is complicated and can lead to unexpected and undesired negative consequences.

We also discussed about 'what we talk about when we talk about HEC mitigation', and reached the following consensus:

3. **Traditional HEC mitigation strategies throughout Asia have focused on reducing costs for people, not elephants**. This is important because the general perception is often the opposite. It is not unusual to hear arguments such as 'the government care more about elephants than about people'. We are noticing, however, a shift in paradigm with new approaches focusing on human-elephant coexistence. Human-elephant coexistence approaches really consider some benefits for elephants. Despite the ongoing change, there are still few human-elephant coexistence success stories to bank on.

Final remarks

Peer-to-peer exchanges such as those at the ECG meetings are an important resource for conservation researchers and practitioners. These slow, deep, informal, and open discussions are very different to what happens in formal learning environments and academic events, such as courses and conferences. These discussions allow participants to learn from colleagues with generally similar but slightly different experiences and even to co-produce knowledge by the common interpretation of information.

We encourage more of these initiatives to take place, including forming informal groups within countries and regional blocs. We also encourage ECG members to continue finding the time and resources for future meetings and perhaps exploring further the potential of consensus statements to move forward in our understanding of what drives HEC and the potential mechanisms to promote human-elephant coexistence in Asian landscapes.

Guidelines for the Rehabilitation of Captive Elephants as a Possible Restocking Option for Wild Populations

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Context and scope of the guidelines

Asian elephant (*Elephas maximus*) populations have declined across the 13 elephant range countries due to habitat loss and degradation, poaching and human-elephant conflict. Several wildlife management authorities plan to rehabilitate the captive Asian elephants and return them to the wild in order to revive depleted or extirpated populations. This is no simple task. Here we provide an overview of guidelines compiled based on the experience of practitioners and members of the Asian Elephant Specialist Group as a resource for such programs. We first provide a rationale and brief history of elephant reintroduction programs, followed by more specific guidance in sections as summarized below. The full document can be found on the website of the Asian Elephant Specialist Group.

Why (re)introduce Asian elephants?

There are several categorically distinct reasons for wanting to introduce or reintroduce Asian elephants into the wild from captivity, depending on whether one takes the perspective of the elephants, the people, or the landscape. This section considers each of these viewpoints briefly in presenting the rationale for initiating a rehabilitation and reintroduction program.

Which elephants should be considered and who should apply these guidelines?

There are at least two types of source populations that one may consider. One consists of those that have already spent a substantial fraction of their adult lives among people. The other consists of juveniles that may have been injured or orphaned and re-habilitated with the explicit aim of eventual re-introduction. These two types merit separate evaluation. More realistic are animals that are semi-wild, that have experience in foraging, such as those that may have been employed at timber camps. We discuss which types of individuals are appropriate candidates for release. Moreover we highlight the range of expertise that will be required in planning such a program.

Planning stage – primary considerations

The conservation aim of restoring elephant populations needs to be backed by political will and commitment. Important considerations at the outset are broken down as follows, with each discussed in greater detail in the full document:

· Defining the overall objectives of the proposed rehabilitation of captive elephants in the wild - Before the project starts, the overall objectives of this project should be discussed, identified and planned by all stakeholders for the advantages and disadvantages, prospective gains or losses. It requires a long-term commitment with high investment together with understanding that the local villagers will experience long-term impacts from having elephants around.

· General feasibility and assessment - Many issues need to be considered before starting the project. These include justification of the proposed rehabilitation and translocation, overall objectives, impact of moving the elephants, number of elephants, sex and age groups, government agencies, stakeholders and local communities involved, appropriate rehabilitation and rewilding methods, appropriate relocation approach and timing suitable release sites, logistical coordination and planning mechanisms, socio-economic study of the local communities, mitigation and management of Human-Elephant Conflict (HEC), commitment of long-term financial and political support, and the economic values besides conservation.

· Budgeting - Long term support from both governmental and non-governmental organizations, as reintroduction projects require a lot of funding and resources, especially for a species that is as large, long-lived and behaviourally complex as an elephant.

· Identification of recipient area(s) for Asian elephants - Ecological as well as human dimensions to consider in site selection. The recipient areas should have plenty and variety of elephant food and water across the year, particularly the dry season. Ideally natural areas that once contained wild elephants would be preferable as the required food sources can be expected to be available, and should not ever have human-elephant conflict.

· Identifying source animals - Age, sex, and history of potential candidates to be considered for reintroduction programs. The ideal elephants are from the logging or those raised in natural habitat, who have spent time in the forest.

· Logistical coordination and planning - Programs may have at least four types of key personnel: the elephant team, site preparation team, legal team, and community engagement team. The planning of elephant translocation, quarantine, rehabilitation and reintroduction will require input from each team and execution will require good coordination and communication among them.

· Personnel capacity and experience (including building local capacity) - The expertise of individuals with varied backgrounds will be helpful. This includes ecologists, behaviourists (ethologists), veterinarians, educators, researchers, fundraisers, mahouts, rangers, coordinators from both government and non-governmental organizations. The involvement of government law enforcement, police, or in some cases, military may also be required, as well as representatives of the local community engagement.

· Demographic, genetic and behavioural considerations - Differing needs based on age/sex class and the context for which the reintroduction is being designed. Asian elephants exhibit very dynamic fission-fusion social organization with complication to identify clear dominance hierarchies. Thus, this should be concerned with closed monitoring for social behaviour and demography.

· Veterinary considerations - Release of the captive animals into the wild may result in introduction of disease to conspecific or unrelated species. The planning process is very important in order to prevent disease transmission, and let the animal adapt to the climate and environment.

· Security considerations - Aspects concerning both the safety of the elephants and the people within the landscapes that populations will be situated within or adjacent to.

· Legal considerations - There will likely be country-specific legal frameworks, and possibly loopholes within such frameworks, that must be accounted for.

Rehabilitation period

The actual rehabilitation period can range from months to years, and will likely involve the bulk of the expense. There are three main sections that extensively detail the various needs to prepare for and address during this crucial period:

· Socialization - As elephants are highly social animals, it is absolutely critical to provide opportunities for the development of social relationships in a careful manner that is age- and sex-appropriate and ensures the safety and well-being of individuals both while in rehabilitation, as well as upon release. This section covers the many diverse aspects of social interaction to be addressed.

· Food and foraging - When releasing the captive elephants back to the wild, their ability to find food and water resources will be crucial for their survival. They should be released in a group with other foraging-experienced elephants, or be trained for foraging, before bringing them to the project, and during the rehabilitation period.

· Health progress - One of the most important indicators that elephants can adapt themselves during the rehabilitation process is their health. Body condition score and dung composition are the most convenient health indicators, and should be regularly monitored.

Post-release period

Post-release monitoring is as crucial as the previous two phases, and no program can be considered complete or deemed a success without it. The main goal is to be able to answer the question: which factors have a positive or negative influence on reintroduction success? The monitoring itself is broken down into phases:

· Intensive monitoring period (1-5 years) - This period should ideally include

Group of released elephants with calves born from natural mating in the forest at Sub Lanka Wildlife Sanctuary, Thailand.

medical/physical, behavioural, and movement observations. This section details the types of monitoring that programs should strive for in order to be able to evaluate whether animals are properly assimilating to their new surroundings and any potential problems, risks, hazards etc. that might not have been foreseen. If there are wild elephants in the vicinity, it may be as important to include a component studying them as well, and their responses to released individuals, in order to have some basis for determining whether the latter are faring comparatively well or poorly.

· Long-term basic monitoring (2 or more years) - Depending on the available budget and feasibility, intensive monitoring may need to transition to more basic longer-term monitoring at some point within the first five years. This section covers the types of data that are only obtainable through longer-term observations, such as demographic events.

In both of these components, the need for preparatory and ongoing communication with local communities is emphasized, especially where specialized education programs may be needed.

Lessons learned

Things often do not go as planned. Some of the issues that arise may be wholly unpredictable, but others may benefit from past experience. This final section summarizes experiences collected from various existing initiatives, broken up according to the preceding sections of the guidelines. It is hoped that these aggregated observations will be useful for anticipating what might happen at any stage, to the extent possible.

Community awareness

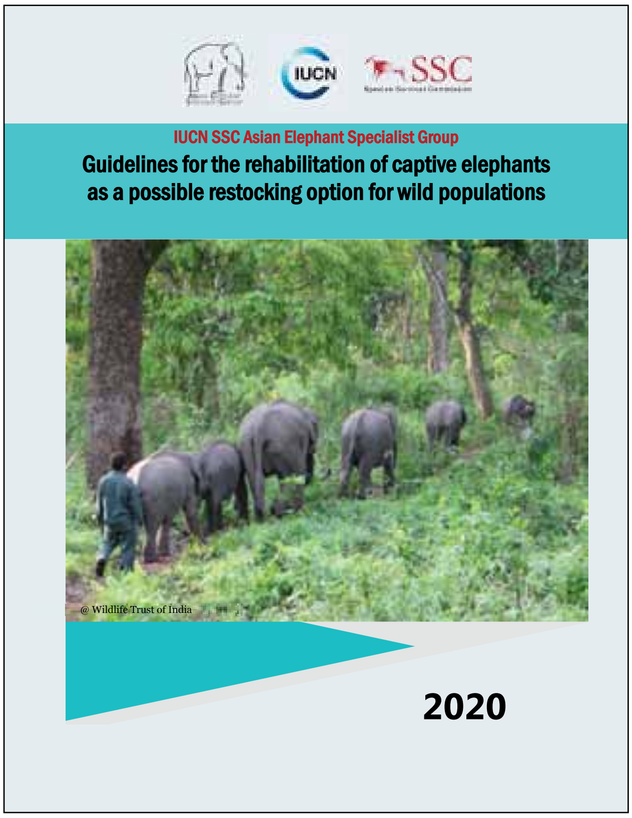
The absence of good communication and community awareness programs, can foster a lot of misunderstanding, anger and resentment toward reintroduction programs among local people. This is especially true in areas where wild elephants may already be perceived as a risk to life, property, and livelihoods. Released animals may consequently be killed, either intentionally or unintentionally, constituting not only a tragedy but a tremendous waste of resources. The burden is on the re-introduction program to work with people to ensure transparency from start to finish, even if this involves facing opposition or difficult situations.

Over-habituation

Certain individuals from early cohorts of animals that were over-habituated sought out human company to the extent that they tried to find their way back to the care facility or became a nuisance to visitors of protected areas in which they were released. It is therefore crucial to avoid over-habituation.

Social support

If the calves are released in a mixed sex group, male calves will wander large distances and may be more likely to encounter difficulties. It is suggested to release calves at the same sex cohort. Elephant calves need socialization while undergoing rehabilitation to prevent these problems.



Maternal drive

Captive-reared subadult females that are overzealous alloparents can separate offspring from other mothers while being unable to supply milk themselves, and may cause the calves to starve. Conversely, these captive-born mothers might ignore, attack or kill their own wild born calves for possibly due to lack of role models or practiced maternal experience.

Integration to the habitat and wild elephants

Some released calves may be easily accepted by the adults, and integrated to the wild herd. However, elephant-elephant conflict (male-male, female-female, male-female) can occur, and result in deaths of elephants.

Conclusion

When the elephants are released in that particular area, the goal is to ensure persistence for a long-term by integrating with existing wild populations or possibly seeding new populations. The rehabilitation of captive-born or orphaned wild elephants in human care for release back to the wild is a long and complicated process with many issues to consider. This includes not only thinking about the budget and co-operation from various organizations and stakeholders, but about what the elephants themselves truly need to be successful. All three stages - planning, rehabilitation, and post-release monitoring - are equally important. We hope this summary of guidelines helps to understand the various considerations for such program.

Citation

The full document can be found on the website of the Asian Elephant Specialist Group at <https://www.asesg.org/resources.php>.

Thitaram C, de Silva S, Soorae P, Daim S & Pérez ABL (2020) *Guidelines for the Rehabilitation of Captive Elephants as a Possible Restocking Option for Wild Populations*. IUCN SSC Asian Elephant Specialist Group.

Management and Care of Captive Asian Elephant Bulls in Musth

Janine L. Brown*, Ravi Corea, Ashoka Dangolla, E. K. Easwaran, Susan Mikota, Zaw Min Oo, Kushal Sarma and Chatchote Thitaram

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Introduction

Of all the challenges facing captive elephant owners/managers in Asia today, none may be greater than those related to how to properly care for musth bulls. Musth is the physical and behavioural manifestation of physiological changes that include temporal swelling, temporal gland secretion (TGS), urine dribbling, and elevated testosterone (see review, Brown 2014). Behavioural changes include increased aggression and reduced obedience, making them more difficult to control. There are legitimate concerns about poor welfare of musth bulls (see Fig. 1). Restraint by short tethers, social isolation, and lack of access to fresh food and clean water exacerbate frustration and aggressive behaviours. Repetitive behaviours, such as rocking and swaying, often develop in elephants under such restricted containment.

Thus, a set of guidelines has been created by the Asian Elephant Specialist Group (AsESG) to help facilities with Asian elephants ensure proper management that meets elephant welfare needs while protecting people. This paper provides an overview of the biology of musth in Asian elephants and factors affecting musth status, and summarizes the guidelines put forth by the AsESG.

Signs of musth

The intensity and duration of musth, and associated aggression, can vary considerably among bulls (e.g. Lincoln & Ratnasooriya 1996; Brown 2014). While some bulls are manageable during musth, others are not. So, it is important to recognize the signs of musth, which can be broken down into definable stages:

Pre musth

The temporal glands begin to swell, appetite is reduced, and the bull may display frequent penile erections and masturbation. Testosterone concentrations are slightly elevated over baseline. Behavioural changes can include occasional defiance to mahout commands. They may seek out females, sniff the urogenital area, and display flehmen. They may also check the genitals of other bulls to exert dominance.

Early musth

Characterized by more TGS, which becomes odorous as the period progresses. Behaviour becomes increasingly aggressive and erratic, and a bull may become unresponsive to commands.

Full musth

Temporal glands secrete a thick tar-like fluid, and urine dribbling is continuous. Androgen concentrations increase significantly (10–20 times baseline) and many, though not all, males become more disobedient, unpredictable and highly aggressive. A bull in musth will exercise dominance over other adult males, and some may become overly aggressive with females.

Post musth

Presence and staining of dried TGS on the face and urine on the rear legs is still evident. The bull may be in poorer condition due to reduced feed intake (human or self-induced). Physical and behavioural activity generally return to baseline; however, many bulls are still very dangerous in the 2 weeks after musth signs disappear, when testosterone is declining.

Factors associated with musth

Age

In the wild, musth occurs in sexually mature bulls, generally those over 25 years of age. However, in elephants under human care, it can occur in those as young as 7 years old.

Season

Bulls generally exhibit musth annually, and often at the same time each year making it possible to predict time of onset in many bulls. In Asian range countries, musth generally occurs between October and February and lasts for 1-2 months. However, some bulls exhibit musth more than once a year with highly variable and unpredictable patterns.

Diet and body condition

Consumption of highly nutritious or caloric foods (e.g. grains, bananas, sugar cane) and maintaining a high body condition can prolong or intensify musth.

Activity

Bulls are more prone to entering musth if they have a sedentary life style, are not engaged in daily physical activities, or are offered rest after a strenuous work period (e.g. logging season).

Social conditions

Musth can be moderated by social dominance status. In younger bulls, it can be suppressed by older, more socially dominant bulls. Groups of bulls may show asynchronous musth periods, with dominant males coming into musth first. It can also be triggered by oestrous females.

General guidelines

The management of musth bulls in Asia has remained largely unchanged for centuries. Traditional methods often involve tethering to trees or posts with short ropes or chains, or hobbles, and often in areas with little shade or water, and are considered inhumane. Restriction of water during musth is dangerous because of increased fluid loss due to urine dribbling and TGS, which can result in kidney damage. Food intake is sometimes restricted based on the assumption that this will terminate musth sooner. Aggressive bulls may be difficult to approach, which can result in a lack of hygiene on its keeping ground, leading to health problems such as foot rot and high parasitic infestation. Managers of musth bulls must be willing to invest in resources and facilities to ensure the safety and welfare needs of both animals and humans. The following are recommended guidelines for proper musth bull management, although actual practices should be take individual elephant temperament into consideration.

1. Identify all prospective musth candidates and keep a written record of all musth activity (e.g. use a musth log) to predict future musth episodes. Musth records should

Figure1. Examples of inadequate management of musth bulls indicating lack of shade and/or short chains. Photos courtesy of Sri Lanka Wildlife Conservation Society.

include: age of first musth if known, dates of musth, duration of musth, intensity of musth signs, severity of aggression, injuries to staff or other elephants, and if mitigating actions were taken (drugs, isolation, etc.). Records should be computerized and transferred when a bull changes ownership.

2. Mahouts should receive adequate training in elephant handling, including using positive training/handling techniques. A chief mahout should be appointed who can ensure that all mahouts at a facility follow proper guidelines.
3. Facilities should have an isolated area where musth bulls can be safely maintained. Ideal options for musth bull containment are:
   a. Long chain in a forested area with water, natural forage, and shade (recommended, 20–30 m chains).
   b. Electrified paddock (recommended 12 x 12 m).
   c. Steel enclosure with natural substrate (recommended 12 x 12 m).

d. Large paddock with access to water and shade, with opportunities to socialize with other elephants if possible.

4. During the daytime, the living area should have shade, either by forest canopy or a well-constructed roof.
5. Elephant resting areas (day and night) should be cleaned of faeces and urine daily faeces should be stored/disposed of away from the elephant (composting of faeces is recommended).
6. As the bull enters musth, provisioning of concentrated rations and high calorie foods (e.g., grains, bananas, sugar cane, etc.) should be limited; instead feed primarily fodder (e.g., napier grass, cornstalks, etc.), with access to drinking water. Bulls should not be over-conditioned, and fed to maintain a body condition score of 2.5–3 (1–5 scale) or 5 (1–11 scale). Withholding food and water to lower body condition as a means of reducing musth symptoms should not be allowed.
7. Bulls should have an annual veterinary exam.
8. Facilities should have an on-site veterinarian or an agreement with nearby veterinarians or elephant hospital for medical or emergency services.
9. For public venues, there must be signs in at least two languages (local + English) to warn staff and visitors about the musth-reserved area.
10. Facilities should have a written emergency/aggression management plan and equipment (e.g. gun, blow pipe) for uncon-trollable musth bulls, following a protocol whereby the least amount of force is used and equipment (chains, ankus) is not misused.

Mitigation of musth

Drugs and other pharmaceuticals can diminish musth symptoms and control aggressive behaviour for variable lengths of time. These affect neural function or act on the hypothalamo-pituitary-gonadal (HPG) axis to reduce androgen production and potentially ease a bull out of musth, thus making it more manageable. Sedatives may calm bulls, while other drugs have been shown to suppress the HPG axis or block testosterone action (e.g., anti-androgens, GnRH analogs, GnRH vaccines). However, reduced testosterone concentration or function does not guarantee alleviation of aggressive behaviours, or that a bull is safe to work with.

It is important to note that musth is a natural phenomenon in adult bulls and chemically suppressing it is not normal. It also is vital that musth-suppressing treatments only be used when the welfare of the bull or human safety is in question, and not for routine control of aggression. Chemical treatment should never replace good management. Many of these drugs have not been fully tested in elephants. It also is not known what the long-term consequences of these treatments are. Finally, because behaviour can be unpredictable, precautions for handling musth bulls should be followed even if they are being treated and show reductions in testosterone.

Short-term treatments to diminish musth symptoms

a. Sedatives
   i. Xylazine
b. Antipsychotics/anti-anxiety

    i. Haloperidol (antipsychotic, may reduce agitation)
    ii. Diazepam (benzodiazepine, anti-anxiety)
    iii. Trilafon (dose and efficacy undetermined)
    iv. Zuclopenthixol (dose and efficacy undetermined)
c. Antiandrogens
    i. Flutamide
    ii. Cyproterone acetate
d. GnRH analogs
    i. Detirelix (GnRH antagonist)
    ii. Degarelix acetate (GnRH antagonist, Gonax®)
    iii. Leuprolide acetate (GnRH agonist, Lupron®)
e. Steroids
    i. Synthetic progestagens [e.g., medroxyprogesterone acetate (i.e., Depo-Provera)]

Long-term methods to prevent or suppress musth

GnRH vaccines (e.g., Improvac®, Improvest®) have shown promise in controlling reproductive and sex-related behaviours that are testosterone driven, including in elephants (Pushpakumara *et al*. 2018). GnRH vaccination 1-2 months prior to the predicted musth period has been shown to shorten the musth period or result in a complete cessation for that year. However, not all bulls respond to vaccination with a reduction in musth symptoms even when testosterone is reduced. It is also important to note that long-term treatment with GnRH vaccines may result in permanent immune-castration and sub- or infertility.

Conclusion

Balancing human and animal safety, and animal welfare needs is undeniably one of the greatest challenges facing handlers of elephant bulls in musth. More creative thinking is needed to explore more humane and enriching management practices. Use of long chaining in the forest with access to food and water, or a secure paddock with enrichment (e.g. pool, mud, dust, scratching post) and shelter should replace traditional methods involving short chains and hobbles (e.g. Santiapillai *et al*. 2011). Positive training methods should be part of this daily management, beginning when bulls are young. Integrating bulls into herds with females and calves is important for meeting social needs, because like females, bull elephants also are highly social. It is important to extend protocols to involve a lifelong commitment to use of proper training, management and care techniques for all bulls, not just when they are in musth. Members of the AsESG are willing to provide recommendations and assist facilities to improve conditions for bull elephants.

Citation

The full document can be found on the website of the Asian Elephant Specialist Group at <https://www.asesg.org/resources.php>.

Brown JL, Corea R, Dangolla A, Easwaran EK, Mikota S, Oo ZM, Sarma K & Thitaram C (2020) *Management and Care of Captive Asian Elephant Bulls in Musth*. IUCN SSC Asian Elephant Specialist Group.

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Pushpakumara PGA, Thitaram C & Brown JL (2018) Reproduction in elephants. In: *Veterinary Reproduction and Obstetrics. 10th Edition*. Noakes D, Parkinson TJ & England G (eds) W.B. Saunders Ltd. pp 724-744.

Santiapillai C, Read B, Jacobson G, Wijeyamohan S & Rambukpotha S (2011) A paradigm shift in the management of musth among bull elephants in captivity in Sri Lanka. *Ceylon Journal of Science (Biological Sciences)* **40:** 25-32.

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 (2020) publications on Asian elephants.

T.D. Allendorf, B. Gurung, S. Poudel, S. Dahal & S. Thapa
Using community knowledge to identify potential hotspots of mammal diversity in southeastern Nepal
Biodiversity and Conservation 29 (2020) 933-946
Abstract. No permission to print the abstract.

N.R. Anoop & T. Ganesh
The forests and elephants of Wayanad: Challenges for future conservation
Current Science 118 (2020) 362-367
Abstract. The Wayanad district of Kerala, India, is an important conservation and cultural landscape located in the Western Ghats biodiversity hotspot. It is a slightly east-sloping plateau with a unique geographical feature of small rolling hills interspersed with low-lying swamps and meandering streams. Extensive deforestation that occurred in the last century has severely fragmented and degraded the forest of Wayanad, leaving it as a mosaic of forests, wetlands, croplands and towns. The remaining forests in Wayanad are part of the Brahmagiri-Nilgiri-Eastern Ghats Elephant Landscape (NEG), which holds the single largest contiguous population of Asian elephants globally. The NEG is prone to seasonal fluctuation in resource availability, where a large tract of dry forest reduces its carrying capacity for elephants during summer. The Wayanad forests are a critical microhabitat for elephants in the NEG due to availability of fodder and perennial water sources during summer. Despite the importance of this region for elephants, the forest is 'degrading' drastically that will have a far-reaching impact on the long-term conservation of elephants in the NEG. Similarly, human-elephant conflict is on the rise and it is one of the biggest threats to the conservation of elephants and the well-being of rural communities in Wayanad. In this article we identify the current conservation issues and recommend future management of Asian elephants and their habitat in Wayanad.

L. Baker & R. Winkler
Asian elephant rescue, rehabilitation and rewilding
Animal Sentience 5 (28) (2020) e296
Abstract. Thailand has fewer than 10,000 elephants left. More of them are living in captivity to serve the tourist industry under grim conditions than are living free in what is left of their wild habitat. Conservation efforts need to be focused on all surviving members of the species, captive and free, but they need to take into account the inextricable entanglement of human and nonhuman animal lives in Thailand today. There is an opportunity for rescuing, rehabilitating and reintroducing captive elephants to the wild with the help of the traditional expertise of a mahout culture that has been elephant-keeping for centuries. We advocate a state of wildness that is meaningful to the elephants and can be attained in a way in which both elephant and human cultures are valued. This would be far better than the status quo for the elephants, restoring to them a life worth living.

P. Bansiddhi, J.L. Brown, C. Thitaram, V. Punyapornwithaya & K. Nganvongpanit
Elephant tourism in Thailand: A review of animal welfare practices and needs
Journal of Applied Animal Welfare Science 23

(2020) 164-177
Abstract. Elephant tourism in Thailand has developed into an important socio-economic factor after a logging ban initiated in 1989 resulted in thousands of out-of-work elephants. However, the welfare of captive elephants has been a topic of intense debate among tourists, scientists and stakeholders because of the range of working conditions and management practices to which they are exposed. The aim of this paper is to summarize the current state of knowledge on captive elephant welfare, with an emphasis on tourist elephants in Thailand, and highlight information gaps and recommendations for future directions. Tourist-oriented elephant camps could improve the welfare of elephants through better management practices that take into account physiological and psychological needs of individual animals, including meeting social and nutritional requirements, providing good health care, and maintaining adequate facilities. Our goal is to develop science-based guidelines that government agencies can use to develop an enforceable set of practical regulations to ensure good management of tourist elephants in Thailand. © 2019 Informa UK Limited.

L.P. Barrett & S. Benson-Amram

Can Asian elephants use water as a tool in the floating object task?

Animal Behavior and Cognition 7 (2020) 310-326

Abstract. One of the greatest challenges in comparative cognition is to design tasks that accurately assess cognitive abilities across a diverse set of taxa with differing morphologies and behaviors. The floating object task was designed to test insightful problem solving via water tool use in animals but so far has been tested only in primates. In the floating object task, animals add water to a tube in order to reach a floating food reward. A similar task, the Aesop's fable task, which is solved by adding stones to the tube, has been used with corvids and raccoons in addition to human children. Elephants are considered to exhibit complex cognitive abilities on par with primates, and they possess a prehensile trunk appendage well-suited for tests of water tool use. Here, we presented the floating object task to 12 zoo-housed Asian elephants (*Elephas maximus*) to determine if they demonstrate innovative problem solving or social learning. One elephant solved the task on her own. Additionally, elephants at one zoo that observed a conspecific solve the task exhibited increased interest in the task compared to baseline elephants, demonstrating social learning via stimulus enhancement. Asian elephants are capable of learning to use water as a tool, but the cognitive abilities underpinning their ability to solve the floating object task remain unclear. Our findings may bolster support for the convergent cognitive evolution of problem solving in elephants and apes, but further research using additional paradigms is needed.

S. Biswas, S. Bhatt, S. Paul, S. Modi, T. Ghosh, B. Habib, P. Nigam, G. Talukdar, B. Pandav & S. Mondol

A practive faeces collection protocol for multidisciplinary research in wildlife science

Current Science 116 (2019) 1878-1885

Abstract. Faecal samples have become an important non- invasive source of information in wildlife biology and ecological research. Despite regular use of faeces, there is no universal protocol available for faeces collection and storage to answer various questions in wildlife biology. In this study we collected 1408 faeces from ten different species using a dry sampling approach, and achieved 77.49% and 75.25% success rate in mitochondrial and nuclear marker amplifications respectively. We suggest a universal framework to use the same samples to answer different questions. This protocol provides an easy, quick and cheap option to collect non-invasive samples from species living in different environmental conditions to answer multidisciplinary questions in wildlife biology.

H.M. Chel, R. Nakao, N. Ohsawa, Z.M. Oo, N. Nonaka & K. Katakura

First record and analysis of the COI gene of *Cobboldia elephantis* obtained from a captive Asian elephant from Myanmar

Parasitology International 75 (2020) e102035

Abstract. The stomach bot fly species in Asian elephants has long been known as *Cobboldia elephantis*. However, there is no genetic information available for this species to date.

Here, we report that a third-instar fly larva was excreted from a captive Asian elephant four months after export from an elephant camp in Myanmar to a zoological garden in Japan. Morphological characteristics of the larva were coincident with published descriptions of *C. elephantis*. The mitochondrial cytochrome c oxidase subunit I (COI) gene was amplified from the larva by PCR using primers modified from those designed for DNA barcoding of insects and amphibians. The COI gene of *C. elephantis* showed 76.6 % and 83.6 % identity at the nucleotide and amino acid levels, respectively, to that of *C. loxodontis*, the stomach bot fly species in African elephants. Phylogenetic analysis of the COI genes of several stomach bot fly species revealed that the two *Cobboldia* species formed a clade separate from the stomach bot fly species found in rhinoceros and equids. © 2019 Reprinted with permission from Elsevier.

S. Debata & K.K. Swain

Mammalian fauna in an urban in uenced zone of Chandaka-Dampara Wildlife Sanctuary in Odisha, India

Journal of Threatened Taxa 12 (2020) 15767-75

Abstract. A camera trapping survey to estimate the species richness and relative abundance of different mammalian fauna and various anthropogenic activities was carried out for four months within an urban influenced zone of Chandaka-Dampara Wildlife Sanctuary, Odisha. The survey extended over 120 days in January–April 2019 over 10% of the total sanctuary area. With nine cameras and a total effort of 771 trap days, 2,855 independent photographs including 14 species of wild mammals and birds, human traffic, and movement of stray animals were captured. Among the mammalian fauna, golden jackal was the most photographed species whereas the Asian elephant, striped hyaena, and common palm civet were the least photographed species. Various anthropogenic activities like intensive movement of departmental vehicles, staff, feral livestock, and stray dogs and cats were also recorded and these activities need to be addressed in management activities for long term conservation of the area and its mammalian fauna. In order to enhance biological connectivity and improve movement of wildlife between the main part of the Chandaka Sanctuary and its near-detached reserved forests in Jagannathprasad-Bharatpur, the study recommends removal of feral cattle, extensive plantations, and construction of a fly-over for vehicular traffic. © 2020 The Authors.

N. Ertl, P. Wendler, E. Sós, M. Flügger, F. Schneeweis, C. Schiffmann, J.-M. Hatt & M. Clauss

Theory of medical scoring systems and a practical method to evaluate Asian elephant (*Elephas maximus*) foot health in European zoos

Animal Welfare 29 (2020) 163-176

Abstract. Several established models in human and veterinary medicine exist to evaluate an individual health or disease status. Many of these seem unsuitable for further epidemiological research aimed at discovering underlying influential factors. As a case example for score development and choice, the present study analyses different approaches to scoring the foot health of Asian elephants (*Elephas maximus*) living in European facilities. Sum scores with varying degree of detail, and without or with a weighting method, were compared using descriptive statistics, ie kurtosis, skewness, Shannon entropy, total redundancy, their maximum and their actual ranges. With increasing score complexity, a higher level of differentiation was reached. In parallel, the distribution of score frequencies in the population shifted systematically: with the least complex scoring model the pattern indicated a severely unhealthy population with an opposite skew to a hypothetically healthy population, whereas the most complex scoring model indicated a mildly affected population with a skew corresponding to that expected for a healthy population. We propose the latter, in the form of the Particularised Severity Score (ParSev), which accounts for every nail and pad individually and weights the sub-scores by squaring, as the most relevant score for further investigations, either in assessing changes within an elephant population over time, or correlating foot health in epidemiological studies to potentially influencing factors. Our results emphasise the relevance of choosing appropriate scoring models for welfare-associated evaluations, due to implications for the applicability as well as the perceived welfare status of the test population.

A.M. Greene, P. Panyadee, A. Inta & M.A. Huffman

Asian elephant self-medication as a source of ethnoveterinary knowledge among Karen mahouts in northern Thailand

J. of Ethnopharmacology 259 (2020) e112823

Abstract. Ethnoveterinary medicine is often assumed to be a subset of human medicinal knowledge. Here we investigate the possibility that some ethnoveterinary medicine rather originates from observations of animal self-medication. We document and analyze the ethnoveterinary medicine used by Karen mahouts for elephant care and attempt to determine whether this knowledge originated from humans or elephants. Elephant camp owners and mahouts in four communities in northern Thailand were interviewed about their knowledge and use of plants for ethnoveterinary elephant care. For each ethnoveterinary plant, data were collected on Karen human medicinal uses and whether elephants independently consume them. Based on overlaps between ethnoveterinary use, human medicinal use and elephant dietary use, plants were classified into three categories: those that originated from Karen human medicine, those that originated from Asian elephant self-medication, and those which were present in both human and elephant knowledge traditions. The use of 34 plants (32 identified at least to genus) and two additional non-plant remedies (salt and human urine) were reported to be used in ethnoveterinary elephant medicine. A total of 44 treatments in 11 use categories were recorded: tonic, wounds, compress, eye problems, indigestion, broken bones, galactagogue, snakebite, fatigue, skin and musth regulation. Of the ethnoveterinary plants, 55% had the same use in human medicine, 43% had different uses and 2% had no use. Elephants consume 84% of the ethnoveterinary plants as part of their natural diet. Analysis indicates that 32% of plant uses likely originated from Karen human medicine, 60% of plant uses likely existed independently in both human and elephant knowledge systems, and 8% of plant uses likely originated from elephant self-medicating behavior. The tonic use category shows the strongest evidence of influence from observations of elephant self-medication. The use of tonic medicines appears to be increasing as a way to mitigate the unnaturally limited diet of elephants in tourist camps. Ethnoveterinary medicine for elephant care is influenced by both human medicinal knowledge and elephant knowledge of plants for self-medication. The ethnoveterinary knowledge domain appears to be the result of an interactive process linked to convergent evolution or co-evolution between humans and Asian elephants.

T. Guntawang, T. Sittisak, S. Srivorakul, V. Kochagul, K. Photichai, C. Thitaram, N. Sthitmatee, W.-L. Hsu & K. Pringproa

In vivo characterization of target cells for acute elephant endotheliotropic herpesvirus (EEHV) infection in Asian elephants (*Elephas maximus*)

Scientific Reports 10 (2020) e11402

Abstract. Elephant endotheliotropic herpesvirus-hemorrhagic disease (EEHV-HD) is a dangerous viral infectious disease in young Asian elephants. Despite hypotheses underlying pathogenesis of the disease, it is unclear which cell types the virus targets during acute or persistent infections. This study investigated the tissues and target cells permissive for EEHV infection and replication in vivo. Rabbit polyclonal antibodies against the non-structural proteins of EEHV, DNA polymerase (EEHV DNAPol), were generated and validated. These were used to examine EEHV infection and replication in various tissues of acute EEHV-HD cases and compared to an EEHV-negative control. The results indicated that viral antigens were distributed throughout the epithelia of the alimentary tract and salivary glands, endothelia and smooth muscle cells, and monocytic lineage cells of the EEHV-infected elephants. Moreover, EEHV DNAPol proteins were also found in the bone marrow cells of the EEHV1A-HD and EEHV1A/4-HD cases. This study demonstrated for the first time the target cells that favor in vivo EEHV replication during acute infection, providing a promising foundation for investigating EEHV propagation in vitro.

H. Hoelzig, T. Muenster, S. Blanke, G. Kloess, R. Garmasukis & A. Koenig

Ivory vs. osseous ivory substitutes – Non-invasive diffractometric discrimination

Forensic Science International 308 (2020) e110159

Abstract. A new discrimination method for the bioapatite materials bone, antler and ivory was developed using X-ray diffractometry and comprises non-invasive measurements in order to take valuable objects into account. Our approach deals with the analysis of peak intensity ratios resulting from several measurements on each object. For instance, the intensity ratio of the apatite reflections 002 and 310 has been described in the literature as representing the degree of apatite crystal orientation and varies depending on the sample orientation. The decisive factor for the material identification is the value dispersion of intensity ratios resulting from the total of all measurements on one object. This pattern of data points, visualised via kernel density estimation (KDE), is characteristic for ivory, bone and antler, respectively, and enables the discrimination of these materials. The observation is justifiable since apatite crystal orientation adapts to the collagen fibre arrangement which shows major differences between different sorts of bioapatite materials. The patterns of data points were received via analysis of 88 objects made of bone (n = 30), antler (n = 27) and ivory (n = 31). In order to verify several identifications X-ray computer tomography was supplemented. The presented method usefully supplements already existing approaches concerning microscopic, elementary and biochemical analyses.

F.G. Horgan & E.P. Kudavidanage

Farming on the edge: Farmer training to mitigate human-wildlife conflict at an agricultural frontier in south Sri Lanka

Crop Protection 127 (2020) e104981

Abstract. Efforts to increase food production across Asia have relied on the intensification of established farms, as well as the expansion of farming activities into previously wild areas. Farms at agricultural frontiers face distinct challenges from those in historically farmed regions and require distinct support structures. We interviewed 324 rice farmers at seven sites in southern Sri Lanka to determine challenges to rice production in the region and the propensity for human wildlife conflict. Farmers (80%) reported wildlife including peafowl (*Pavo cristatus*) and other birds, as well as free-ranging (semi-) domestic animals such as buffalo (*Bubalus bubalis*), as their principal biotic constraints across sites, with relatively few farmers regarding weeds, insect pests, or diseases as a constraint (mentioned by 25% of farmers in total). Farmers near wilderness areas reported elephants (*Elephas maximus*) and wild boar (*Sus scrofa*) as major constraints to rice production. 64% of farmers had received training from government and other support agencies during the five years prior to our survey. Training mainly addressed insect pests and diseases and focused on lethal product-based solutions (88% of training). Farmers did not receive support or advice to mitigate crop foraging and human-wildlife conflict; instead, farmers relied heavily on repellence (human activated) responses, such as early warning systems and active scaring. We suggest that Agriculture, Development and Wildlife authorities might increase intergovernmental cooperation and coordination of farmer training to better manage crop foraging in our study region. We present a review of possible non-lethal, farm-based methods that could be promoted during training programs for farmers facing challenges from wildlife in such a biologically diverse region. Currently, a wide range of low-cost avoidance, barrier and deterrence systems (that are not monitored or activated by humans) are available. These can be used to avoid harmful repellence practices.

S.R. Hota, S. Sahoo, M. Dash, A. Pahar, B. Mohanty & N. Sahoo

Molecular detection of *Murshidia linstowi* in a free-ranging dead elephant calf

Journal of Threatened Taxa 12 (2020) 15359-15363

Abstract. Gastrointestinal helminths are ubiquitous in both domestic and wild animals. Infections are often sub-clinical except in circumstances of destabilization of host-parasite equilibrium by innate or environmental factors.

The present case deals with microscopic and molecular diagnosis of *Murshidia linstowi* recovered from an elephant. A post-mortem examination of a free-ranging juvenile male elephant calf that had died of electrocution in Athagarh Wildlife Division revealed the presence of slender, whitish nematodes in the stomach. No gross lesions were noticed either in the site of predilection or any other internal organs. The average length of the parasites was 3.8cm. These parasites were collected for further gross as well as microscopic examination following routine parasitological techniques. Temporary mounts prepared after cleaning the nematodes in lactophenol were observed under a microscope. Morphological features such as a well-developed mouth collar, large and globular buccal capsule with fine tubercles, cone shaped oesophageal funnel, short bursa having indistinctly divided lobes and closely apposed ventral rays and stout spicules with club shaped tips bent dorsally corroborated with that of *M.linstowi* (male). Amplification of the rDNA from the internal transcribed spacer (ITS) region using universal nematode primers NC2 and NC5 revealed a product size of 870 bp. The PCR product was subjected to sequencing followed by NCBI-BLAST which revealed 98% homology with *M. linstowi*. A phylogenetic study showed a maximum similarity with *M.linstowi* recovered from elephants in Kenya. This particular nematode species belonging to the family Strongylidae and sub-family Cyathostominae appears to be the first documented report in India. © 2020 The Authors.

A. Jayadevan, R. Nayak, K.K. Karantha, J. Krishnaswamy, R. De Fries, K.U. Karantha & S. Vaidyanathan

Navigating paved paradise: Evaluating landscape permeability to movement for large mammals in two conservation priority landscapes in India

Biological Conservation 247 (2020) e108613

Abstract. Human land use and activity results in the loss of habitat and biodiversity, and alters how animals move through landscapes. Spatially explicit information on where animal movement is affected at large spatial scales is crucial for prioritizing conservation efforts. We evaluated landscape permeability to movement in two conservation priority landscapes in India, the Western Ghats (WG) and Central India (CI). Using an agent-based model we simulated movement and dispersal of five wide-ranging species in WG (elephant, gaur, leopard, sambar and sloth bear) and four in CI (gaur, leopard, sambar and sloth bear). For each species we compared movement in the presence and absence of land-use land-cover, infrastructure and human population to identify areas where movement is impeded and reduced due to high-resistance features; unrestricted due to relatively low-resistance features; and increased and channelled due to surrounding high-resistance areas. In both landscapes, median movement was reduced. Human land-use, human population and high linear infrastructure density contribute the highest to impeded movement for all species. Natural areas constitute only 20–55% and 50–70% of unrestricted, increased and channelled movement areas in WG and CI respectively. This suggests that a large percentage of the landscape crucial for maintaining movement is not completely permeable. Such areas are often neglected in conservation planning. Our spatially explicit results help identify and prioritize areas where restoration or mitigation should be planned to improve permeability to movement for large mammals. Our approach can be used for other landscapes where data on large mammal movement is lacking. © 2020 Reprinted with permission from Elsevier.

J. Kambe, Y. Sasaki, R. Inoue, S. Tomonaga, T. Kinjo, G. Watanabe, W. Jin & K. Nagaoka

Analysis of infant microbiota composition and the relationship with breast milk components in the Asian elephant (*Elephas maximus*) at the Zoo

Journal of Veterinary Medical Science 82 (2020) 983-989

Abstract. The prevention of diseases through health control is essential at zoos. Recently, the gut microbiota, which is an ecosystem consisting of the bacteria living in the digestive tract, has been found to be one of the key systems that mediates animal health. However, there is little basic knowledge about gut microbiota in zoo animals, particularly the relationship between mothers and infants during lactation. Here, we

investigated the formation of the gut microbiota during infancy in an Asian elephant (*Elephas maximus*) in Okinawa Zoo and compared the composition between infant and mother. In addition, we analyzed the components of breast milk and examined the correlation with the infant gut microbiota. Analysis revealed that the gut microbiota of the infant contained high amount of Lactobacillales and its diversity was relatively low compared to that of the mother. We found several milk components, such as lactose, threonine and estradiol-17β, which showed a positive correlation with the change of Lactobacillales during the lactation period. In conclusion, the present study sheds light on the mechanism of gut microbiota formation during infancy in an Asian elephant and provides important insights into the health control of Asian elephants in zoos. © 2020 Japanese Society of Veterinary Science.

S. Kandel, S. Sripiboon, P. Jenjaroenpun, D.W. Ussery, I. Nookaew, M.S. Robeson II, & T. Wongsurawata

16S rRNA gene amplicon profiling of baby and adult captive elephants in Thailand

Microbiology Resource Announcements 9 (2020) e00248-20

Abstract. Here, we present a 16S rRNA gene amplicon sequence data set and profiles demonstrating the bacterial diversity of baby and adult elephants from four different geographical locations in Thailand. The dominant phyla among baby and adult elephants were Bacteroidetes, Firmicutes, Proteobacteria, Kiritimatiellaeota, Euryarchaeota, and Tenericutes. © 2020 The Authors.

Krithi K. Karanth & Anubhav Vanamamalai

Wild seve: A novel conservation intervention to monitor and address human-wildlife conflict

Frontiers in Ecology and Evolution 8 (2020) e198

Abstract. Human-wildlife interactions resulting in conflict remains a global conservation challenge, requiring innovative solutions to ensure the persistence of wildlife amidst people. Wild Seve was established in July 2015 as a conservation intervention program to assist people affected by conflict to file and monitor claims and receive ex-gratia payments from the Indian government. In 48 months of operation, Wild Seve filed and tracked 13,808 claims on behalf of those affected from 19 forest ranges around the Bandipur and Nagarahole National Parks in Karnataka, India. This included 10,082 incidents of crop loss, 1,176 property damage incidents, and 1,720 incidents where crop and property loss occurred together. Wild Seve also filed claims for 782 livestock predation incidents, and assisted in 45 human injury incidents and three human fatalities. Elephant related losses comprised 93.9%, and big cat losses comprised 5.5% of reported cases. Wild Seve provides an immediate response to human-wildlife conflict incidents and improves access to ex-gratia payment schemes. Wild Seve is a low cost intervention that uses open-source technology and leverages existing policies to facilitate ex-gratia payments. The Wild Seve model of monitoring and addressing human-wildlife conflict is adaptable and scalable to high conflict regions globally, to the benefit of people and wildlife. © 2020 The Authors.

N. Kido, S. Tanaka, T. Omiya, Y. Kamite, K. Sawada, Y. Komatsu, Y. Shoji, M. Senzaki, S. Hanzawa, M. Ando & I. Suto

Emotion estimation using a wearable heart rate monitoring device in Asian elephants (*Elephas maximus*) during veterinary clinical procedures

Journal of Veterinary Medical Science 82 (2020) 856-860

Abstract. Fatal accidents in captive elephants occasionally occur because humans are unable to gauge elephants' emotions solely by their behavior. The intellectual capacity of elephants makes them capable of understanding circumstantial changes and associated emotions, allowing them to react accordingly. Physiological markers, such as heart rate variability, may be effective in determining an elephant's emotional state. In this study, a wearable heart rate monitor was used to determine the emotional state of a female Indian captive elephant (*Elephas maximus indicus*). The average heart rate was higher when the elephant underwent painful treatment than when it underwent non-painful treatment. In addition, the heart rate increased both before and after the treatment, which included radiography

and blood collection. © 2020 Japanese Society of Veterinary Science.

R. Kobayashi, K. Nagaoka, N. Nishimura, S. Koike, E. Takahashi, K. Niimi, H. Murase, T. Kinjo, T. Tsukahara & Ryo Inoue

Comparison of the fecal microbiota of two monogastric herbivorous and five omnivorous mammals

Animal Science Journal 91 (2020) e13366

Abstract. Fecal microbiota in seven different monogastric animal species, elephant, horse, human, marmoset, mouse, pig and, rat were compared using the same analytical protocol of 16S rRNA metagenome. Fecal microbiota in herbivores showed higher alpha diversity than omnivores except for pigs. Additionally, principal coordinate analysis based on weighted UniFrac distance demonstrated that herbivores and pigs clustered together, whereas other animal species were separately aggregated. In view of butyrate- and lactate-producing bacteria, predominant genera were different depending on animal species. For example, the abundance of *Faecalibacterium*, a known butyrate producer, was 8.02% ± 3.22% in human while it was less than 1% in other animal species. Additionally, *Bifidobacterium* was a predominant lactate producer in human and marmoset, while it was rarely detected in other omnivores. The abundance of lactate-producing bacteria in herbivores was notably lower than omnivores. On the other hand, herbivores as well as pig possess Fibrobacter, a cellulolytic bacterium. This study demonstrated that fecal microbiota in herbivorous animals is similar, sharing some common features such as higher alpha diversity and higher abundance of cellulolytic bacterium. On the other hand, omnivorous animals seem to possess unique fecal microbiota. It is of interest that pigs, although omnivore, have fecal microbiota showing some common features with herbivores. © 2020 The Authors.

A. Kshettry, S. Vaidyanathan, R. Sukumar & V. Athreya

Looking beyond protected areas: Identifying conservation compatible landscapes in agro-forest mosaics in north- eastern India

Global Ecology and Conserv. 22 (2020) e00905

Abstract. Small-sized protected areas face increasing pressures from developmental activities and are often rendered inadequate and isolated to conserve wide-ranging species. However, in situations where wildlife persists outside protected areas, conservation goals may be met by aligning the ecological needs of wildlife with the socio-economic needs of local communities and offsetting losses arising due to shared spaces. We explore the potential of a tea-plantation dominated landscape of multiple land-use in north-eastern India to conserve the Asian elephant and the Indian leopard. We assess conservation potential by identifying predictors of species use of particular habitats using species distribution models and identify challenges by reviewing the available literature. Elephants used ~680 km^2 of this 1200 km^2 non-forested landscape; within this area, habitats with a higher proportion of deciduous forest patches were favored. Leopards were found to be ubiquitous in tea-plantation and used ~950 km^2 of the study area, with the proportion of tea cover being the single best predictor of leopard habitat-use. With more than 30 human deaths and 100 injuries per year caused by these two species in the study area alone, the high frequency of human casualties and economic losses remain the prime hurdles to long-term conservation efforts. We discuss specific mitigation measures to reduce human casualties and call for the inclusion of important stakeholders in the mitigation process. The study provides a template for identifying conservation-compatible landscapes outside protected areas and a framework for identifying challenges and potential to mitigate current or future conservation conflicts. © 2020 The Authors.

A. Larramendi, H. Zhang, M.R. Palombo & M.P. Ferretti

The evolution of *Palaeoloxodon* skull structure: Disentangling phylogenetic, sexually dimorphic, ontogenetic, and allometric morphological signals

Quaternary Science Reviews 229 (2020) e106090

Abstract. This paper presents a reappraisal of evolution in the extinct Pleistocene straight-tusked elephant *Palaeoloxodon*, based on cranial morphology. Particular emphasis is given to the parieto-occipital crest (POC), a specialised

structure of the *Palaeoloxodon* skull. A key aim of this contribution is to discuss the systematic significance of the so-called "Stuttgart" and "namadicus" cranial morphs among Eurasian *Palaeoloxodon*. Materials examined and discussed mostly represent large-sized continental species from several Afro-Eurasian localities, but includes also the small-sized endemic elephant *Palaeoloxodon* cf. *mnaidriensis* from the late Middle-early Late Pleistocene of Sicily. In Africa, where the lineage originated, the morphological evolution of *Palaeoloxodon* concerned both skull and molariform teeth, which became strongly hypsodont and bore up to 19 lamellae. This dental morphology underwent little notable evolutionary change in Eurasian *Palaeoloxodon*, contrasting to the marked disparity in their cranial morphology, best elucidated by variations in the POC. Maturation of a strong POC in *Palaeoloxodon antiquus*, *P. namadicus* and *P.* cf. *mnaidriensis* (Puntali Cave, Sicily) during ontogeny shows a consistent pattern: incipient folding at the M1 stage; complete folding at the M2 stage; further downward migration of the POC towards the nasals at the M3 stage. The POC morphology and variation result from complex interactions of factors, which include, to varying degrees, ontogeny (juvenile vs adult), allometry (e.g. skull size and shape) and possible phylogenetic inertia. Some evidence of sexual dimorphism in POC development is observed in *P. namadicus*, *P. naumanni*, and possibly *P. antiquus*, this is a possible allometric effect which reflects on the markedly greater body size of males at full maturity compared to females. Skull shape and variability of the POC, as well as postcranial proportions, support the specific separation of *P. namadicus* and *P. antiquus*. However, the observed pattern of intrapopulational POC variability from German and Italian *P. antiquus* samples does not support a turnover of the two distinct *Palaeoloxodon* species in Europe during the Middle Pleistocene (MIS 11–MIS 7). The poorly known *P. turkmenicus* might represent a separate Middle Pleistocene *Palaeoloxodon* species from Central Asia more plesiomorphic than either *P. antiquus* or *P. namadicus*. *P. naumanni* from Japan possesses a combination of primitive and derived, autapomorphic characters, supporting its interpretation as an early offshoot during Eurasian *Palaeoloxodon* evolution. © 2019 Reprinted with permission from Elsevier.

V.P.W. Loke, T. Lim & A. Campos-Arceiz

Hunting practices of the Jahai indigenous community in northern peninsular Malaysia

Global Ecology and Conservation 21 (2020) e00815

Abstract. Humans have been part of the ecology of Southeast Asian rainforests for millennia. Understanding the hunting practices of forest-dwelling people is important for designing policies and practices aimed to protect both vulnerable wildlife populations and human communities. The Jahai people are forest-dwelling hunter-gatherers living in northern Peninsular Malaysia and believed to be direct descendants of the first anatomically modern humans that arrived to the Malay Peninsula at least 50,000 years ago. We conducted semi-structured interviews in three Jahai villages around the Royal Belum State Park, asking about their knowledge and hunting habits of 11 wild mammal species. Specifically, we asked whether they were able to identify and whether they hunted the 11 animals, their relative prey preference, perceived trends of the animals' populations, and how they hunted and handled them. Our respondents were familiar with all the species in the survey. None of the 87 respondents claimed to hunt tigers and elephants. The most preferred and commonly hunted species were medium-sized arboreal animals (gibbons and giant squirrels, hunted by >80% of respondents), whereas larger and more dangerous animals (gaur, sun bear, and tapir) were only hunted by a minority (<10%). The Jahai use traditional hunting methods, mainly blowpipes, spears, traditional snares, and fire traps (for smoking animals out of burrows). Only two respondents reported using firearms. Elephant numbers were perceived to be stable; all the other species were perceived to be declining moderately. Almost all the meat caught by the Jahai is for self-consumption, very little is traded with outsiders. The impacts of Jahai hunting on wildlife populations remain unclear, but our study provides a fundamental understanding of Jahai hunting practices for future management and conservation purposes. © 2019 The Authors.

F. Li, S. Lu, X. Xie, S. Fan, D. Chen, S. Wu & J. He

Antiviral properties of extracts of *Streptomyces* sp. SMU 03 isolated from the feces of *Elephas maximus*

Fitoterapia 143 (2020) e104600

Abstract. Actinobacteria are historically and continued to be an important source for drug discovery. The annual epidemics and periodic pandemics of humans induced by influenza A virus (IAV) prompted us to develop new effective antiviral drugs with different modes of action. An actinobacterium of *Streptomyces* sp. SMU 03 was identified from the feces of *Elephas maximus* in Yunnan Province, China. By employing an H5N1 pseudo-typed virus drug screening system, the anti-IAV effect of the dichloromethane extracts (DCME) of this bacterium was investigated. DCME showed broad and potent activities against several influenza viruses, including the H1N1 and H3N2 subtypes and influenza B virus, with IC50 values ranging from 0.37 ± 0.22 to 14.44 ± 0.79 µg/ml. A detailed modes-of-action study indicated that DCME might interact with the HA2 subunit of hemagglutinin (HA) of IAV by interrupting the fusion process between the viral and host cells' membranes thereby inhibiting the entry of the virus into host cells. Furthermore, the in vivo anti-IAV activity test of DCME showed that compared with the no-drug treated group, the survival rates, appearances, weights, lung indices and histopathological changes were all significantly alleviated. Based on these results, the chemical constituent study of DCME was then investigated, from which a number of antiviral compounds with various structural skeletons have been isolated and identified. Overall, these data indicated that the DCME from *Streptomyces* sp. SMU 03 might represent a good source for antiviral compounds that can be developed as potential antivirus remedies.

Imke Lueders & W.R. Twink Allen

Managed wildlife breeding – An undervalued conservation tool?

Theriogenology 150 (2020) 48-54

Abstract. Knowledge of and the technologies and resources applied to the ex situ care for wildlife have improved greatly in recent years. This has resulted in numerous successes bringing back populations from the brink of extinction by the reintroduction or restoration of animals from conservation breeding programmes. Controlled breeding of wildlife by humans is discussed controversially in society and in scientific circles and it faces a number of significant challenges. When natural breeding fails, Assisted Reproduction Technologies (ART) have been postulated to increase reproductive output and maintain genetic diversity. Furthermore, technical advances have improved the potential for successful collection and cryopreservation of gametes and embryos in many wildlife species. With the aim of creating a better understanding of why ex situ and in situ conservation of threatened species must complement each other, and under which circumstances ART provide additional tools in the rescue of a threatened population, we elucidate the current situation here by using as examples three different megavertebrate families: elephantidae, rhinoceridae and giraffidae. These mammal families consist of charismatic species, and most of their members are currently facing dramatic declines in population numbers. On the basis of these and other examples, we highlight the importance of captive zoo and other managed wildlife populations for species survival in a human dominated world. Without the possibility to study reproductive physiology in trained or habituated captive individuals, major advances made in wildlife ART during the past 20 years would not have been possible. This paper reviews the benefits and future challenges of large mammal conservation breeding and examines the role of assisted reproduction in such efforts.

C.L. Lynsdale, N.O. Mon, D.J. F. dos Santos, H.H. Aung, U K. Nyein, W. Htut, D. Childs & V. Lummaa

Demographic and reproductive associations with nematode infection in a long-lived mammal

Scientific Reports 10 (2020) e9214

Abstract. Infection by macroparasites, such as nematodes, varies within vertebrate host systems; elevated infection is commonly observed in juveniles and males, and, for females, with different reproductive states. However, while

such patterns are widely recognized in short-lived model systems, how they apply to long-lived hosts is comparatively understudied. Here, we investigated how infection varies with host age, sex, and female reproduction in a semi-captive population of individually marked Asian elephants *Elephas maximus*. We carried out 1,977 faecal egg counts (FECs) across five years to estimate nematode loads for 324 hosts. Infection patterns followed an established age-infection curve, whereby calves (5 years) exhibited the highest FECs and adults (45 years) the lowest. However, males and females had similar FECs across their long lifespan, despite distinct differences in life-history strategy and clear sexual dimorphism. Additionally, although mothers invest two years in pregnancy and a further three to five years into lactation, nematode load did not vary with four different measures of female reproduction. Our results provide a much-needed insight into the host-parasite dynamics of a long-lived host; determining host-specific associations with infection in such systems is important for broadening our knowledge of parasite ecology and provides practical applications for wildlife medicine and management. © 2020 The Authors.

Z.M. Oo, Y.H. Aung, T.T. Aung, N. San, Z.M. Tun, G.S. Hayward & A. Zachariah

Elephant endotheliotropic herpesvirus hemorrhagic disease in Asian elephant calves in logging camps, Myanmar

Emerging Infectious Diseases 26 (2020) 63-69

Abstract. In recent years, an alarming number of cases of lethal acute hemorrhagic disease have occurred in Asian elephant calves raised in logging camps in Myanmar. To determine whether these deaths were associated with infection by elephant endotheliotropic herpesvirus (EEHV), we conducted diagnostic PCR subtype DNA sequencing analysis on necropsy tissue samples collected from 3 locations. We found that EEHV DNA from 7 PCR loci was present at high levels in all 3 calves and was the same EEHV1A virus type that has been described in North America, Europe, and other parts of Asia. However, when analyzed over 5,610 bp, the strains showed major differences from each other and from all previously characterized EEHV1A strains. We conclude that these 3 elephant calves in Myanmar died from the same herpesvirus disease that has afflicted young Asian elephants in other countries over the past 20 years.

H. Padalia, S. Ghosh, C.S. Reddy, S. Nandy, S. Singh & A.S. Kumar

Assessment of historical forest cover loss and fragmentation in Asian elephant ranges in India

Environmental Monitoring and Assessment 191 (2019) e802

Abstract. No permission to print the abstract.

S. Paudel & S. Sreevatsan

Tuberculosis in elephants: Origins and evidence of interspecies transmission

Tuberculosis 123 (2020) e101962

Abstract. Tuberculosis (TB) is a devastating disease in elephants caused by either *Mycobacterium tuberculosis* or *M. bovis*. It is an ancient disease, and TB in elephants was first reported over two millennia ago in Sri Lanka. Outbreaks of TB worldwide, in captive and free-ranging elephant populations, have been recorded. Interspecies transmission of TB among elephants and humans has been confirmed in several geographic localities using spoligotyping, MIRU-VNTR analysis, and/or comparative genomics. Active surveillance of TB in wild and captive elephants and their handlers is necessary to prevent TB transmission at the elephant-human interface and to aid in the conservation of Asian and African elephants. In this review, we present an overview of diagnosis, reports of TB outbreaks in the past 25 years, TB in wild elephants, its transmission, and possible prevention and control strategies that can be applied at the elephant-human interface. © 2020 Reprinted with permission from Elsevier.

M. Perera & R. Vandercone

Some aspects of seed dispersal by Asian elephants (*Elephas maximus*) in Kaudulla National Park, Sri Lanka

Current Science 118 (2020) 648-654

Abstract. Our understanding of the qualitative and quantitative aspects of seed dispersal by Asian elephants is at its infancy. We explored some of these aspects at Kaudulla National Park, Sri Lanka, focusing on the germination potential of dispersed seeds, and the influence of gut passage on germination and latency in the seeds of *Bauhinia racemosa*. Seeds of ten species were dispersed and their germination potential was generally poor. However, gut passage significantly reduced the latency period of *B. racemosa*. Long-term research on frugivory, passage times of seeds and ranging behaviour will help develop wildlife management plans.

M.J. Potoczniak, M. Chermak, L. Quarino, S.S. Tobe & J. Conte

Development of a multiplex, PCR-based genotyping assay for African and Asian elephants for forensic purposes

International Journal of Legal Medicine 134 (2020) 55–62

Abstract. No permission to print the abstract.

M.R. Puspaningrum, G.D. van den Bergh, A.R. Chivas, E. Setiabudi & I. Kurniawan

Isotopic reconstruction of Proboscidean habitats and diets on Java since the Early Pleistocene: Implications for adaptation and extinction

Quaternary Science Reviews 228 (2020) e106007

Abstract. Since its sub-aerial emergence, Java has experienced multiple tectonic, geographic and climatic changes, which affected the megafaunal occupation, adaptation and succession. Six Proboscidean taxa have been found from various localities throughout Java extending back to the Early to Late Pleistocene. The six taxa are: *Stegoloxodon indonesicus*, *Sinomastodon bumiajuensis*, pygmy *Stegodon* sp., *Stegodon trigonocephalus*, *Elephas hysudrindicus* and *Elephas maximus*, in which respective taxa are included in successive faunal stages. The aim of this research was to reconstruct the succession of Proboscidea in Java and the adaptation of each taxon to environmental changes by incorporating stable isotope analysis with the fossil faunal record, geology and stratigraphy. We conducted stable carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotope analysis of the carbonate phase in the tooth enamel of six proboscidean taxa from numerous localities and ages. Our results suggest that for the earliest terrestrial fauna from Java, represented by *Stegoloxodon indonesicus*, the feeding ecology was restricted to a closed canopy rainforest during the earliest Pleistocene, while towards the late Early Pleistocene, the successive taxon, *Sinomastodon bumiajuensis*, was adapted to different or increasingly drier grassy habitats. C_4 expansion on the island took place since the later part of the Early Pleistocene (before 1.5 Ma) and continued until the Middle Pleistocene, as suggested by the carbon and oxygen isotope composition of assemblages of proboscidean taxa from Sangiran, Kedung Brubus, Trinil, and western Java, which also predominantly display the expected range of C_4-dominant feeders. However, the occurrence of mixed C_3/C_4 feeder Proboscidea in the Ngandong Fauna suggests that fragmented dense evergreen forests, shrubby or woodland vegetation reappeared towards the end of the Middle Pleistocene. This environmental shift is detected in the later stage of the Middle Pleistocene, as the dietary preference of all analysed samples from individuals from this age shifted back from a C_4-dominated into a C_3-dominated diet, which suggests a change from a dry to more humid climate conditions.

R. Rajapakse, K.L.T. Pham, K.J.K. Karunathilakea, S.P. Lawton & T.H. Leb

Characterization and phylogenetic properties of the complete mitochondrial genome of *Fascioloides jacksoni* (syn. *Fasciola jacksoni*) support the suggested intergeneric change from *Fasciola* to *Fascioloides* (Platyhelminthes: Trematoda: Plagiorchiida)

Infection Genetics and Evolution 82 (2020) e104281

Abstract. *Fascioloides jacksoni* (syn. *Fasciola jacksoni*, Cobbold, 1869) (Platyhelminthes: Echinostomatoidea), is a liver fluke that causes severe morbidity and mortality of Asian elephants (*Elephas maximus maximus*). Understandings on molecular diagnosis, epidemiology, genetics and evolution of this flatworm are limited. In this study, we present the complete mitochondrial DNA (mt) sequence of 14,952 bp obtained from an individual fluke and comparative characterization of mitogenomic features with fasciolids, primarily, *Fascioloides magna* and other taxa in the superfamily Echinostomatoidea. Taxonomic relationship within and between Echinostomatoidea, Opisthorchioidea and

Paramphistomoidea in the order Plagiorchiida, are also taxonomically considered. The complete circular mt molecule of *F. jacksoni* contained 12 protein-coding, two ribosomal RNA, 22 transfer RNA genes, and a non-coding region (NCR) rich in tandem repeat units. As common in digenean trematodes, *F. jacksoni* has the usual gene order, the absence of atp8 and the overlapped region by 40 bp between nad4L and nad4 genes. The NCR located between tRNA(Glu) (trnE) and cox3 contained nine nearly identical tandem repeat units (TRs of 113 bp each). Special DHU-arm missing tRNAs for Serine were found for both, tRNA(S1(AGN)) and tRNA(S2(UCN)). Base composition indicated that cox1 of *F. jacksoni* showed the lowest (11.8% to *F. magna*, 12.9–13.6% to Fasciola spp. and 18.1% to *Fasciolopsis buski*) and nad6 the highest divergence rate (19.2%, 23.8–26.5% and 27.2% to each fasciolid group), respectively. A clear bias in nucleotide composition, as of 61.68%, 62.88% and 61.54%, with a negative AT-skew of the corresponding values (-0.523, -0.225 and -0.426) for PCGs, MRGs and mtDNA for *F. jacksoni* and likewise data for the fasciolids. Phylogenetic analysis confirmed the sister branch of *F. jacksoni* and *F. magna* with the nodal support of 100%, clearly separated from the taxonomically recognized *Fasciola* spp. With the previous studies, mitogenomic data presented in this study are strongly supportive for *Fasciola jacksoni* reappraisal as *Fascioloides jacksoni* in the *Fascioloides* genus.

T. Revathe, S. Anvitha & T.N.C. Vdiya

Development of motor control and behaviour in Asian elephants in the Kabini elephant population, southern India

International Journal of Developmental Biology 64 (2020) 377-392

Abstract. Although neonates of precocial mammals are capable of locomotory, sensory, nutritional, and thermoregulatory independence to some extent soon after birth, they attain their adult body mass more slowly than altricial mammals, allowing for an extended period of learning or perfecting skills to an adult-like degree. Asian elephants are precocial but are nutritionally dependent on the mother for at least two years and are long-lived and social. We wanted to examine the ontogeny of trunk motor control and various behaviours in Asian elephant calves and see whether the former develops faster than the latter since limb motor control is achieved soon after birth. We collected field data on trunk use, lateralisation, and behaviours from individually identified, free-ranging elephants in southern India and examined how they were affected by age and other factors. Unlike limb motor control, we found trunk motor skills and behaviours to develop gradually with age. Trunk lateralisation occurred very early on, was not highly dependent on trunk motor skills, and is probably not a developmental marker in Asian elephants. Adult-like behaviours that required low trunk usage emerged within 3 months, while some feeding behaviours emerged later. Calves spent less time resting and more time feeding as they grew, and their activity budgets resembled those of adults only after a year; hence, mother-offspring behavioural synchrony was low for young calves and increased with age. Behavioural development and trunk motor control in Asian elephants are both gradual processes, taking about a year to mature.

S. Saaban, M.N. Yasak, M. Gumal, A. Oziar, F. Cheong, Z. Shaari, M. Tyson & S. Hedges

Viability and management of the Asian elephant (*Elephas maximus*) population in the Endau Rompin landscape, Peninsular Malaysia

PeerJ 8 (2020) e8209

Abstract. The need for conservation scientists to produce research of greater relevance to practitioners is now increasingly recognized. This study provides an example of scientists working alongside practitioners and policy makers to address a question of immediate relevance to elephant conservation in Malaysia and using the results to inform wildlife management policy and practice including the National Elephant Conservation Action Plan for Peninsular Malaysia. Since ensuring effective conservation of elephants in the Endau Rompin Landscape (ERL) in Peninsular Malaysia is difficult without data on population parameters we (1) conducted a survey to assess the size of the elephant population, (2) used that information to assess

the viability of the population under different management scenarios including translocation of elephants out of the ERL (a technique long used in Malaysia to mitigate human-elephant conflict (HEC)), and (3) assessed a number of options for managing the elephant population and HEC in the future. Our dung-count based survey in the ERL produced an estimate of 135 (95% CI [80-225]) elephants in the 2,500 km^2 area. The population is thus of national significance, containing possibly the second largest elephant population in Peninsular Malaysia, and with effective management elephant numbers could probably double. We used the data from our survey plus other sources to conduct a population viability analysis to assess relative extinction risk under different management scenarios. Our results demonstrate that the population cannot sustain even very low levels of removal for translocation or anything other than occasional poaching. We describe, therefore, an alternative approach, informed by this analysis, which focuses on in situ management and non-translocation-based methods for preventing or mitigating HEC. The recommended approach includes an increase in law enforcement to protect the elephants and their habitat, maintenance of habitat connectivity between the ERL and other elephant habitat, and a new focus on adaptive management.© 2020 The Authors.

F. Sach, E.S. Dierenfeld, S.C. Langley-Evans, E. Hamilton, R.M. Lark, L. Yon & M.J. Watts

Potential bio-indicators for assessment of mineral status in elephants

Scientific Reports 10 (2020) e8032

Abstract. The aim of this study was two-fold: (1) identify suitable bio-indicators to assess elemental status in elephants using captive elephant samples, and (2) understand how geochemistry influences mineral intake. Tail hair, toenail, faeces, plasma and urine were collected quarterly from 21 elephants at five UK zoos. All elephant food, soil from enclosure(s), and drinking water were also sampled. Elemental analysis was conducted on all samples, using inductively coupled plasma mass spectrometry, focusing on biologically functional minerals (Ca, Cu, Fe, K, Mg, Mn, Na, P, Se and Zn) and trace metals (As, Cd, Pb, U and V). Linear mixed modelling was used to identify how keeper-fed diet, water and soil were reflected in sample bio-indicators. No sample matrix reflected the status of all assessed elements. Toenail was the best bio-indicator of intake for the most elements reviewed in this study, with keeper-fed diet being the strongest predictor. Calcium status was reflected in faeces, (p 0.019, R^2 between elephant within zoo - 0.608). In this study urine was of no value in determining mineral status here and plasma was of limited value. Results aimed to define the most suitable bio-indicators to assess captive animal health and encourage onward application to wildlife management. © 2020 The Authors.

Willem Schaftenaar

The challenge of obtaining reference values for use in captive animals like elephants

Veterinary Quarterly 40 (2020) 115-117

Abstract. none.

A. Sengupta, V.V. Binoy & . Radhakrishna

Human-elephant conflict in Kerala, India: A rapid appraisal using compensation records

Human Ecology 48 (2020) 101-109

Abstract. No permission to print the abstract.

N. Sharma, S.S. Pokharel, S. Kohshima & R. Sukumar

Behavioural responses of free-ranging Asian elephants (*Elephas maximus*) towards dying and dead conspecifics

Primates 61 (2020) 129-138

Abstract. Reactions to dying and dead conspecifics have been observed in many non-human animals. Elephants, particularly African elephants, are thought to have an awareness of the death of their conspecifics, as they show compassionate behaviour towards others in distress. However, there is a paucity of scientific documentation on thanatological responses displayed by Asian elephants. Here, we report three detailed, directly observed cases of free-ranging Asian elephants (*Elephas maximus*) responding to dying and dead conspecifics. Behavioural responses were recorded opportunistically and described as pre-, peri- and post-mortem phases based on the status of the individual before, near or after its death. In all three observations, elephants showed approach and exploratory (sniffing and inspecting) behaviours, and epimeletic or helping (physically supporting dying calves) in pre- and peri-mortem phases. We also recorded high-frequency vocalizations (trumpets) by an adult female in the presence of a dying calf. Our observations indicate that, like their African counterparts, Asian elephants might experience distress in response to the death of conspecifics, and may have some awareness of death. This information furthers our understanding of the emotional and cognitive complexities of highly social elephants, and contributes to the growing field of elephant thanatology. © 2019 Japan Monkey Centre and Springer Japan KK.

N. Sharma, V. Prakash S., S. Kohshima & R. Sukumar

Asian elephants modulate their vocalizations when disturbed

Animal Behaviour 160 (2020) 99-111

Abstract. When disturbed, animals use various modes of communication to alert conspecifics about the source of danger. Some species have evolved graded or continuous signals specific to the type of threats. African elephants, *Loxodonta africana*, are known to differentiate between threats from bees and humans by changing the energy concentrations of their alarm calls. However, the mechanism by which Asian elephants, *Elephas maximus*, use vocalizations to alert conspecifics about imminent danger remains poorly explored. To understand disturbance-induced communication in free-ranging Asian elephants, we compared two call types, 'rumbles' (low-frequency calls) and 'trumpets' (high-frequency calls), produced in disturbed (by humans or other animals) and undisturbed (social interaction) states. We then analysed acoustic characters for both call types: absolute frequency parameters including fundamental frequency (F0), mean, minimum, maximum and range; temporal parameters including call duration, time to minimum F0, time to maximum F0, peak time and minimum time; and filter-related parameters including mean, minimum and maximum of first (F1) and second (F2) formant locations. We found that under disturbed conditions, Asian elephants increased the duration of rumbles and decreased the duration of trumpets. Similarly, the mean F0 and mean positions of F1 and F2 of rumbles decreased compared with the undisturbed condition; among trumpets, no significant differences were observed in mean F0 or formant position in either F1 or F2 between the two contexts. We also found that the duration of rumbles was influenced by an interaction between group size and context: smaller groups produced longer rumbles when disturbed. These results suggest that when disturbed Asian elephants can modify vocal signals whose likely function could be to alert conspecifics about potential threats. © 2019 Reprinted with permission from the Association for the Study of Animal Behaviour.

P. Sharma, S. Panthi, S.K. Yadav, M. Bhatta, A. Karki, T. Duncan, M. Poudel & K.P. Acharya

Suitable habitat of wild Asian elephant in Western Terai of Nepal

Ecology and Evolution 10 (2020) 6112-6119

Abstract. There is currently very little available research on the habitat suitability, the influence of infrastructure on distribution, and the extent and connectivity of habitat available to the wild Asian elephant (*Elephas maximus*). Information related to the habitat is crucial for conservation of this species. In this study, we identified suitable habitat for wild Asian elephants in the Western Terai region of Nepal using Maximum Entropy (MaxEnt) software. Of 9,207 km^2, we identified 3194.82 km^2 as suitable habitat for wild Asian elephants in the study area. Approximately 40% of identified habitat occurs in existing protected areas. Most of these habitat patches are smaller than previous estimations of the species home range, and this may reduce the probability of the species continued survival in the study area. Proximity to roads was identified as the most important factor defining habitat suitability, with elephants preferring habitats far from roads. We conclude that further habitat fragmentation in the study area can be reduced by avoiding the construction of new roads and connectivity between areas of existing suitable habitat can be increased through the identification and management of wildlife corridors between habitat patches. © 2020 The Authors.

J.E. Smith, C.A. Ortiz, M.T. Buhbe & M. van Vugt

Obstacles and opportunities for female leadership in mammalian societies: A comparative perspective

The Leadership Quarterly 31 (2020) e101267

Abstract. Women remain universally underrepresented in the top leadership positions. A comparative evolutionary framework may offer new insights into the value of and potential barriers to female leadership. Here we define leaders as individuals who impose a disproportional influence on the collective behaviors of group members. We reviewed data for 76 social species of non-human mammals to reveal the circumstances favoring female leadership and species exhibiting female-biased leadership in two or more contexts (e.g., collective movements, group foraging, conflict resolution within groups, or conflicts between groups). Although rare across the lineage, female-biased leadership is pervasive in killer whales, lions, spotted hyenas, bonobos, lemurs, and elephants; leaders emerge without coercion and followers benefit from the social support and/or ecological knowledge from elder females. Our synthesis elucidates barriers to female leadership, but also reveals that traditional operationalizations of leadership are themselves male-biased. We therefore propose a new agenda for assessing the overlooked ways that females exert influence in groups. © 2018 Reprinted with permission from Elsevier.

C. Soundararajan, K.P. Prabhu, K. Nagarajan & T. Divya

Wound and gastric myiasis due to *Chrysomyia bezziana* and *Cobbaldia elephantis* and its pathological lesions in wild elephants in the Nilgiris hills of Tamil Nadu

Journal of Parasitic Diseases 43 (2019) 134-138

Abstract. Thirty-five years old female and 12 years old male wild elephant were found dead at Seviyodu and Cherangode of Cherambadi range at Nilgiris district, Tamil Nadu state. On post mortem examination, maggots were recovered from palate of oral cavity and gastric mucosa of the stomach and identified as *Chrysomyia bezziana* and *Cobbaldia elephantis*, respectively. Histopathology of oral tissue specimen revealed myonecrosis of soft palate due to myiasis and cross section of encysted larvae surrounded by fibrous capsule and inflammatory cells. This study reports the mixed infection of wound and gastric myiasis due to *C. bezziana* and *C. elephantis* and its histopathological lesions in wild elephants. © 2018 Indian Society for Parasitology.

S. Sripiboon, W. Ditcham, R. Vaughan-Higgins, B. Jackson, I. Robertson, C. Thitaram, T. Angkawanish, S. Phatthanakunanan, P. Lertwatcharasarakul & K. Warren

Subclinical infection of captive Asian elephants (*Elephas maximus*) in Thailand with elephant endotheliotropic herpesvirus

Archives of Virology 165 (2020) 397-401

Abstract. No permission to print the abstract.

K. Takehana, R, Kitani, K. Hatate, R, Onomi & N. Yamagishi

Anthropometric and blood data on a hand-reared captive Asian elephant (*Elephas maximus*) calf: A retrospective case report

J. of Vet. Medical Science 82 (2020) 943-947

Abstract. The anthropometric and blood data of an unsuccessfully hand-reared Asian elephant (*Elephas maximus*) calf were retrospectively compared with the data for calves raised by their real mothers or allomothers, to identify potential reasons for poor outcomes in the hand-reared case. The hand-reared calf grew normally in terms of body weight and withers height. However, blood biochemical data suggested reduced bone metabolism, low immune status, and malnutrition during its life. Blood bone markers were measured to determine whether a skeletal disorder was present in the Asian elephant calf, which was not clear from the anthropometric data. Monitoring these parameters in hand-reared Asian elephant calves, with the aim of keeping them within the normal range, may increase the success rate of hand-rearing of Asian elephant calves. © 2020 The Japanese Society of Veterinary Science.

S.N. Teng, C. Xu, L. Teng & J.-C. Svenning

Long-term effects of cultural filtering on megafauna species distributions across China

PNAS 117 (2020) 486-493

Abstract. Human activities currently play a dominant role in shaping and eroding Earth's biodiversity, but the historical dynamics leading to this situation are poorly understood and contentious. Importantly, these dynamics are often studied and discussed without an emphasis on cultural evolution, despite its potential importance for past and present biodiversity dynamics. Here, we investigate whether cultural filtering, defined as the impact of cultural evolution on species presence, has driven the range dynamics of five historically widespread megafauna taxa (Asiatic elephant, rhinoceroses, tiger, Asiatic black bear, and brown bear) across China over the past 2 millennia. Data on megafauna and sociocultural history were compiled from Chinese administrative records. While faunal dynamics in China are often linked to climate change at these time scales, our results reveal cultural filtering as the dominant driver of range contractions in all five taxa. This finding suggests that the millennia-long spread of agricultural land and agricultural intensification, often accompanied by expansion of the Han culture, has been responsible for the extirpation of these megafauna species from much of China. Our results suggest that cultural filtering is important for understanding society's role in the assembly of contemporary communities from historical regional species pools. Our study provides direct evidence that cultural evolution since ancient times has overshadowed climate change in shaping broadscale megafauna biodiversity patterns, reflecting the strong and increasing importance of sociocultural processes in the biosphere.

D.Vasudev, V.R. Goswami, P. Hait, P. Sharma, B. Joshi, Y. Karpate & P.K. Prasad

Conservation opportunities and challenges emerge from assessing nuanced stakeholder attitudes towards the Asian elephant in tea estates of Assam, Northeast India

Global Ecology and Conserv. 22 (2020) e00936

Abstract. Interactions between wildlife and people lie at the core of conservation planning in heterogeneous landscapes. Understanding stakeholder perspectives towards wildlife is a key endeavour in this regard. In particular, it can be useful to separate notional or generic attitudes towards wildlife, from those that pertain to more practical considerations at localised scales. We assessed nuances in stakeholder attitudes and underlying beliefs towards the endangered Asian elephant *Elephas maximus* – a wide-ranging species that needs landscape-scale conservation, while also being an animal that is both culturally revered and conflict-prone. We instrumented semi-structured questionnaire surveys using a 5-point Likert score, to 2252 respondents representing tea estate labour and management across 17 estates in the Kaziranga–Karbi Anglong landscape of Assam, Northeast India. Respondents were overwhelmingly positive (80–98%) towards elephants notionally. In our landscape, this stemmed more from cultural links and beliefs about the animal's intrinsic right to persist, rather than utilitarian benefits in terms of ecosystem health. At localised scales, responses were more varied with issues relating to safety concerns and crop loss maximally inciting non-positive responses. Similarly, stakeholder attitudes towards elephant conservation at localised scales were varied. Elephant use of lands outside forests, for instance, incited equivocal responses. Interestingly, while safety concerns clearly limit the potential for human-elephant co-occurrence, stakeholders still believed that elephants do not harm people unprovoked; this highlights the opportunities a culture of tolerance provides for stakeholder support of, and engagement with, wildlife conservation. Ultimately, understanding stakeholder attitudes can determine our ability to encourage 'wildlife-friendly' behavioural change and shape human-wildlife interactions into the future.

Z. Wang, Z. Li, Y. Tang, C. Yao, Y. Liu, G. Jiang, F. Wang, L. Liang, W. Zhao, G. Zhu & M. Chen

China's dams isolate Asian elephants

Science 367 (2020) 373-374

Abstract. none.

Elephants at Minneriya National Park, Sri Lanka

News Briefs

Compiled by Jayantha Jayewardene

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1. Indonesia probes death of 5 protected Sumatran elephants

China.org.cn - 16.1.2020

The Indonesian police have been investigating the death of five Sumatran elephants, in order to preserve the critically endangered animal in the vast-archipelagic country. Earlier this month, five skeletons of the Sumatran elephants were discovered in an oil palm plantation in Aceh province's district of Aceh Jaya on the northern tip of Sumatra Island. Local police investigators said on Wednesday that they had questioned several people and some of them were potentially declared suspects in the poaching of the giant animals.

The investigation focused on the existence of an electric fence on the scene, which is believed to be placed to ensnare elephants, not wild pigs. "Based on information from the electricity firm, the electric fence was made for elephants," said Putra. The Sumatran elephant is a sub-species of Asian elephant which is extremely rare at present with a population of just over 2,000 based on the estimation in 2000.The Sumatran elephants occur exclusively on Sumatra Island, but their number has plunged as they lost more than 80% of habitat due to deforestation.

2. Jumbo electrocution on rise in Dhenkanal (India)

The Orissa Post - 18.1.2020

Deaths of elephants due to electrocution are on the rise in Dhenkanal. While many cases are the fallout of accidental contacts with live electricity wires, poachers in some ranges killed the animals by laying electrically charged wires. It was alleged that electrocution of elephants by poachers is increasing due to lack of patrolling by the forest officials. Over last five years, 21 elephants have died due to electrocution. Besides, CESU, the distribution company, was accused of adopting a casual attitude towards illegal hooking from its transmission wires. The animals suffered huge blow October 27, 2018 when seven elephants came in contact with live electric wires at Kamalang village and died.

Some experts pointed out that large-scale tree felling and unplanned industrial activities in the forest vicinities have also pushed the elephants to nearby villages in search of food and water causing serious problems for both humans and elephants. Human-animal conflict is another factor responsible for the alarming rise of elephant deaths. It has raised serious concern among environmentalists and wildlife enthusiasts. As for electrocution of elephants, DFO Bimal Prasanna Acharya said the forest department is to find out the wires laid by poachers for hunting animals while the energy department is supposed to detect illegal hooking meant to kill elephants.

3. New MoEF guidelines for elephant deaths from anthrax (India)

Down to Earth Magazine – 17.1.2020

An official team to oversee safe disposal of elephant carcasses infected with anthrax as well as a map of anthrax hotspots are some of the steps recommended in a new standard operating procedure (SOP) formulated by the Union Ministry of Environment, Forest and Climate Change (MoEF&CC). The overall authority responsible at the state level under the SOP's provisions will be the chief wildlife warden, in accordance with the Wildlife (Protection) Act,

1972. The SOP also lays down rules for the constitution of a team to oversee assessment and disposal of elephant carcasses suspected to be infected with anthrax.

The procedure will also have steps to assess whether the elephant died due to anthrax and the collection of biological samples. A map of anthrax hotspots is to be created as well. "The deaths of elephants due to anthrax are not widespread. But they occur sporadically. That was the trigger to form this SOP. One can only know if an elephant has died from anthrax after proper post-mortem is done. This SOP has the provisions for that. Anthrax is an infectious zoonotic disease, which means it could be transferred from animals to humans. It is primarily a disease of herbivorous animals particularly cattle, sheep, goats, horses and mules. It occurs among omnivores and carnivores through contaminated meat, bone meals or other feeds; and among wild animals from feeding on anthrax-infected carcasses. Infected animals shed the bacilli in terminal haemorrhage or spilt blood at death. Anthrax spores can persist in soil for many years.

4. Yunnan looks to boost protection of Asian elephant (China)

Ecns.cn – 22.1.2020

Multiple efforts will be made in Yunnan province to strengthen the protection of wild Asian elephants. A total of 7500 ha of land will be transformed into a new habitat for the elephants, according to Yunnan Forestry and Grassland Administration. Based on current surveillance of the province's elephants, the newly added habitat will cover six areas in the province, including Pu'er city, Jinghong city and Xishuangbanna Dai autonomous prefecture.

The number of wild Asian elephants in China – all of which live in Yunnan – has doubled to about 300 thanks to protection efforts. Yunnan has established 11 nature reserves with a total area of about 510,000 ha. The area inhabited by wild Asian elephants in the province has expanded from seven counties in 2017 to eight last year. The habitat expansion is expected to encourage the elephants to live within a certain area and avoid conflicts with residents. The administration started a pilot project in 2016 to use an elephant alert system using drones in Menghai County, successfully avoiding 46 cases of possible conflicts in the past three years. Moreover, artificial intelligence and broadcast systems have also been introduced to improve the efficiency of the alert system since 2017.

5. Plantation management probed for allegedly hiding death of pygmy elephant (Malaysia)

The Star – 26.1.2020

Wildlife rangers have located the site of a Bornean pygmy elephant that was buried at an oil palm plantation in Sabah's Kinabatangan area after the estate management allegedly hid its death. Sabah Wildlife Department director Augustine Tuuga, when contacted, confirmed that they were investigating the case and are awaiting the full report from their team on the ground. It was learned that wildlife officials had received a tip-off about a week ago claiming that an elephant was buried at a plantation in Kinabatangan. Sources claimed that the senior management decided not to report its death.

Some sources in Kinabatangan indicated that the estate involved had at least three to four previous elephant deaths that were reported to wildlife officials in 2019. A source, who provided a picture of an excavator allegedly used to bury the dead elephant, said that most of the elephants that died in the area were due to suspected poisoning. Under Sabah's wildlife conservation enactment, it is mandatory to report the death of a fully protected animal like elephants. Wildlife investigators suspect that the unrecorded elephant death was done with estate officials knowingly concealing its death.

6. Carcass of skinned elephant found in Ayeyarwady (Myanmar)

The Myanmar Times – 27.1.2020

Local authorities in Ngapudaw Township,

Ayeyarwady Region found a wild elephant poached and skinned with its trunk cut off in Sinma Forest Reserve on Friday. Officials with the forest department, police and administrative authorities were investigating a report by local residents that wild elephants were running in the forest reserve when they found the dead elephant near the Pathein-Mawtin road. The female pachyderm was around 2.5 m tall, over 2 m long and estimated to be 28 years old. According to the elephant veterinarian of the Forest Department, the elephant was killed by a poisoned arrow.

"Elephant poachers had skinned the elephant and were preparing to take it away," said U Kyaw Myint Tun, administrator for Ngapudaw's Tin Chaung Village-Tract. "When they saw us, they left their equipment and ran away. We feel sorry that elephants are being poached despite the fact that we are doing our best to prevent elephant poaching." Friday's poaching was the first case in 2020. A total of six wild elephants died last year, two of them from natural causes and four killed by poachers. In the past, elephants were mainly poached for their tusks but over the past few years they have increasingly been poached for their hides, which are believed to have medicinal properties. Demand for elephant hides has increased and, as with the tusks, the hides are mostly smuggled to China.

7. Telling Numbers: 2361 humans, 510 elephants killed in conflict in five years (India)

The New Indian Express - 13.2.2020

Between 2014–2015 and 2018–2019, 2361 humans were killed as a result of conflict with elephants, while 510 elephants were killed in incidents of electrocution, train accidents, poaching and poisoning during the same period according to data tabled in Parliament by the Ministry of Environment, Forest and Climate Change.

Among elephant deaths caused in conflict with humans, electrocution is the primary cause, accounting for nearly two-thirds of the deaths (333 out of 510). The Wild Life (Protection) Act, 1972 empowers the State Chief Wildlife Warden for taking appropriate measures for management of human wildlife conflict situations. The Ministry of Environment, Forest and Climate Change has issued advisories dated 24th December 2014 and 1st June 2015, in context of human wildlife conflicts to all the States /UT's, wherein they have been requested to take proactive steps including exercise of powers under the Wild Life (Protection) Act, 1972, for mitigation of human wildlife conflict.

8. Poison found in two dead pygmy elephants (Malaysia)

Free Malaysia Today - 15.2.2020

Two female pygmy elephants found dead had died of poison, Sabah's environment minister, Christina Liew, said today. However, the authorities had yet to identify the type of the poison. "We will investigate further," she told reporters here today. The two female Borneo pygmy elephants were found dead at a plantation in Sukau and in the Dermakot Sandakan Reserve Forest. The two deaths are the second and third cases this year following the first carcass found at Lower Kinabatangan last month. Liew said the state government had approved the Sabah State Elephant Action Plan (2020-2029) in an effort to resolve the conflict between humans and elephants in the state. Borneo pygmy elephants form a subspecies of the Asian elephant and are the smallest elephants in Asia. They are listed as an endangered species and are protected under the Wildlife Conservation Enactment.

9. Malaysia develops world's first human-elephant conflict resolution mechanism

Malaysiakini - 18.2.2020

The world's first publicly available human-elephant conflict (HEC) resolution mechanism is being developed with the partnership of the academia with the public and private sectors in the country. The science-backed mechanism in the form of standard operating procedures is made possible by a collaboration between the Management and Ecology of Malaysian Elephants (MEME) and Sime Darby Plantation

Bhd (SDP) through Yayasan Sime Darby to champion the co-existence between humans and the endangered animals. In the next three years under phase three, MEME will be working with various communities on the ground through capacity building to find effective ways to help them manage HEC and test if the intervention is effective as it is aimed at not just reducing HEC, but also to increase the tolerance of the various communities towards elephants.

While noting that Malaysian palm oil is continuously being targeted by international NGOs as well as foreign countries, in particular, the European Union for being unsustainable, Kok said Malaysia is committed to ensure sustainable practices in all the value chain of palm oil production.

10. Odisha finds 'fodder plantation' solution for man-elephant conflict (India)

The New Indian Express - 26.2.2020

With man-elephant conflict in Odisha continuing unabated, the State Government has decided to take up fodder plantation in 1250 acre of land in 2020-2021 to prevent the gentle giants from straying into human habitations in search of food. The situation was at its worst towards the end of the 2019-2020 fiscal as more than 10 human lives were lost in elephant attack in the last one and a half months. Death due to elephant attack has already crossed 75.

Lack of fodder and water, and increase in cropping areas surrounding forests are considered to be the key reasons behind the elephants frequently approaching human habitations. Forest and Environment department officials said the fruitbearing trees will be planted in more than 500 hectare (ha) of land under the Compensatory Afforestation Fund Management and Planning Authority (CAMPA) scheme and Rs 803.65 crore has been approved for 2020-2021.

The fund will be spent for block plantation, assisted natural regeneration, bald hill and fruit-bearing plantation, maintenance and plantation for wildlife management. A senior officer of the department said apart from carrying out the plantation drive, a project will be taken up for revival of 200 water bodies in forest areas and elephant corridors to ensure adequate water for the wild animals under the scheme.

11. Asian elephant gives birth to third calf in SW China

CGTN - 24.2.2020

A 32-year-old Asian elephant gave birth to a calf last Saturday in southwest China's Yunnan Province. This is the third offspring of the elephant called Ping Zai. The baby elephant Jiu Mei, which literally means "the ninth sister," is in good health, according to the Asian Elephant Breeding and Rescue Center where Ping Zai lives. She is 94 cm tall and weighs 85 kg. The calf stood to her feet just 40 min after being born, and was nursed for the first time two hours and 15 min later. The center is closely monitoring the newborn's health. Ping Zai got pregnant in April 2018. She was carefully looked after by the keepers of the center during the 693-day gestation. Located in Xishuangbanna Dai Autonomous Prefecture, a popular tourist destination in China, the Asian Elephant Breeding and Rescue Center was established in November 2008 to carry out artificial breeding research and rescue injured and sick wild elephants. A total of nine elephants were bred at the center since its establishment, and another 11 rescued are now receiving rehabilitation training here.

12. Tamil Nadu farmer electrocutes crop-raiding elephant to death, carcass exhumed (India)

The New Indian Express - 2.3.2020

The Forest Department has arrested one person in connection with killing and secretly burying a tusker who had been on a crop-raiding spree in a far-off village of Vellore. The carcass was exhumed for an autopsy.

A manhunt has been launched to nab two more persons, including the key accused. The incident came to light when the forest personnel on patrolling duty in Gudiyatham Range found that one of the two straying elephants was missing. Enquiries revealed that the elephant was electrocuted to death as it had touched the electrified fence erected on the paddy field owned by S Pichandi of Kudimipatti village.

"After our personnel noticed one of the elephants was missing, an investigation was held secretly. On receiving a tip-off, we traced the perpetrators and nabbed one of them," Sewa Singh told Express. Subsequently, on Monday, the carcass was exhumed in the presence of DFO Bhargava Teja by a team of veterinarians. The arrested person was identified as Selvaraj who had operated an earthmover to dig up a pit to bury the elephant after it was electrocuted. The farmer, S Pitchandi, who had electrified the fence around his paddy field, and the owner of the earthmover Ashok are still at large, sources said, adding a hunt is on to nab them.

13. After tusker, electric fence snaps life of youngster in Vellore (India)

The New Indian Express - 2.3.2020

Close on the heels of a tusker killed in electrocution, a young man died after coming into contact with an electrified fence erected illegally in a farmland at Pallikuppam village near Gudiyattam in Vellore district. 20-year-old S Santhosh Kumar of Poomalai village at Pillayarkuppam was found dead at the land owned by D Mahadevan early on Tuesday. Police sources said Mahadevan went to his land in the early hours and found Santhosh Kumar lying dead. Following information, police reached the spot and retrieved the body.

Mahadevan had cultivated sugarcane and groundnut crops in his two-acre land, and erected an electric fence around the land illegally to prevent wild animals from damaging the crops, the sources said. Santhosh Kumar, unaware of the electric fences, presumably walked in the land at night, before being electrocuted. Deputy Superintendent of Police (DSP), N Balakrishnan told Express, "We have begun the investigation to ascertain how the deceased came into contact with the fence and what for he had gone there." The police had secured the landowner, and a case was registered following a complaint lodged by the victim's father.

14. Myanmar closes elephant camps

The Myanmar Times - 27.3.2020

All elephant camps operated under the Ministry of Natural Resources and Environmental Conservation nationwide have been closed to visitors as a precaution against COVID-19, the Myanmar Timber Enterprise said. U Saw John Shwe Ba, managing director of the MTE, said the ministry ordered elephants camps to stop accepting visitors on Tuesday, and they will re-open only after the pandemic is contained. "Our elephant camps are not as crowded as shopping centres and city buses, but we will close them as a precaution," he said, adding that while the camps will be closed until at least April 30, their staffs will stay on to maintain them. Among the more popular camps in the country is the Palin River View elephant camp in Nyaung-U township in Mandalay Region, which suspended operations on Wednesday. The MTE operates 22 elephant camps nationwide, U Saw John Shwe Ba said.

15. Study suggests elephants may get drunk naturally after all

Phys.org - 29.4.2020

A team of researchers at the University of Calgary has found that variations in ethanol metabolism abilities in different species may account for the "myth" of natural animal intoxication. The group describes comparing mutations in the ADH7 gene in multiple species and what they found by doing so. For many years, there has been anecdotal evidence of wild animals getting drunk and behaving badly after consuming fermented fruits and berries. One notorious example was of elephants consuming fruit from the malura tree after it fell and fermented.

But back in 2005, a team of researchers from the University of Bristol appeared to discredit such stories with a study in which they claimed to have found evidence that elephants were so large that it would take more fruit than they could consume to make them drunk. In this new effort, the researchers suggest that the team at Bristol forgot to account for a major contributing factor to drunkenness. The work involved looking at the gene ADH7—it is present in a wide variety of animals. Its purpose is to instigate the production of enzymes that metabolize ethanol.

Prior research has shown that most primates have an ADH7 mutation that allows them to metabolize ethanol more efficiently than those without it. It is believed the mutation persisted because it allowed primates to consume large amounts of fermented fruits and berries without getting too drunk to function. The researchers looked at ADH7 in 85 mammals and found that many of them, such as horses, cows and elephants, do not have the mutation, and are thus not nearly as good at metabolizing ethanol. This suggests that if such animals were to consume fermented fruits, they would become intoxicated much more easily. Thus, they suggest it is possible that elephants at times become inebriated, and because of that, may behave out of character.

16. Villagers in Assam get respite as hanging fence deters jumbos (India)

The Hindu - 4.5.2020

Elephants in Assam may have finally run into a barrier beyond their ability to bulldoze — a solar-powered hanging electric fence. Camera trap records show the elephants attempting unsuccessfully to enter areas near eight villages, which lie at the edge of a 350 km^2 reserve forest that was added to the Manas National Park in 2016, on at least 59 of the 65 occasions that the pachyderms had been sighted since October 14, 2019. The elephants, however, did manage to cross the fence without damaging it on eight occasions, due to a sudden discharge of the batteries powering it around midnight. But the villagers, who have borne the brunt of the elephant-man conflict, aren't ready as yet to call the latest barrier a success. For that, they would rather wait to see how the fence performs during the monsoon months ahead.

The earlier project entailed stringing a solar-powered fence between two ordinary 7 feet tall poles, set 10 m apart. Elephants, however, would frequently uproot them for gorging on the granaries in the villages. The hanging fence involves sturdier metallic poles with a strong cable strung from the top. Wires arranged 3 feet apart dangle from this cable without touching the ground for letting smaller animals pass.

17. Plan adopted to prevent Kingdom's Asian elephants from extinction (Cambodia)

Phnom Penh Post - 12.5.2020

The Ministry of Environment, in collaboration with Fauna & Flora International (FFI), has adopted an action plan to save Asian elephants in Cambodia from extinction. The conservation plan was compiled by the ministry's General Directorate of Administration for Nature Conservation and Protection (GDANCP) and all stakeholders with technical support from the FFI's Cambodian Elephant Conservation Group (CECG). Established in 2015 by the FFI in cooperation with the ministry and the Forestry Administration, the CECG aims to conserve the endangered species by stabilising and increasing its populations throughout Cambodia.

GDANCP director-general Meas Sophal said the action plan is a significant milestone. "We developed this action plan, the first for Asian elephants in Cambodia, that will guide effective protection of the country's most iconic species," he said. Classified as endangered on the International Union for Conservation of Nature (IUCN) Red List, Asian elephants face a "very high risk" of extinction. Between 400 and 600 of them are believed to remain in Cambodia and are concentrated mainly in the Cardamom Mountains in the southwest of the country and the eastern plains of Mondulkiri province.

Habitat degradation due to deforestation has taken a toll on elephant populations and their long-term survival. Elephant calves have also fallen victim to snares, which hinder population recovery. The action plan aims to strengthen the management of Asian elephants with involvement from all stakeholders so that their populations are protected and able to recover.

18. The carefree life of wild Asian elephants in SW China

CGTN - 12.5.2020

For wild Asian elephants roaming between rainforests and croplands, life is simple. They eat, play and sleep every day. In scorching summer, they love to drink and bath openly in the nitrate-rich pond. This is the natural playground for them to escape the heat and dryness. Just like humans, wild Asian elephants also need to drink salty water to supplement their salt intake. Sometimes, they would even break into villagers' homes to find salt. Although Asian elephants are the largest living land animal in Asia, these giants are plant-lovers. Considering their huge size, they spend 16-18 h eating roots, trees and bark every day. Whenever you see them, they are probably eating or on the way to finding food.

Having lived side by side with farmers in Yunnan for many years, smart wild Asian elephants know the right time to find tasty food like sugarcane in croplands near the rainforest. After the harvest, they would visit the croplands less and return to the rainforest for nourishment. In China, wild Asian elephants only live in Xishuangbanna Dai Autonomous Prefecture, Pu'er and Lincang cities in southern Yunnan. There are about 250 of them left due to habitat loss. In Xishuangbanna National Nature Reserve, people are replanting native plants that elephants favour on degraded land far away from villages in the hope that these giants can stay carefree in their homeland many years to come.

19. Sabah Wildlife rescues elephant with oral abscess caused by brooch

New Straits Times - 22.5.2020

An elephant wandering alone in a forest corridor in Tingkayu was in fact suffering with an abscess in its oral cavity caused by a brooch, which was stuck. Sabah Wildlife department assistant director Dr Sen Nathan, in his Facebook posting, said they were alerted about the presence of the elephant on Tuesday. "A team headed by our Wildlife Rescue Unit veterinarian Dr Navaneetha Roopan arrived in the area they immediately found the poor elephant," he said, adding the 1.5 m tall sub-adult bull elephant was darted, removed and treated around 11 am.

Upon examination, the team found a large abscess had caused swelling to the elephant's left cheek. A brooch that had been stuck in the teeth had caused severe ulceration of its tongue, and the brooch was removed. The abscess was lanced and topical antibiotics were applied and the pus in the oral cavity was rinsed out.

20. Officials discover 5 million-year-old elephant fossils in forests near Dehradun (India)

The Weather Channel – 19.6.2020

A camera-trap study in the reserve forests near Dehradun, which was conducted to develop a new tiger reserve, led to the discovery of one of the world's oldest fossil remains of elephants, dating back to 5 million years. "We are taking the help of 'van gujjars' (a forest tribe), to discover even more," says Sanjay Kumar, the Commissioner of Saharanpur Division of Uttar Pradesh bordering Dehradun, capital of Uttarakhand. The rare fossils of elephants suggest that the foothills of the Himalayas, the beautiful lush green Terai region in Uttarakhand and Uttar Pradesh, were once inhabited by giant elephants, giraffes, horses and hippopotamus.

Commissioner Sanjay Kumar initiated a camera trap study to develop a new tiger reserve in this forest range. "The growing tiger population in Jim Corbett and Eastern Rajaji Park has been migrating gradually towards the west, including Siwalik forests. Therefore we thought to conduct the wildlife study here," Sanjay Kumar, a wildlife enthusiast, told IANS.

The camera trap study, a powerful tool to investigate the presence of animals in a given area, was conducted with help of forest officials and experts of the World Wildlife Fund (WWF) in Siwalik range." In May, last month, the forest officials stumbled upon a rare fossil elephant near a river bed. Chief Conservator V.K. Jain and his team later sent this fossil sample for testing to the Wadia Institute, located in Dehradun. "The scientists at the Wadia Institute have now opined the age of this elephant fossil, ranging from 5-8 million years.

21. Farmer offers jackfruit to jumbos to keep estate safe (India)

The Hindu - 17.6.2020

Distraught over repeated instances of elephants damaging coffee plants in his estate, a planter at Kirehalli in Sakleshpur taluk has been voluntarily offering jackfruit grown in his land to the elephants. Krishne Gowda dumped two tractor loads of fruits along the path usually taken by elephants roaming around the village in the hope that it would satiate them and they would not enter his farm. The farmer owns a 30-acre coffee estate in the village. A herd consisting of more than 20 elephants has been moving around the place for the past few days. Neither planters nor workers can freely walk into their estates, as they could encounter elephants any time. "If they enter our estate, they will eat the jackfruits, besides damaging the coffee plants. He dumped around 1000 kg of jackfruit.

More than 60 elephants have been roaming in Sakleshpur, Yeslur, and Alur forest ranges. The Forest Department gets reports of crop damage caused by the herds every day. The department sends rapid response teams, formed by involving the local youth, to avoid human-elephant encounters. "We park our vehicles facing towards the road. As elephants can show up any time, we flee in the vehicles," said Mr. Gowda. The department sends alerts on the movement of herds through mobile phones. They have radio-collared a few elephants to track the herds. The rapid response teams also alert local people. Many planters have not been able to take up any work in their estates due to the presence of elephants. The planters have demanded that the state government capture all of them.

22. SW China village finds way to ease elephant-human conflict

CGTN - 22.6.2020

Jiangcheng County, located in Puer City in the province, often receive "unpleasant visits" from the wild elephants. Since January, there have been about 96 cases of elephants breaking into the village and causing damage of over two million yuan. Besides, many villagers are fearful of encountering wild elephants as they can harm people. In recent years, the local government has come up with ways to ease these conflicts. A monitoring system that can track the elephants has been set up. Staff of the system will keep eyes on the route the animals take and send evacuation alerts to villagers via radio, text and phone calls if necessary. The government has also purchased insurance plans to compensate villagers for the damage to houses, livestock and crops caused by the incursions. Because of these efforts, the conflicts have eased, without harming the elephants.

23. Elephant population crosses 2000-mark in Uttarakhand, around 30% rise since 2015 (India)

The Hindustan Times - 29.6.2020

With a 29.9% increase since 2015, Uttarakhand government said that the state now has 2026 elephants. Chief minister Trivendra Singh Rawat released the fresh elephant census on Monday during the 15th State Wildlife Advisory Board meeting. Rawat said elephants were counted in Uttarakhand for three days. "It was found that there are a total of 2026 elephants in the state. In 2012, there were 1559 elephants while in 2017 there were 1839 elephants," Rawat said.

For the first time drones were used for counting the jumbos in the hill state. Parag Madhukar Dhakate, who is the coordinator of the forest department's drone force, said the drones flew over forest blocks in a zigzag manner and captured images of elephants that helped in verifying the ground reports.

Instructions for Contributors

Gajah welcomes articles related to Asian elephants, including their conservation, management, and research, and those of general interest such as cultural or religious associations. Manuscripts may present research findings, opinions, commentaries, anecdotal accounts, reviews etc. but should not be mainly promotional.

All articles will be evaluated by the editorial board of *Gajah*. Peer-reviewed articles will be sent out for review. Word limits for submitted articles are for the entire article (title, authors, abstract, text, tables, figure legends, acknowledgements and references).

Correspondence: Readers are encouraged to submit comments, opinions and criticisms of articles published in *Gajah*. Such correspondence should be a maximum of 500 words, and will be edited and published at the discretion of the editorial board.

News and Briefs: Manuscripts on anecdotal accounts and commentaries on any aspect of Asian elephants, information about organizations, and workshop or symposium reports with a maximum of 1000 words are accepted for the "**News and Briefs**" section.

Research papers: Manuscripts reporting original research with a maximum of 5000 words are accepted for the "**Research Article**" section. They should also include an abstract (100 words max.). A second abstract in the local language of the authors is optional (100 words max.). *Gajah* also publishes "**Peer-Reviewed Research Articles**". Peer-reviewed papers will carry a notation to that effect. Authors are requested to specify that they are submitting their paper to the peer-reviewed section. Shorter manuscipts (2000 words max.) will be published as a "**Short Communication**" (no abstract).

Tables and figures should be kept to a minimum. Legends should be typed separately (not incorporated into the figure). Figures and tables should be numbered consecutively and referred to in the text as (Fig. 2) and (Table 4). The lettering on figures must be large enough to be legible after reduction to final print size. Include tables and line drawings in the MS Word document you submit. In addition, all figures must be provided as separate files in JPEG or TIFF format.

References should be indicated in the text by the surnames(s) of the author(s) with the year of publication as in this example: (Olivier 1978 ; Baskaran & Desai 1996; Rajapaksha *et al*. 2004) Avoid if possible, citing references which are hard to access (e.g. reports, unpublished theses). Format citations in the 'References' section as in the following examples, writing out journal titles in full.

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

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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 University Press, Cambridge, UK.

Manuscripts should be submitted by e-mail to the editor <jenny@aim.uzh.ch>. Submission of an article to *Gajah* is taken to indicate that ethical standards of scientific publication have been followed, including obtaining concurrence of all co-authors. Authors are encouraged to read an article such as: Benos *et al*. (2005) Ethics and scientific publication. *Advances in Physiology Education* **29:** 59-74.

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