Recent Publications on Asian Elephants

Compiled by Jennifer Pastorini

Anthropologisches Institut, Universität Zürich, Zürich, Switzerland and
Centre for Conservation and Research, Tissamaharama, Sri Lanka
E-mail: jenny@aim.uzh.ch

If you need additional information on any of the articles, please feel free to contact me. You can also let me know about new (2021) publications on Asian elephants.

Y. An, S. Liu, Y. Sun, F. Shi & R. Beazley
Construction and optimization of an ecological network based on morphological spatial pattern analysis and circuit theory
Landscape Ecology 36 (2021) 2059-2076
Abstract. No permission to print abstract.

J.M.P.N. Anuradha, M. Fujimura, T. Inaoka & N. Sakai
Role of social and human capital in household resilience: Empirical evidence from an agricultural village community with exposure to significant environmental stresses in Sri Lanka
Global Social Welfare 8 (2021) 81-92
Abstract. No permission to print abstract.

T.K. Athira & T.N.C. Vidya
Elephant social systems: What do we know and how have molecular tools helped?
Journal of the Indian Institute of Science 101 (2021) 257-278
Abstract. No permission to print abstract.

R. Badola, T. Ahmed, A.K. Gill, P. Dobriyal, G.C. Das, S. Badola & S.A. Hussain
An incentive-based mitigation strategy to encourage coexistence of large mammals and humans along the foothills of Indian Western Himalayas
Scientific Reports 11 (2021) e5235
Abstract. Escalation of human–wildlife conflict (HWC) is a barrier to the conservation of ecological corridors across the globe. The existing mechanisms to counter HWC are either economically and socially taxing, or ineffective for long-term management. We assessed HWC in the corridor linking the Rajaji and Corbett Tiger Reserves in Uttarakhand, India, and its drivers, along with the benefits derived by local communities from the forest. We designed an innovative incentive-based mitigation mechanism to encourage coexistence of people and wildlife around the corridor. Costs incurred due to conflict and benefits derived from the forest were assessed using semi-structured questionnaire-based personal interviews (n = 757) with representatives from forest dependent households (hh). Fuelwood (1678.7 ± 131 kg hh^{-1} year^{-1}), fodder (4772 ± 186 kg hh^{-1} year^{-1}) and green/dry grass (3359 ± 104 kg hh^{-1} year^{-1}) contributed $3 \pm 1\%$, $6 \pm 0.5\%$ and $9 \pm 1\%$, respectively, to the annual income of dependent households. 69% of the households practising agriculture reported crop damage by wild animals, 19% of the households that owned livestock reported livestock loss, and 1.58% reported attack on humans resulting in injuries. The cost incurred due to crop raiding and livestock depredation was US$ 159.83 ± 1.0 hh^{-1} year^{-1} and US$ 229.32 ± 34.0 hh^{-1} year^{-1}, respectively. Crop loss was positively associated with the number of crops grown per season and cultivation of sugarcane, wheat and pulses, and negatively with distance from forest and cultivation of fodder and finger millet. Livestock depredation was negatively associated with distance from forest and positively with number of livestock owned, primarily calves. The accounting profit from cultivating a hectare of land, in the absence of crop depredation by wild animals, was estimated at US$ 3571.84 ha^{-1} year^{-1} and US$ 361.44 ha^{-1} year^{-1} for the plains and hills, respectively. This value can be used to calculate the payments to be paid to local communities to en-

courage them to adopt HWC resistant agricultural and pastoralism practices. The net present value of benefits from participating in the payments to encourage coexistence programme for 5 years, discounted at 12%, was US$ 12,875.7 ha^{-1} for the plains and US$ 1302.9 ha^{-1} for the hills. © 2021 The Authors.

V.C. Beeck, G. Heilmann, M. Kerscher & A.S. Stoeger

A novel theory of Asian elephant high-frequency squeak production

BMC Biology 19 (2021) e121

Abstract. Anatomical and cognitive adaptations to overcome morpho-mechanical limitations of laryngeal sound production, where body size and the related vocal apparatus dimensions determine the fundamental frequency, increase vocal diversity across taxa. Elephants flexibly use laryngeal and trunk-based vocalizations to form a repertoire ranging from infrasonic rumbles to higher-pitched trumpets. Moreover, they are among the few evolutionarily distantly related animals (humans, pinnipeds, cetaceans, birds) capable of imitating species-atypical sounds. Yet, their vocal plasticity has so far not been related to functions within their natural communicative system, in part because not all call types have been systematically studied. Here, we reveal how Asian elephants (*Elephas maximus*) produce species-specific squeaks (F0 300–2300 Hz) by using acoustic camera recordings to visualize sound emission and examining this alongside acoustic, behavioral, and morphological data across seven captive groups. We found that squeaks were emitted through the closed mouth in synchrony with cheek depression and retraction of the labial angles. The simultaneous emission of squeaks with nasal snorts (biphonation) in one individual confirmed that squeak production was independent of nasal passage involvement and this implicated oral sound production. The squeaks' spectral structure is incongruent with laryngeal sound production and aerodynamic whistles, pointing to tissue vibration as the sound source. Anatomical considerations suggest that the longitudinal closed lips function as the vibrators. Acoustic and temporal parameters exhibit high intra- and inter-individual variability that enables individual but no call-subtype classification. Only 19 of 56 study subjects were recorded to squeak, mostly during alarming contexts and social arousal but some also on command. Our results strongly suggest that Asian elephants force air from the small oral cavity through the tensed lips, inducing self-sustained lip vibration. Besides human brass players, lip buzzing is not described elsewhere in the animal kingdom. Given the complexity of the proposed mechanism, the surprising absence of squeaking in most of the unrelated subjects and the indication for volitional control, we hypothesize that squeak production involves social learning. Our study offers new insights into how vocal and cognitive flexibility enables mammals to overcome size-related limitations of laryngeal sound production. This flexibility enables Asian elephants to exploit a frequency range spanning seven octaves within their communicative system. © 2021 The Authors.

C.E. Bentley, J.M. Cracknell, A.C. Kitchener, Y. Martinez Pereira & R. Pizzi

Improved diagnosis of foot osteoarthritis in elephants (*Elephas maximus*, *Loxodanta africana*) using stereoradiography

Journal of Zoo and Wildlife Medicine 52 (2021) 67-74

Abstract. Diagnosis of foot disease in elephants is challenging. Owing to their large size, the available diagnostic tools and the expense of imaging are diagnostically limiting. Stereoradiography is the preparation of paired radiographs that form a three-dimensional (3D) image when viewed stereoscopically. Clinicians and veterinary students graded osteoarthritis in the feet of African (*Loxodonta africana*) and Asian (*Elephas maximus*) elephants taken postmortem with standard 2D radiographs, as well as 3D stereoradiographs. These gradings were compared with the actual gross pathology identified in the specimens. Although veterinary students diagnoses were no better than chance from 2D radiographs, 83.6% of the students could correctly differentiate severity between joints on stereoradiography; this is an absolute improvement of 30.1% (95% confidence interval [CI] = 19.6%–40.6%). Overall, participants were 27.4% (95% CI = 18.4%–36.3%) more

successful at diagnosing pathology on stereoradiographs. Half of participants were shown standard 2D radiographs first, the others stereoradiographs first, but the difference in gradings between the two groups was not statistically significant. Stereoradiography appears to hold the potential to improve diagnosis of osteoarthritis in elephant feet, particularly by less experienced clinicians, and the technique is low-cost and applicable under field conditions. © 2021 American Association of Zoo Veterinarians.

C. Boehlke, S. Schuster, L. Kauthe, O. Zierau & C. Hannig

Nutritional influences on enzyme activities in saliva of Asian and African elephants

Journal of Comparative Physiology B 191 (2021) 955-970

Abstract. Asian and African elephants show morphological adaptations to their ecological niche including the oral cavity. Variety and preferences of forage plants differ between both herbivorous elephant species. Diet can affect salivary enzymes. Asian elephants were shown to have a higher salivary amylase activity than African elephants. Species-specific differences were presumed to be influenced by feeding during collection procedure. This study aimed to determine the influence of feeding on enzyme activities in saliva of both elephant species to differentiate from species-specific effects. Additionally, season and housing conditions on salivary enzyme activities in non-fed elephants of both species were investigated. Salivary amylase (sAA), lysozyme (sLYS) and peroxidase (sPOD) activity were measured photometrically or fluorometrically. Results of this study reinforce previous observations of higher basic sAA activity in Asian elephants compared to African elephants. Salivary LYS and sPOD activity showed neither species-specific nor housing-specific differences. Independent from season, most elephants of both species revealed a lack of or low sPOD activity. Feeding caused a temporary decrease of sAA, sLYS and sPOD activity in both elephant species kept in four of eight tested zoos. Furthermore, sAA activity in Asian elephants was higher and sLYS activity lower in spring than in autumn. This study summarizes that sAA and sLYS are components of Asian and African elephant saliva in an active conformation in contrast to sPOD. Diet varying between season and zoos might influence sAA and sLYS activities primarily in Asian elephants but temporary low effects suggest sufficient buffer capacity of elephant saliva of both species. © 2021 The Authors.

A. Brady, B.J. McMahon & F. Naulty

Estimates of locomotion in Asian elephants *Elephas maximus* using video monitoring at Dublin Zoo, Ireland

Journal of Zoo and Aquarium Research 9 (2021) 124-133

Abstract. Welfare of elephants in zoos is a major concern within the public and zoo community. Asian elephants *Elephas maximus* are classified as endangered with one in three currently in human care. Elephants, in particular, are known to suffer from a number of health and behavioural issues when held in a zoo environment and physical activity is particularly important, with a lack of exercise leading to health issues, such as obesity, arthritis and foot problems. The aim of this study was to examine locomotory behaviour and associated habitat use in the adult members of the Dublin Zoo herd over a 2-month period using pre-recorded closed circuit television (CCTV) footage. Distance travelled was calculated using video footage and a grid overlay system to manually track the movements within the habitat. A total of 84 randomly selected 20-min focal observations were collected per individual over a 42 day period. Overall, the elephants in Dublin Zoo were found to display behaviours and travel distances comparable to those in the wild. The mean daily distance travelled (24 hours) was 9.35 km/day. Asian elephant herds in the wild travel distances of 5–10 km/day during non-extreme weather conditions. Free-ranging elephants are reported to spend 60–80% active hours feeding and up to 20 hours of their day is spent actively moving. The elephants in Dublin Zoo were found to spend 50% of their time foraging and 18% engaging in locomotion. Dublin Zoo elephants displayed locomotion and behavioural patterns more similar to the wild than to previous zoo studies. This study provides

baseline data on the Dublin Zoo herd adding to existing knowledge about locomotion in Asian elephants in urban zoo environments in addition to demonstrating the applicability of CCTV footage to zoo behavioural studies.

J. Caballero-Gómez, I. García-Bocanegra, N. Navarro, R. Guerra, E. Martínez-Nevado, P. Soriano & D. Cano-Terrizaa

Zoo animals as sentinels for Schmallenberg virus monitoring in Spain

Veterinary Microbiology 252 (2021) e108927

Abstract. Schmallenberg virus (SBV) is a newly emerged vector-borne pathogen that affects many domestic and wild animal species. A serosurvey was carried out to assess SBV exposure in zoo animals in Spain and to determine the dynamics of seropositivity in longitudinally sampled individuals. Between 2002 and 2019, sera from 278 animals belonging to 73 different species were collected from five zoos (A–E). Thirty-one of these animals were longitudinally sampled at three of these zoo parks during the study period. Seropositivity was detected in 28 (10.1%) of 278 animals analyzed by blocking ELISA. Specific anti-SBV antibodies were confirmed in 20 (7.2%; 95% CI: 4.2–10.3) animals of six different species using virus neutralization test (VNT). The multiple logistic regression model showed that "order" (Artiodactyla) and "zoo provenance" (zoo B; southern Spain) were risk factors potentially associated with SBV exposure. Two (8.7 %) of the 31 longitudinally-sampled individuals showed specific antibodies against SBV at all samplings whereas seroconversion was detected in one mouflon (*Ovis aries musimon*) and one Asian elephant (*Elephas maximus*) in 2016 and 2019, respectively. To the best of the author's knowledge, this is the first surveillance conducted on SBV in zoos in Spain. The results confirm SBV exposure in zoo animals in this country and indicate circulation of the virus before the first Schmallenberg disease outbreak was reported in Spain. Surveillance in zoological parks could be a complementary approach to monitoring SBV activity. Further studies are warranted to assess the impact of this virus on the health status of susceptible zoo animals. © 2020 Reprinted with permission from Elsevier.

K.L. Carrothers, L.E. Goodmiller, M.J. McLellan & A.M. Spicer

A novel approach to combatting proboscidean ivory trafficking using a multiplex High-Resolution Melt (M-HRM) assay

Forensic Science International: Genetics 53 (2021) e102511

Abstract. To support efforts in prosecuting wildlife crimes, we developed and validated a multiplex High-Resolution Melt (M-HRM) assay for the identification of proboscidean taxa commonly required to be identified or excluded in ivory seizures and forensic casework: Asian elephant (*Elephas maximus*), African elephant (*Loxodonta* spp.), mammoth (*Mammuthus* spp.), and mastodon (*Mammut* spp.). Five hundred and fifty (550) blood, tissue, and ivory samples from individuals of these 4 proboscidean taxa were used to develop and validate the 2 proboscidean-specific mitochondrial sites targeted by this assay. The 28-basepair (bp) 16S ribosomal RNA (rRNA) and 54-bp cytochrome b (Cytb) gene segments yield a combination of melt peaks that create composite melt profiles unique to each of the 4 proboscidean taxa. Wildlife forensic laboratories can use this sensitive, rapid, and cost-effective assay to assist efforts to combat the unlawful commercialization of proboscidean ivory and to stop the poaching crisis leading to the decline of these ivory-bearing species in the wild. © 2021 The Authors.

S. Chen, G.-Z. Sun, Y. Wang, C. Huang, Y. Chen, P. Liu, Y. Deng, D.-F. Cao, M.-X. Zhang, S. Ong, H.-P. Yang, Q.-Y. Wang, Z.-Y. Zhang, B. Wang, X. Zheng, Y. Lei, C. Li, J. Sun, M.-W. Bao, Z.-C. Yang, L. Guan, Y.-K. Sun, F.-Y. Zhou, J.-X. Liu, L.-L. Li, F. Wang, R.T. Corlett, R.-C. Quan, M.-Y. Chen, L. Zhang, K. Shi & A. Campos-Arceiz

A multistakeholder exercise to identify research and conservation priorities for Asian elephants in China

Global Ecology and Conservation 27 (2021) e01561

Abstract. China is home to a small but expanding population of wild Asian elephants (*Elephas maximus*). Both research interest and conservation efforts have increased in recent years, but these have been fragmented. Here we present

the results from a collaborative, multi-sectorial, multi-stakeholder exercise to identify priorities for Chinese elephant research and conservation. We first compiled a comprehensive list of issues, categorized under nine research and nine conservation themes, through an on-line survey of stakeholders. These issues were subsequently consolidated, timelined (as short-, mid-, or long-term issues), and ranked by their perceived priority in a two-day workshop attended by 44 people representing 28 organizations. The initial list of 656 issues (337 research and 319 conservation) was consolidated into a list of 251 (121 research and 130 conservation) issues. After priority ranking, we retained the top-three issues within each theme (making a total of 55 priority issues, due to a tie), which are then discussed in detail in this paper. Most (87%, n=55) priority issues were classified as short-term, suggesting that the exercise might have succeeded in identifying the current priorities, but not emerging issues that might require attention in future. Some issues appeared in various forms in different themes. Among research questions, participants highlighted the importance of understanding the carrying capacity of the current elephant range habitats, elephant movement patterns and expected range changes, the drivers of human-elephant conflict (HEC), improvements to the current HEC financial compensation mechanism, and ways of engaging local communities in HEC mitigation. Regarding elephant conservation, recurrent issues included effectively engaging communities, improving HEC early-warning systems and financial compensation mechanisms, establishing a new national park within elephant range, and creating mechanisms for communication and collaboration among elephant research and conservation stakeholders in China. Our exercise was effective in engaging experts from a diversity of different sectors and organizations in discussions about Asian elephants in China, and generated a list of priorities that can help guide elephant research and conservation efforts. © 2021 The Authors.

D.E. Chusyd, T.R. Nagy, L. Golzarri-Arroyo, S.L. Dickinson, J.R. Speakman, C. Hambly, M.S. Johnson, D.B. Allison & J.L. Brown

Adiposity, reproductive and metabolic health, and activity levels in zoo Asian elephant (*Elephas maximus*)

Journal of Experimental Biology 224 (2021) jeb219543

Abstract. Many captive Asian elephant populations are not self-sustaining, possibly due in part to obesity-related health and reproductive issues. This study investigated relationships between estimated body composition and metabolic function, inflammatory markers, ovarian activity (females only) and physical activity levels in 44 Asian elephants (n=35 females, n=9 males). Deuterium dilution was used to measure total body water from which fat mass (FM) and fat-free mass (FFM) could be derived to estimate body composition. Serum was analyzed for progestagens and estradiol (females only), deuterium, glucose, insulin and amyloid A. Physical activity was assessed by an accelerometer placed on the elephant's front leg for at least 2 days. Relative fat mass (RFM) – the amount of fat relative to body mass – was calculated to take differences in body size between elephants into consideration. Body fat percentage ranged from 2.01% to 24.59%. Male elephants were heavier (P=0.043), with more FFM (P=0.049), but not FM (P>0.999), than females. For all elephants, estimated RFM (r=0.45, P=0.004) was positively correlated with insulin. Distance walked was negatively correlated with age (r=–0.46, P=0.007). When adjusted for FFM and age (P<0.001), non-cycling females had less fat compared with cycling females, such that for every 100 kg increase in FM, the odds of cycling were 3 times higher (P<0.001). More work is needed to determine what an unhealthy amount of fat is for elephants; however, our results suggest higher adiposity may contribute to metabolic perturbations. © 2021 The Company of Biologists Ltd.

G.R. Clements, S. Rostro-Garciá, J.F. Kamler, S.H. Liang & A.K.B.A. Hashim

Conservation status of large mammals in protected and logged forests of the greater Taman Negara Landscape, Peninsular Malaysia

Biodiversitas 22 (2021) 272-277

Abstract. Peninsular Malaysia contains a large

community of IUCN Threatened mammal species, although recent records in some protected areas is unknown. The greater Taman Negara Landscape is one of the national priority areas for tiger conservation, but the recent occurrence of large mammals in the landscape has not been sufficiently updated. Here, we conducted systematic camera-trap surveys in protected and logged forests of the Taman Negara Landscape: Merapoh in Taman Negara National Park (TNM), and the Dungun Timber Complex (DTC), respectively. We found that the diversity of large mammals in TNM appeared to be the same between 2000 and 2016. The detection frequencies (DF) of several Threatened species, such as Malayan tiger, dhole, and Malayan pangolin, were similar between surveys, suggesting the relative abundance of these species likely remained stable during the past 16 years. However, the DF of Asian elephant and Malayan tapir were lower compared to 2000. In DTC, overall mammalian diversity was relatively lower than in TNM, primarily due to the non-detection of two large ungulates: gaur and sambar. Nevertheless, we recorded several other Threatened species of mammals, suggesting there is potential for this forest reserve to preserve some of Peninsular Malaysia's most Threatened mammal species. Our results suggest that the Taman Negara Landscape is still an important global site for the conservation of several Threatened species, and we recommend an increase in wildlife law enforcement efforts to ensure the survival of its large and diverse mammalian community.

J.A.H. Crawley, O. Lierhmann, D.J. Franco dos Santos, J. Brown, U.K. Nyein, H.H. Aung, W. Htut, Z.M. Oo, M.W. Seltmann, J.L. Webb, M. Lahdenperä & V. Lummaa

Influence of handler relationships and experience on health parameters, glucocorticoid responses and behaviour of semi-captive Asian elephants

Conservation Physiology 9 (2021) coaa116,

Abstract. Declining wild populations combined with accumulating captive populations of e.g. livestock, pets, draught and zoo animals have resulted in some threatened species with substantial proportions of their populations in captivity. The interactions animals have with humans in captivity depend on handler familiarity and relationship quality and can affect animal health, growth and reproduction with consequences for the success of conservation programmes. However, assessments of how specific human–animal relationships affect a range of physiological and behavioural outcomes are rare. Here, we studied semi-captive Asian elephants with detailed records of elephant–handler (mahout) relationships and veterinary management, allowing assessment of multiple welfare indicators in relation to specific mahout–elephant relationship lengths and mahout experience. These included measures of physiological stress (faecal glucocorticoid metabolite [FGM], heterophil:lymphocyte ratio [H:L]), muscle damage (creatine kinase [CK]), immunological health (total white blood cell count [TWBC]) and behaviour (response to mahout verbal commands). We found no evidence that FGM or H:L related to aspects of the mahout–elephant relationship. Longer overall mahout experience (i.e. years of being a mahout) was linked to increased muscle damage and inflammation, but the lengths of specific mahout–elephant relationships were inversely associated with muscle damage in working-age elephants. Elephants responded more to familiar mahouts in behavioural tasks and faster to mahouts they had known for longer. In summary, our results found little evidence that the mahout–elephant relationship affects physiological stress in this population based on FGM and H:L, but mahout experience and relationships were linked to other physiological responses (CK, TWBC), and elephants require behavioural adjustment periods following mahout changes. © 2021 The Authors.

M.P. Deepthi, P. Kathireswari. J. Rini, K. Saminathan & N. Karmegam

Vermitransformation of monogastric *Elephas maximus* and ruminant *Bos taurus* excrements into vermicompost using *Eudrilus eugeniae*

Bioresource Technology 320 (2021) e124302

Abstract. No permission to print abstract.

R. Drinkwater, T. Jucker, J.H.T. Potter, T. Swinfield, D.A. Coomes, E.M. Slade, M.T.P. Gilbert, O.T. Lewis, H. Bernard, M.J. Struebig, E.L. Clare & S.J. Rossiter

Leech blood-meal invertebrate-derived DNA reveals differences in Bornean mammal diversity across habitats

Molecular Ecology 30 (2021) 3299-3312

Abstract. The application of metabarcoding to environmental and invertebrate-derived DNA (eDNA and iDNA) is a new and increasingly applied method for monitoring biodiversity across a diverse range of habitats. This approach is particularly promising for sampling in the biodiverse humid tropics, where rapid land-use change for agriculture means there is a growing need to understand the conservation value of the remaining mosaic and degraded landscapes. Here we use iDNA from blood-feeding leeches (*Haemadipsa picta*) to assess differences in mammalian diversity across a gradient of forest degradation in Sabah, Malaysian Borneo. We screened 557 individual leeches for mammal DNA by targeting fragments of the 16S rRNA gene and detected 14 mammalian genera. We recorded lower mammal diversity in the most heavily degraded forest compared to higher quality twice logged forest. Although the accumulation curves of diversity estimates were comparable across these habitat types, diversity was higher in twice logged forest, with more taxa of conservation concern. In addition, our analysis revealed differences between the community recorded in the heavily logged forest and that of the twice logged forest. By revealing differences in mammal diversity across a human-modified tropical landscape, our study demonstrates the value of iDNA as a noninvasive biomonitoring approach in conservation assessments. © 2020 The Authors.

L.J. Evans, B. Goossens, A.B. Davies, G. Reynolds & G.P. Asnera

Natural and anthropogenic drivers of Bornean elephant movement strategies

Global Ecology and Conservation 22 (2020) e00906

Abstract. Endangered Bornean elephants are severely threatened by ongoing habitat transformation and increasing levels of human-elephant conflict. Understanding how elephants move across intact and transformed landscapes, as well as within them, is therefore of vital importance for the successful implementation of conservation management initiatives. We combined remote sensing and GPS telemetry data to identify broad habitat utilization and key movement areas to aid elephant management and conflict mitigation in three spatially-isolated populations in central and eastern Sabah, Malaysian Borneo. Home ranges were estimated using Brownian Bridge Movement Models and specific behavioral movement traits were identified by pathway analyses. These behavioral traits enabled a fine-scale evaluation of movements between and adjacent to forest patches and the role of large-scale agriculture in shaping elephant movements. Both natural (topological) and anthropogenic (agricultural) landscape features were found to have a broad influence on elephant movements. All elephant populations exhibited human-mediated behavioral responses, regardless of disturbance level. Throughout their range, elephants appeared to actively select relatively degraded forests, as measured by aboveground carbon density. However, elephants actively avoided urbanized areas, including roads and villages. Throughout the elephant range, high-speed, low-trajectory movements were found at low aboveground carbon locations, with 27% of all such movements located in large-scale agriculture. Our results suggest that agriculture impacts movement strategies of elephants, with evidence of repeat agricultural use pointing towards an active rationale for this behavior. Elephants were also found to use ridgelines as movement pathways, providing further context for the protection of such forested areas. The Lower Kinabatangan population, located in small remnant forests, travelled further to meet their ecological needs, suggesting the population is under added strain. Our work represents the broadest landscape assessment of Bornean elephant movements to-date and has important implications for both future work and habitat-level protected area management strategies. © 2020 The Authors.

P. Fernando, M.K.C.R. De Silva, L.K.A. Jayasinghe, H.K. Janaka & J. Pastorini

First country-wide survey of the endangered Asian elephant: Towards better conservation and management in Sri Lanka

Oryx 55 (2021) 46-55

Abstract. The endangered Asian elephant *Elephas maximus* comes into widespread conflict with agrarian communities, necessitating active management. The species' distribution is of primary importance for management planning. However, data-based countrywide distribution maps have not been available for any of the 13 Asian elephant range states. We conducted a 5 × 5 km grid-based questionnaire survey in Sri Lanka to produce an island-wide elephant distribution map. Elephants occur over 59.9% of Sri Lanka and people are resident in 69.4% of elephant range, indicating the challenge of separating people and elephants at a landscape scale. Elephants in Sri Lanka have lost 16.1% of their range since 1960 but their current distribution remains largely contiguous. We found the range of adult males was 15.1% greater, and less seasonal, than that of herds, possibly because males have a higher tolerance for conflict with people. The distribution of conflict coincided with the co-occurrence of humans and elephants. We conclude that a human-elephant coexistence model is the only viable option for effectively mitigating human-elephant conflict and conserving elephants in Sri Lanka. The findings are currently being used to effect a paradigm change in elephant conservation and management in the country. © 2019 Fauna & Flora International.

A. Feuerbacher, C. Lippert, J. Kuenzang & K. Subedi

Low-cost electric fencing for peaceful coexistence: An analysis of human-wildlife conflict mitigation strategies in smallholder agriculture

Biological Conservation 255 (2021) e108919

Abstract. With a growing global population, human-wildlife conflicts (HWCs) are intensifying and cost-effective mitigation strategies to conserve biodiversity and support rural livelihoods become increasingly relevant. This article presents evidence on how low-cost electric fencing (EF) technology can contribute to a peaceful coexistence between farmers and wildlife. Applying an economic analysis, the effectiveness of smallholders' predominant HWC mitigation strategies in Bhutan are assessed. In Bhutan, HWCs are severe and investments in EF are expanding with about 10% of agricultural land already fenced. The analysis reveals high effectiveness and profitability of EF compared with labor-intensive crop guarding strategies despite smallholders' high time preference. EF profitability particularly depends on net labor savings from reduced time-use for crop guarding. Results emphasize the need for collective action at the community level, since due to small landholdings individually operated EF schemes are unprofitable in most cases. The findings are robust across ecological conditions and variations in key parameters, such as the discount rate (reflecting smallholders' time preference) and opportunity cost of labor. Particularly in contexts where hunting is banned, investments in EF technology could be a main ingredient of comprehensive policies for wildlife conservation and agricultural development. Further research is needed to investigate the biological implications of large-scale fencing policies, the relevance of spatial spillover effects and game-theoretic aspects of community-based EF schemes. © 2020 Reprinted with permission from Elsevier.

V.R. Goswami, D. Vasudev, B. Joshi, P. Hait & P. Sharma

Coupled effects of climatic forcing and the human footprint on wildlife movement and space use in a dynamic floodplain landscape

Science of the Total Environment 758 (2021) e144000

Abstract. With climate change, terrestrial fauna in riparian floodplain ecosystems must adapt to a predicted increase in frequency and magnitude of fluvial perturbations. Seasonal migration to seek refuge from floodwaters represents a central adaptation strategy, but may entail risky navigation of anthropogenic spaces in heterogeneous landscapes. Here, we demonstrate the opportunities and constraints large-bodied mammalian herbivores face during an adaptive response of obligatory flood-driven

refuge migration, across a human-dominated environment. Our study system, centred around a productive protected area – Kaziranga National Park in Assam, Northeast India – on the floodplains of the Brahmaputra River, is home to an abundance of large herbivores that undertake seasonal migrations in response to floods. We contrast species distribution data during a major flood event with those from the dry season to illustrate season-specific movement and space use decisions of large herbivores ranging in body mass from the 3000-kg Asian elephant *Elephas maximus* to the 20-kg muntjac *Muntiacus muntjak*. In the dry season, most large herbivores – a majority of which are endangered and threatened by anthropogenic pressures – avoided areas with a strong human footprint, while preferring spaces with high land-use diversity. During the floods, such species were pushed out of inundated habitats within the protected area, and they chose to move through woodlands and areas under bamboo cover on private lands, as they migrated to forested refugia on higher ground. Our results show how seasonal environmental constraints shaped by floods determine the internal motivation of animals to risk traversing a human-dominated space to seek refuge, which contextually defines how animals view and navigate the landscape. Such insights underscore the importance of dynamic and adaptive planning, and participatory conservation efforts, to facilitate connectivity in the changing environment and climate of the present Anthropocene. © 2020 Reprinted with permission from Elsevier.

S.K. Govind & E.A. Jayson

Human–wildlife interactions and people's attitudes towards conservation: A case study from Central Kerala, India

Animal Biodiversity and Conservation 44 (2021) 139-151

Abstract. This paper studies the human-wildlife interaction in Central Kerala, India, and attempts to understand local people's attitude toward wildlife and conservation. Data were collected from April 2009 to March 2014. A structured questionnaire survey was carried out among people living in the fringe areas of the forest (n = 210). Self–reported household crop loss was modelled as a function of agricultural, demographic and environmental factors. Wild pig (*Sus scrofa*) (57.1 %) was the main crop foraging species, followed by Asian elephant (*Elephas maximus*) (12.9 %). It was reported that 36 % of farmers' annual income was lost due to crop foraging by wild animals. Leopard (*Panthera pardus*) (69.76 %), Indian rock python (*Python molurus*) (13.95 %), dhole (*Cuon alpinus*) (9.3 %) and stray dogs (6.97 %) were responsible for the attacks on livestock. The factors that influenced crop loss according to the farmers were the extent of agriculture land that they owned (coefficient = 0.968), the distance to reserve forest from crop fields (–0.009), and age of respondents (0.78). Due to people's awareness concerning the importance of wildlife, reports on human-wildlife interaction in the newspapers and strict enforcement of wildlife laws, people's attitude towards conservation of wildlife was good, and they were not taking any negative precautions against wild animals. © 2021 The Authors.

E.M. Gross, B.P. Lahkar, N. Subedi, V.R. Nyirenda, E. Klebelsberg & O. Jakoby

Elephants in the village: Causes and consequences of property damage in Asia and Africa

Conservation Science and Practice 3 (2021) e343

Abstract. In recent years, reports of elephants causing damage in rural villages by destroying houses and foraging on stored food have been increasing, but little is known about the determinants and magnitude of this damage. In this study, we have examined the extent of property damage by elephants (*Loxodonta africana* and *Elephas maximus*), in one African and two Asian study areas over a six-year period. A total of 1,172 damaged constructions were observed on site, involving detailed damage assessment by trained enumerators and standardized interviews with witnesses. Depending on the study area, between 67.1 and 86.4% of damage events were attributed to single, individual elephants or pairs of males. The majority of properties were damaged in search for food (62.5–76.7% respectively). Property damage caused higher mean losses than crop damage on

farmland in all study areas. Results suggest that property damage by elephants has been largely underestimated and needs to form a focus in future human–elephant conflict research. We suggest a need to reduce the attractiveness of villages by storing food in locked and safe places, away from sleeping areas and to foster the development of elephant safe stores, appropriate to the particular cultural background of the target area. © 2020 The Authors.

T. Guntawang, T. Sittisak, V. Kochagul, S. Srivorakul, K. Photichai, K. Boonsri, T. Janyamethakul, K. Boonprasert, W. Langkaphin, C. Thitaram & K. Pringproa

Pathogenesis of hemorrhagic disease caused by elephant endotheliotropic herpesvirus (EEHV) in Asian elephants (*Elephas maximus*)

Scientific Reports 11 (2021) e12998

Abstract. Elephant endotheliotropic herpesvirus-hemorrhagic disease (EEHV-HD) is an acute fatal disease in elephants. Despite the fact that the underlying pathogenesis of EEHV-HD has been proposed, it remains undetermined as to what mechanisms drive these hemorrhagic and edematous lesions. In the present study, we have investigated and explained the pathogenesis of acute EEHV-HD using blood profiles of EEHV-HD and EEHV-infected cases, hematoxylin and eosin (H&E) stain, special stains, immunohistochemistry, quantitative polymerase chain reaction (PCR) and reverse transcriptase polymerase chain reaction (RT-PCR). It was found that EEHV genomes were predominantly detected in various internal organs of EEHV-HD cases. Damage to endothelial cells, vasculitis and vascular thrombosis of the small blood vessels were also predominantly observed. Increases in platelet endothelial cell adhesion molecules-1 (PECAM-1)- and von Willebrand factor (vWF)-immunolabeling positive cells were significantly noticed in injured blood vessels. The expression of pro-inflammatory cytokine mRNA was significantly up-regulated in EEHV-HD cases when compared to EEHV-negative controls. We have hypothesized that this could be attributed to the systemic inflammation and disruption of small blood vessels, followed by the disseminated intravascular coagulopathy that enhanced hemorrhagic and edematous lesions in EEHV-HD cases. Our findings have brought attention to the potential application of effective preventive and therapeutic protocols to treat EEHV infection in Asian elephants. © 2021 The Authors.

L.J. Hale, K. Shi, T.C. Gilbert, K.S.-H. Peh & P. Riordan

Social structure and demography of a remnant Asian elephant (*Elephas maximus*) population and the implications for survival

Oryx 55 (2021) 473-478

Abstract. The Asian elephant *Elephas maximus* is at risk of extinction as a result of anthropogenic pressures, and remaining populations are often small and fragmented remnants, occupying a fraction of the species' former range. Once widely distributed across China, only a maximum of 245 elephants are estimated to survive across seven small populations. We assessed the Asian elephant population in Nangunhe National Nature Reserve in Lincang Prefecture, China, using camera traps during May–July 2017, to estimate the population size and structure of this genetically important population. Although detection probability was low (0.31), we estimated a total population size of c. 20 individuals, and an effective density of 0.39 elephants per km^2. Social structure indicated a strong sex ratio bias towards females, with only one adult male detected within the population. Most of the elephants associated as one herd but three adult females remained separate from the herd throughout the trapping period. These results highlight the fragility of remnant elephant populations such as Nangunhe and we suggest options such as a managed metapopulation approach for their continued survival in China and more widely. © 2020 The Authors.

N.N.P. Htet, R. Chaiyarat, N. Thongthip, P. Anuracpreeda, N. Youngpoy & P. Chompoopong

Population and distribution of wild Asian elephants (*Elephas maximus*) in Phu Khieo Wildlife Sanctuary, Thailand

PeerJ 9 (2021) e11896

Abstract. The populations of wild Asian elephants (*Elephas maximus*) have increased re-

cently after a period of worldwide decline in protected areas. It is important to understand the dynamics and distribution of the remaining populations to ensure their conservation and prevent human-elephant conflicts. We monitored the population distribution of elephants between 2016 and 2019 in the Phu Khieo Wildlife Sanctuary, Thailand. We set one hundred forty-nine camera trap locations; cameras recorded 38,834 photos over 6,896 trap nights. Elephants were captured in 4,319 photographs. The maximum entropy modeling software MaxEntwas used to identify elephants' habitat preferences within 49 of the 149 total camera trap locations according to five environmental factors. One hundred fourteen elephants were identified. We identified 30 adult males, 43 adult females, 14 sub-adult males, nine sub-adult females, 11 juveniles, and seven calves. The age structure ratio based on adult females was 0.7:1:0.3:0.2 :0.3:0.2, and the ratio of reproductive ability between adult females, juveniles, and calves was 1:0.2:0.1. A suitable elephant habitat was determined to be 1,288.9 km^2 using Area Under the Curve (AUC). An AUC = 0.061 indicated good performance. Our model classified habitat preferences associated with elevation, forests, salt licks, human activity, and slope. According to our probability map this sanctuary can provide a suitable habitat for elephants. Our results indicate that effective management practices can protect wild Asian elephants in the region and reduce conflict between humans and elephants. © 2021 The Authors.

T. Jansson, B.V. Perera, A. Edner & Å. Fahlman

Standing sedation with xylazine and reversal with yohimbine in juvenile Asian elephants (*Elephas maximus*)

Journal of Zoo and Wildlife Medicine 52 (2021) 437-444

Abstract. Evaluation and improvement of immobilization methods are important for wildlife welfare and biodiversity conservation. The sedative and physiological effects of xylazine (50–110 mg per elephant; 0.09–0.15 mg/kg IM) were evaluated in 15 juvenile Asian elephants (*Elephas maximus*) in Sri Lanka. The time from xylazine injection until first sign of sedation, handling, and reversal with yohimbine (0.009–0.03 mg/kg IV) were recorded. Behavioral signs, level of sedation (no effect, light, moderate, or deep) and response to handling were assessed. Rectal temperature, pulse, and respiratory rates were recorded and arterial blood samples were analyzed 30 and 45 min after xylazine injection. The first sign of sedation occurred within 5–18 min. Standing sedation was induced in all elephants, but the level of sedation varied differently over time for each elephant. Twelve elephants remained standing throughout the sedation period, while 3 elephants became laterally recumbent. Sedative effects included lowered head and trunk, droopy ears, snoring, and penis protrusion. Pulse rate, respiratory rate, and rectal temperature ranged between 30–45 beats/min, 4–12 breaths/min, and 35.6–37.2°C, respectively, at 30 min after xylazine injection, and there were no changes over time. Pulmonary function and acid–base balance were adequate (range partial pressures of arterial oxygen 73–123 mmHg and carbon dioxide 33–52 mmHg, arterial hemoglobin oxygen saturation 96–99%, pH 7.34–7.54, lactate 0.9–2.5 mmol/l). Yohimbine was administered 46–110 min after the injection of xylazine, and the first sign of recovery occurred within 1–4 min. Resedation after reversal with yohimbine was observed in two elephants. In conclusion, xylazine at the doses used induced light to deep sedation with stable physiology and most elephants remained standing. © 2021 American Association of Zoo Veterinarians.

H.-L. Jim, F. Range, S. Marshall-Pescini, R. Dale & J.M. Plotnik

Investigating indirect and direct reputation formation in Asian elephants (*Elephas maximus*)

Frontiers in Psychology 11 (2021) e604372

Abstract. Reputation is a key component in social interactions of group-living animals and appears to play a role in the establishment of cooperation. Animals can form a reputation of an individual by directly interacting with them or by observing them interact with a third party, i.e., eavesdropping. Elephants are an interesting taxon in which to investigate eavesdropping as they are highly cooperative, large-brained,

long-lived terrestrial mammals with a complex social organisation. The aim of this study was to investigate whether captive Asian elephants (*Elephas maximus*) could form reputations of humans through indirect and/or direct experience in two different paradigms: (1) a cooperative string-pulling task and (2) a scenario requiring begging. Fourteen captive Asian elephants in Thailand participated in an experimental procedure that consisted of three parts: baseline, observation, and testing. In the observation phase, the subject saw a conspecific interact with two people – one cooperative/generous and one non-cooperative/selfish. The observer could then choose which person to approach in the test phase. The elephants were tested in a second session 2-5 days later. We found no support for the hypothesis that elephants can form reputations of humans through indirect or direct experience, but these results may be due to challenges with experimental design rather than a lack of capacity. We discuss how the results may be due to a potential lack of ecological validity in this study and the difficulty of assessing motivation and attentiveness in elephants. Furthermore, we highlight the importance of designing future experiments that account for the elephants' use of multimodal sensory information in their decision-making. © 2021 The Authors.

P. Keerthipriya, S. Nandini & T.N.C. Vidya

Effects of male age and female presence on male associations in a large, polygynous mammal in southern India: The Asian elephant

Frontiers in Ecology and Evolution 9 (2021) e616666

Abstract. We present a detailed study of male associations in the Asian elephant, using 6 years of data on identified, non-musth males. Adult males spent greater proportions of their time solitarily than in mixed-sex or in all-male groups. Old (over 30 years) males were sighted more frequently with their age-peers and less frequently with young (15–30 years) males than expected at random in all-male groups. Young males were not sighted more frequently with old males than with young males, and did not disproportionately initiate associations with old males. These results suggest that male associations, in the absence of females, may allow for old non-musth males to test strengths against age-peers. Social learning from older individuals did not seem to be important in male associations, unlike that observed in the African savannah elephant. We also found a constraint on the sizes of all-male groups, similar to that seen in female groups in our study population, and all-male groups were rarer and smaller than those in African savannah elephant. Although male associations were weak, most males had a significant top associate, with whom their association was the strongest, in female absence. In mixed-sex groups, male associations occurred at random, suggesting that males were tracking female groups independently. Differences in male social organization from that of the related African savannah elephant that occupies a similar niche possibly arise from differences in ecology. © 2021 The Authors.

S. Khammesri, Y. Mathura, K. Boonprasert, C. Ampasavate, D. Hongwiset, J.L. Brown & C. Thitaram

Successful treatment of elephant endotheliotropic herpesvirus infection in an Asian elephant (*Elephas maximus*) calf by oral acyclovir medication: Case report

J. of Veterinary Medical 83 (2021) 125-129

Abstract. Elephant endotheliotropic herpesvirus (EEHV) is a major cause of death in Asian elephant (*Elephas maximus*) calves. A 2-year, 11-month-old female, captive Asian elephant presented with facial edema and a mild fever. Blood samples were collected and showed EEHV1A positivity with a high viral load by real time PCR. Heterophil toxicity also was reported for the first time in this case. The calf was treated orally with acyclovir, 45 mg/kg tid for 28 days, which reduced the EEHV1A viral load to undetectable levels within 9 days and the calf survived. A successful outcome with oral acyclovir administration provides another and affordable option to treat EEHV hemorrhagic disease in Asian elephants, and one that is easier to administer in untrained calves. © 2021 The Japanese Society of Veterinary Science.

R.K. Koirala, W. JI, Y.P. Timilsina & D. Raubenheimer

Patterns, perceptions, and spatial distribution of human-elephant (*Elephas maximus*) incidents in Nepal

Journal of Threatened Taxa 13 (2021) 18441-18452

Abstract. Nepal has an estimated population of 109 to 142 wild Asian Elephants *Elephas maximus* L.. We carried out a survey of human-elephant incidents (HEI) of conflict in the buffer zones of Chitwan National Park and Parsa National Park Nepal, using a structured questionnaire, focal interviews, and secondary data collection. Furthermore, data of HEI were also extracted from published literature in order to analyse spatial-temporal patterns of competition throughout Nepal. Elephant related incidents were higher in the pre-winter season and concentrated along the southern forest boundary; incidents decreased with increasing distance from the park/reserve. Crop damage by elephants occurred in pre-monsoon and winter seasons with the most impact on rice (the major crop). Bulls (single or in pairs) were involved in crop raids (44%), property damage (48%), and human casualties (8%); family herds were only recorded to have raided crops (39%) and damaged properties (36%). The average herd size recorded was 10 individuals, with a maximum group size of ≤22 elephants. Generally, incidents per elephant was high in western Nepal, whereas human and elephant casualties were higher in central and eastern regions. To reduce human–elephant incidents 53% of local residents suggested restoring core and boundary areas with native elephant food plants, 40% suggested planting alternative crops along park boundaries, 6% favoured elephant translocation, and only 1% percent was in favour of culling elephants. Mitigation measures already in place include wooden watch towers used by villagers to detect elephant incursions. Low impact traditional averting techniques, such as drumming and the use of flame torches, were used to deter intruding elephants at the areas surveyed. In conclusion we suggest potential mitigation measures such as identifying elephant refugia and mitigate the impact and assessing the year-round availability of preferred foods; in addition, we advocate for introducing an equitable compensation to gain support from local communities adjacent to protected areas. © 2021 The Authors.

Intanon Kolasartsanee

Diversity and habitat use of terrestrial mammals in the area proposed for water resource development in Khao Soi Dao Wildlife Sanctuary, Thailand

Environment and Natural Resources Journal 19 (2021) 186-194

Abstract. The Khlong Ta Liu dam construction plan was re-proposed to be constructed in the forest area of Khao Soi Dao Wildlife Sanctuary in the Ta-riu tributary without a biodiversity impact assessment. Five camera traps were mounted at the hotspot points for terrestrial mammals next to the main trail for 376 trap nights from the forest edge to the forest interior. Fifteen species of terrestrial mammals were found. Two species found were categorized as having endangered status, while seven have vulnerable status. Grazers and browsers, i.e., sambar, gaur, northern red muntjac, and Asian elephant were mostly detected at the forest edge, while omnivores and frugivores, i.e., wild boar, greater hog badger, and northern pig-tailed macaque were largely detected in the forest interior. Dhole should be a carnivore species specific to the forest edge while clouded leopard should be in the forest interior. The Normalized Difference Vegetation Index (NDVI) may relate to species of terrestrial mammals detected at each habitat. Among the five habitats, three would be destroyed upon construction of the dam, including the habitat with the highest diversity of terrestrial mammals. The habitat that would likely be least impacted had the lowest species richness of terrestrial mammals. © 2021 Natural Resources Journal.

C.A. LaDue & B.A. Schulte

Pheromonal enrichment in the zoo: An empirical approach with Asian elephants (*Elephas maximus*)

Applied Animal Behaviour Science 235 (2021) e105228

Abstract. The use of odors is a popular form of sensory enrichment, yet few studies have in-

vestigated the longer lasting effects of biologically relevant chemical signals like pheromones. Asian elephants (*Elephas maximus*) are unique because they are commonly held in zoos and utilize two single-compounds to synchronize reproduction: frontalin (a pheromone produced by male elephants in musth) and (Z)-7-dodecenyl acetate (Z7-12:Ac, a pheromone produced by female elephants around ovulation). While Asian elephant chemical signaling dynamics have been well-studied, no reports exist on the broader behavioral effects (i.e., primer effects) of either of these pheromones. The purpose of this study was to describe the primer effects of both frontalin and Z7-12:Ac for potential enrichment applications. We bioassayed 50 elephants at 10 zoos using synthetic versions of these two pheromones that replicated the concentrations at which they are produced naturally. We found that behavioral diversity in response to these pheromones was influenced both by the degree of exposure to the chemicals and by properties of the receiver, such as sex, sexual experience, age, and social access, with models that included all or most of these factors explaining much of the variation in the bioassay data for frontalin ($R^2_{(c)} = 0.42$) and Z7-12:Ac ($R^2_{(c)} = 0.59$). Furthermore, both males and females exhibited distinct changes in activity levels in the presence of frontalin or Z7-12:Ac, with specific behavioral differences noted. For instance, frontalin stimulated increased activity (and decreased inactivity) among female elephants ($P < 0.001$). Foraging ($P = 0.029$) and walking ($P = 0.001$) increased when males were exposed to frontalin, but it also stimulated increased time spent engaged in stationary stereotypy ($P < 0.001$). On the other hand, Z7-12:Ac encouraged greater activity levels in female ($P < 0.001$) and male ($P = 0.010$) elephants. These results support the use of pheromones as enrichment opportunities for elephants, and suggest appropriate chemical signals should be considered for other species. Because these compounds hold biological, ecological, and/or evolutionary salience, they can have long-lasting effects and are particularly relevant to long-term management strategies. In conjunction with other forms of sensory enrichment—including biologically novel odors—pheromones have the potential to enhance the wellness of zoo-housed species. © 2021 Reprinted with permission from Elsevier.

C.A. LaDue, R.P.G. Vandercone, W.K. Kiso & E.W. Freeman

Scars of human-elephant conflict: Patterns inferred from field observations of Asian elephants in Sri Lanka

Wildlife Research 48 (2021) 540-553

Abstract. Human-elephant conflict (HEC) is a major threat to Asian elephants as humans and elephants are forced to share common resources. In Sri Lanka, human-dominated landscapes adjacent to protected areas promote high rates of HEC, especially in the form of crop-foraging by elephants. Crop-foraging can be dangerous to both elephants and humans involved in the conflict. Gunfire is a common way for human communities to deter crop-foraging elephants, and gunshot wounds are commonly described in this elephant population on necropsy. We sought to quantify and describe unique scar patterns among Asian elephants in a protected area, Wasgamuwa National Park, attributed to HEC. We identified 38 adult female and 64 adult male elephants and recorded the age class and body condition of each with established standards. Using photographs, we counted the number, position, and relative size of all scars on each animal. Male elephants had significantly more scars than did females, and for males, the number of scars increased progressively with age. Additionally, male elephants with higher body conditions had more scars. Finally, males tended to have more scars towards the head, especially at older ages. Differences in total scar counts between the sexes in this population imply that male elephants in this area more frequently engage in HEC than do females, following observations previously described in the literature. Furthermore, the fact that male elephants acquired progressively more scars as they aged, and that fatter elephants had more scars, indicates that previous exposure to HEC may not have been a deterrent for future events among these males, and potentially, crops served as valuable food sources for these animals. Finally, the changing body locations of these scars with age in males possibly

shows plastic behavioural responses during crop-foraging or lower tolerance by farmers towards habitual crop foragers. These results emphasise the need for animal-based approaches to HEC mitigation. Similarly, conservation managers in Sri Lanka and other elephant range countries should investigate similar methods that estimate patterns of HEC to develop effective management strategies directly targeting animals most likely to engage in conflict. © 2021 CSIRO.

J. Leung, T. Beths, M. Lynch, S. Frith & S.H. Bauquier

A simple method to provide positive end expiratory pressure to treat hypoxaemia in an anaesthetised Asian elephant (*Elephas maximus*)

Journal of the South African Veterinary Association 92 (2021) e2118

Abstract. Hypoxaemia is a common complication in anaesthetised or immobilised elephants. It is presumably because of hypoventilation and ventilation-perfusion mismatch. To prevent hypoxaemia, orotracheal intubation and positive pressure ventilation are recommended. This case report describes a hypoxaemic period despite positive pressure ventilation in a 46-year-old female Asian elephant (*Elephas maximus*) anaesthetised with azaperone-etorphine, medetomidine and an etorphine constant rate infusion in lateral recumbency for a dental procedure. The hypoxaemia was corrected utilising positive end-expiratory pressure (PEEP) of 5–10 cm H_2O, a technique that has not previously been reported in the management of anaesthetised elephants. PEEP decreases atelectasis, shunt fraction, and increases lung compliance. Positive end-expiratory pressure was achieved by partial occlusion of the tailpiece of a manually triggered demand valve ventilator during expiration. This is a simple effective method of generating PEEP and correcting hypoxaemia without the need for any additional specialised equipment. However, PEEP decreased arterial blood pressure and should be implemented with caution if arterial blood pressure is not monitored. © 2021 The Authors.

O. Liehrmann, J.A.H. Crawley, M.W. Seltmann, S. Feillet, U.K. Nyein, H.H. Aung, W. Htut, M. Lahdenperä, L. Lansade & V. Lummaa

Handler familiarity helps to improve working performance during novel situations in semi-captive Asian elephants

Scientific Reports 11 (2021) e15480

Abstract. Working animals spend hours each day in close contact with humans and require training to understand commands and fulfil specific tasks. However, factors driving cooperation between humans and animals are still unclear, and novel situations may present challenges that have been little-studied to-date. We investigated factors driving cooperation between humans and animals in a working context through behavioural experiments with 52 working semi-captive Asian elephants. Human-managed Asian elephants constitute approximately a third of the remaining Asian elephants in the world, the majority of which live in their range countries working alongside traditional handlers. We investigated how the familiarity and experience of the handler as well as the elephant's age and sex affected their responses when asked to perform a basic task and to cross a novel surface. The results highlighted that when novelty is involved in a working context, an elephant's relationship length with their handler can affect their cooperation: elephants who had worked with their handler for over a year were more willing to cross the novel surface than those who had a shorter relationship with their handler. Older animals also tended to refuse to walk on the novel surface more but the sex did not affect their responses. Our study contributes much needed knowledge on human-working animal relationships which should be considered when adjusting training methods and working habits. © 2021 The Authors.

T. Mahmood, T.T. Vu, A. Campos-Arceiz, F. Akrim, S. Andleeb, M. Farooq, A. Hamid, N. Munawar, M. Waseem, A. Hussain, H. Fatima, M.R. Khan & S. Mahmood

Historical and current distribution ranges and loss of mega-herbivores and carnivores of Asia

PeerJ 9 (2021) e10738

Abstract. Ecosystem functioning is dependent a lot on large mammals, which are, however, vulnerable and facing extinction risks due to human impacts mainly. Megafauna of Asia has been declining for a long, not only in numbers but also in their distribution ranges. In the current study, we collected information on past and current occurrence and distribution records of Asia's megafauna species. We reconstructed the historical distribution ranges of the six herbivores and four carnivores for comparison with their present ranges, to quantify spatially explicit levels of mega-defaunation. Results revealed that historically the selected megafauna species were more widely distributed than at current. Severe range contraction was observed for the Asiatic lion, three rhino species, Asian elephant, tigers, and tapirs. Defaunation maps generated have revealed the vanishing of megafauna from parts of the East, Southeast, and Southwest Asia, even some protected Areas losing up to eight out of ten megafaunal species. These defaunation maps can help develop future conservation policies, to save the remaining distribution ranges of large mammals. © 2021 The Authors.

M.A.M. Moustafa, H.M. Chel, M.J. Thu, S. Bawm, L.L. Htun, M.M. Win, Z.M. Oo, N. Ohsawa, M. Lahdenperä, W.M.A. Mohamed, K. Ito, N. Nonaka, R. Nakao & K. Katakura

Anthropogenic interferences lead to gut microbiome dysbiosis in Asian elephants and may alter adaptation processes to surrounding environments

Scientific Report 11 (2021) e741

Abstract. Human activities interfere with wild animals and lead to the loss of many animal populations. Therefore, efforts have been made to understand how wildlife can rebound from anthropogenic disturbances. An essential mechanism to adapt to environmental and social changes is the fluctuations in the host gut microbiome. Here we give a comprehensive description of anthropogenically induced microbiome alterations in Asian elephants (n = 30). We detected gut microbial changes due to overseas translocation, captivity and deworming. We found that microbes belonging to Planococcaceae had the highest contribution in the microbiome alterations after translocation, while Clostridiaceae, Spirochaetaceae and Bacteroidia were the most affected after captivity. However, deworming significantly changed the abundance of Flavobacteriaceae, Sphingobacteriaceae, Xanthomonadaceae, Weeksellaceae and Burkholderiaceae. These findings may provide fundamental ideas to help guide the preservation tactics and probiotic replacement therapies of a dysbiosed gut microbiome in Asian elephants. More generally, these results show the severity of anthropogenic activities at the level of gut microbiome, altering the adaptation processes to new environments and the subsequent capability to maintain normal physiological processes in animals. © 2021 The Authors.

Y.S.S. Muir, B. Bryant, M. Campbell-Ward & D.P. Higgins

Retrospective anti-tetanus antibody responses of zoo-based Asian elephants (*Elephas maximus*) and rhinoceros (Rhinocerotidae)

Developmental & Comparative Immunology 114 (2021) e103841

Abstract. Tetanus toxoids (TT) commercially available for use in horses and livestock are commonly used to vaccinate elephants and rhinoceros that are in human care. Although recommendations for booster intervals have changed in human and horse protocols to reduce the risks associated with hyper-immunity (i.e. B-cell anergy and hypersensitivity reactions) these have generally not been adopted in zoo protocols. Additionally, there is no evidence to demonstrate commercial TT immunogenicity in rhinoceros. In this study, a preliminary analysis of rhinoceros antibody responses to TT was conducted, in addition to an exploration of the impact of various booster frequencies on antibody responses in elephant. Retrospective analysis of archived serum samples was conducted for 9 Asian elephants (*Elephas maximus*), 7 southern black (*Diceros bicornis minor*), one southern white (*Ceratotherium simum simum*), and two greater one-horned (*Rhinoceros unicornis*) rhinoceros. Pre-vaccination (baseline) samples and those following priming vaccination (rhinoceros only), annual and non-annual

boosters were targeted. A commercially available competitive ELISA kit was used to quantify serum anti-TT antibodies. Average baseline and post-vaccination anti-tetanus antibody concentrations were greater in elephant (92 ± 42 mg/l; 125 ± 76 mg/l) than in rhinoceros (47 ± 39 mg/l; 44 ± 37 mg/l). Rhinoceros antibody concentrations did not differ markedly following vaccinations from their naturally acquired high pre-vaccination concentrations. Eight elephants demonstrated antibody maintenance for 3–5 years without a tetanus booster. Additionally, although five out of nine elephants developed local reactions consistent with delayed type IV hypersensitivity following some boosters, there was no association between high antibody concentrations and increased incidence of adverse reactions. In addition, no decrease in antibody concentrations was detected as a result of annual vaccination in elephants, though this does not entirely rule out potential for B-cell anergy. © 2020 The Authors.

C. Pabutta, N. Bangkaew, P. Inthawong, P. Mahadthai, W. Jairak, N. Soda, M. Sukmak & S. Sripiboon

The first report on internal transcribed spacer region-based characterization of microfilaria in Asian elephants (*Elephas maximus*) in Thailand

Veterinary World 14 (2021) 2260-2266.

Abstract. Filarial infections can significantly impact the health of both humans and animals. In elephants, filariasis has been associated with cutaneous dermatitis and skin nodules. However, molecular evidence for such infections is limited in Thailand. This study aimed to identify the morphological and molecular characteristics of microfilaria in captive Asian elephants in Thailand. Whole blood collected from the ear vein of 129 captive Asian elephants was hematologically analyzed, and the blood parasites were evaluated using three standard techniques: The microcapillary test, thin blood smears, and polymerase chain reaction (PCR). Conventional PCR revealed that approximately 17% (22/129) of the sampled elephants were positive for microfilaria. Microscopy revealed that microfilariae are large, unsheathed, with extended nuclei, a short headspace, and a curved tail tapering at the end. Results of internal transcribed spacer region analysis show that the elephant microfilariae are closely related to *Onchocerca* spp. All of the elephants positive for microfilaria presented with neither skin lesion nor anemic signs. Microfilaria infection was not associated with age; however, microfilariae were more likely to be detected in male elephants due to differences in management systems. This is the first study to provide both morphological and molecular evidence of microfilaria in Thai elephants. There is an urgent need to investigate the long-term and large-scale effects of microfilaria on the health of elephants. © 2021 The Authors.

M.D. Patil, V.K. Patil & N.A. Mungi

Spatiotemporal movement pattern of Asian elephants *Elephas maximus* Linnaeus, 1758 in Sindhudurg District, Maharashtra, India

Journal of Threatened Taxa 13 (2021) 18099-18109

Abstract. The extension of the Asian elephant's *Elephas maximus* range in the northern Western Ghats (Sahyadri) was observed since 2002. This colonization was marked by elephant crop raiding events in the newly colonized Sindhudurg District, where the local community had no experience of living with elephants. The present study was conducted to understand the spatiotemporal patterns of crop depredation (raiding) and to prioritize areas to inform future interventions on managing this ecological phenomenon turned conflict. Data on crop raiding between 2002 and 2015 was obtained from compensation records with the state forest department, and mapped at village scale. Subsequently, we used three indices of crop raiding, viz., Crop Raiding Frequency (CRF), Relative Crop Raiding Intensity (RCRI), and Crop Raiding Vulnerability Index (CRVI). Results show a gradual northern movement of elephants and of the crop raiding zone over the period of 2002–2015. The rankings provided by CRVI, identified villages in a narrow strip of foothills of the Sahyadri mountains as severely vulnerable. With sufficient long term data, CRVI would be a highly useful index for prioritization of villages for resolving human-ele-

phant negative interactions; and other cases of human-wildlife interactions too. © 2021 The Authors.

E.N. Paul, P. Thompson, N. Miller, P. Meagher & L. Vogelnest

Dispersion of aerosolized bacteria from Asian elephants (*Elephas maximus*)

Journal of Zoo and Wildlife Medicine 52 (2021) 749-754

Abstract. Transmission of tuberculosis typically requires close and prolonged contact with an infected individual. However, several cases of transmission between elephants and from elephants to humans or other animals without direct contact or over long distances have been reported. Elephants have been shown to be capable of producing aerosolized bacterial droplets, suggesting a possible route of transmission that is magnified by the size and force of the elephant respiratory tract. To investigate the dispersion and viability of aerosolized bacteria generated from the elephant respiratory tract, a pre-existing model with a proxy organism was used. A six-stage Andersen sampler was used to detect the proxy organism, a commensal elephant respiratory bacterium, at different locations around an elephant barn at a zoo. The amount of proxy organism detected at various time points and distances from the elephants indicates they are capable of dispersing viable bacterial aerosols further than humans can. The concentration of these aerosols is dependent on proximity to the elephants and does not remain at a high level for prolonged periods of time. These findings support the model of aerosol-mediated transmission of bacteria from elephants and can be used to improve disease management practices and prevent the spread of pathogens from elephants in zoos and other facilities. © 2021 American Association of Zoo Veterinarians.

U. Penjor, Ż. Kaszta, D.W. Macdonald & S.A. Cushman

Prioritizing areas for conservation outside the existing protected area network in Bhutan: The use of multi-species, multi-scale habitat suitability models

Landscape Ecology 36 (2021) 1281-1309

Abstract. Understanding the environmental and anthropogenic factors influencing habitat selection of multiple species is a foundation for quantifying human impacts on biodiversity and developing effective conservation measures. To determine the effect of multiple scales of environmental/topographic and anthropogenic variables and landscape patterns on habitat suitability of terrestrial mammals in Bhutan, assess the effectiveness of the current protected area network, identify areas of high species richness outside of the existing protected area, and evaluate the potential effectiveness of indicator and umbrella species for conservation planning. We modelled multi-scale habitat selection of sixteen species of terrestrial mammals across Bhutan using data from a nation-wide camera trap survey. We used the predicted species distribution maps to assess the multi-species conservation effectiveness of the existing protected area network. We performed simulations to identify high priority areas for multiple species based on their habitat suitability, proximity to existing protected areas and overall connectivity within the predicted distribution of species. We used correlation analysis among predicted occurrence maps and multivariate cluster analysis to identify potential indicator species. We evaluated the potential utility of each species as umbrella species by assessing how well optimal protected areas for that species would protect suitable habitat for all 16 species simultaneously. Protected areas and forest cover were strongly associated with habitat use of most modelled species. Additionally, topographical features, like terrain roughness and slope position, contributed to habitat selection of multiple species, but often in different ways. Environmental and topographical variables were mostly selected at medium to broad scales. Anthropogenic variables (agriculture and built-up areas) were negatively associated with habitat suitability of most species at both fine and broad scales. Conservation effectiveness assessment of existing protected areas found protected areas in south-central Bhutan have high effectiveness in terms of both mean and total richness protected. Similarly, biological corridors in the south-central region offered high mean richness protection. Our simulation of optimal areas for ad-

ditional protection found areas abutting protected areas in southern Bhutan offered high relative species richness protection. Our umbrella species analysis found muntjac, wild pig, serow, sambar and Asian golden cat are the most effective umbrella species for broader biodiversity protection. Our indicator species analysis found tiger, gaur, dhole, clouded leopard, Asian black bear and common leopard as effective indicator species. This study highlights the need to protect optimally located species-rich areas outside the current protected areas. This kind of multi-species habitat assessment provides important information to optimize future conservation and development plans at national and regional scales. © The Authors 2021.

K.L. Perrin, A.T. Kristensen, M.F. Bertelsen & D. Denk

Retrospective review of 27 European cases of fatal elephant endotheliotropic herpesvirus-haemorrhagic disease reveals evidence of disseminated intravascular coagulation

Scientific Reports 11 (2021) e14173

Abstract. Elephant endotheliotropic herpesvirus haemorrhagic disease (EEHV-HD) is widely acknowledged as the most common cause of mortality in young Asian elephants (*Elephas maximus*) in captivity. The objective of the current study was to perform a blinded, retrospective pathology review of European EEHV-HD fatalities, constituting the largest systematic assessment of EEHV-HD pathology to date. Findings between viral genotypes were compared with the aim to investigate if disseminated intravascular coagulation (DIC) could be substantiated as a significant complicating factor, thereby increasing the understanding of disease pathophysiology. Immunohistochemical staining confirmed endothelial cell (EC) damage and the presence of EC intranuclear inclusion bodies, demonstrating a direct viral cytopathic effect. Microthrombi were observed in 63% of cases in several organs, including lungs, which, together with widespread haemorrhage and thrombocytopenia reported in EEHV-HD case reports, supports the presence of overt DIC as a serious haemostatic complication of active EEHV infection. Death was attributed to widespread vascular damage with multi-organ dysfunction, including severe acute myocardial haemorrhage and subsequent cardiac failure. Systemic inflammation observed in the absence of bacterial infection may be caused by cytokine release syndrome. Findings reinforce the necessity to investigate cytokine responses and haemostatic status during symptomatic and asymptomatic EEHV viraemia, to potentially support the use of anti-inflammatory treatment in conjunction with anti-viral therapy and cardiovascular support. © The Authors 2021.

K.L. Perrin, S. Saxmose Nielsen, T. Martinussen & M.F. Bertelsen

Quantification and risk factor analysis of elephant endotheliotropic herpesvirus-haemorrhagic disease fatalities in Asian elephants (*Elephas maximus*) in Europe (1985–2017)

Journal of Zoo and Aquarium Research 9 (2021) 8-13

Abstract. Elephant endotheliotropic herpesvirus-haemorrhagic disease (EEHV-HD) is frequently stated to be the most common cause of death in captive Asian elephant *Elephas maximus* populations in Europe and North America. However, the impact on the European population has not been quantified. The aim of this study was to quantify and describe EEHV deaths in Asian elephants in Europe between 1985 and 2017, and to evaluate potential risk factors. Asian elephants born in the study period were tracked for eight years, or until death, depending on which occurred first. Excluding stillborn and perinatal deaths (<1 day old), 44 elephants died within the study period. EEHV-HD accounted for 57% of these cases, and was therefore the most frequent cause of death. While all known Asian elephant endemic EEHV-genotypes were represented, EEHV-1A was responsible for 80% of EEHV deaths. The median age of EEHV fatalities was 2.6 years and there was no difference in risk between males and females. The only significant risk factor for EEHV death, analysed using Cox regression analysis, was an institutional history of a previous EEHV death. Importantly, exposure to new elephants was not associated with an increased risk of EEHV death.

T. Pitakarnnop, K. Buddhachat, P. Pakdeenarong & K. Nganvongpanit

Elemental distribution in animal carpal and tarsal bones using differences in X-ray fluorescence energy

Biological Trace Element Research 199 (2021) 874-887

Abstract. No permission to print abstract.

S.S. Pokharel, H. Yoneda, M. Yanagi, R. Sukumar & K. Kinoshita

The tail-tale of stress: An exploratory analysis of cortisol levels in the tail-hair of captive Asian elephants

PeerJ 9 (2021) e10445

Abstract. Assessment of physiological states by measuring biomarkers, such as cortisol, has significantly contributed to the monitoring of health, welfare and management of animals. Immunoreactive cortisol in hair (hC) has been used widely for deciphering 'stressful' past-events in various wild and captive animals. However, no such studies have been done in long-lived mammals. In this first exploratory study in elephants, we assessed (i) tail-hair growth rate (TGR) and (ii) hC levels in tail-hair samples from six captive Asian elephants from two zoos in Japan for comparing hC levels with zoo-keepers' records of distinct biological events over a c.0.5–2.0-year period. Tail-hair samples were cut into segments (based on monthly growth rate), pulverized or minced and a validated cortisol enzyme-immunoassay employed to measure hC levels. When the hC levels of all individuals were compared with the keepers' records, a posteriori, most of the high hC levels were found to be associated with 'stressful' or distinct behavioural events such as pathological (anaemia, colic infection, skin infection, oral sores), psychosocial (reluctance in entering the enclosure, presence of a calf) and husbandry practice-related (contact trials/ space sharing) conditions, indicating that tail-hair indeed can be a potential 'retrospective' calendar of physiological health of an animal. Our observations open up the possibility of using the tail-hair as an alternative matrix to reconstruct the physiological history of elephants. © 2021 The Authors.

N.A. Prado, J.L. Brown, J.A. Zoller, A. Haghani, M. Yao, L.R. Bagryanova, M.G. Campana, J.E. Maldonado, K. Raj, D. Schmitt, T.R. Robeck & S. Horvath

Epigenetic clock and methylation studies in elephants

Aging Cell 20 (2021) e13414

Abstract. Age-associated DNA-methylation profiles have been used successfully to develop highly accurate biomarkers of age ("epigenetic clocks") in humans, mice, dogs, and other species. Here we present epigenetic clocks for African and Asian elephants. These clocks were developed using novel DNA methylation profiles of 140 elephant blood samples of known age, at loci that are highly conserved between mammalian species, using a custom Infinium array (HorvathMammalMethylChip40). We present epigenetic clocks for Asian elephants (*Elephas maximus*), African elephants (*Loxodonta africana*), and both elephant species combined. Two additional human-elephant clocks were constructed by combining human and elephant samples. Epigenome-wide association studies identified elephant age-related CpGs and their proximal genes. The products of these genes play important roles in cellular differentiation, organismal development, metabolism, and circadian rhythms. Intracellular events observed to change with age included the methylation of bivalent chromatin domains, and targets of polycomb repressive complexes. These readily available epigenetic clocks can be used for elephant conservation efforts where accurate estimates of age are needed to predict demographic trends. © 2021 The Authors.

P. Prompiram, W. Wiriyarat, B. Bhusri, W. Paungpin, W. Jairak, S. Sripiboon & T. Wongtawan

The occurrence of elephant endotheliotropic herpesvirus infection in wild and captive Asian elephants in Thailand: Investigation based on viral DNA and host antibody

Veterinary World 14 (2021) 545-550

Elephant endotheliotropic herpesvirus (EEHV) is a serious disease, threatening the life of young elephants. Many elephants have been infected with no clinical signs and may serve as carriers

spreading this disease. It is important to monitor the disease through clinical signs and molecular diagnosis. In this study we investigated the occurrence of EEHV and the efficiency of different techniques used to monitor EEHV infection in various samples and populations of Asian elephants. Blood and trunk swabs were collected from live elephants, while visceral organs (lung, digestive tract, spleen, lymph nodes, and kidney) were collected from dead elephants. EEHV was detected by polymerase chain reaction (PCR) in whole blood, trunk swabs, and visceral organs as samples, while elephant anti-EEHV immunoglobulin G (IgG) in serum was detected by enzyme-linked immunosorbent assay (ELISA). A total of 162 samples were analyzed in this study: 129 from healthy, 26 from dead, and 7 from sick elephants. The present study showed that the overall incidence of EEHV was 40.1% (n=65/162). Approximately 46.2% (n=12/26) and 85.7% (n=6/7) of dead and sick elephants were positive for EEHV by PCR, respectively. All sick elephants that were young and affected by EEHV clinical disease tested negative for the IgG antibody ELISA, suggesting primary EEHV infection in this group. In addition, 2.3% (n=3/129) of subclinical infections were detected using PCR, and trunk swab samples showed slightly higher sensitivity (5.3%, n=2/38) to detect EEHV than whole blood (1.2%, n=1/84). As many as, 48.4% (n=44/91) of healthy elephants were EEHV seropositive (ELISA-positive), suggesting that many elephants in Thailand had previously been infected. Overall, 30% of dead wild elephants had been infected with EEHV (n=3/10). Moreover, statistical analysis revealed no significant differences in the EEHV detection rate between different age groups or sexes ($p>0.05$). PCR is better than ELISA to detect EEHV active infection in dead/sick elephants and to monitor EEHV in young elephants. ELISA is suitable for detecting previous EEHV infection and carriers, particularly adults. Theoretically, we could use both PCR and ELISA to increase the sensitivity of testing, along with observing abnormal behavior to efficiently monitor this disease. Identification of EEHV carriers within elephant populations is important to prevent transmission to healthy individuals, especially young elephants with high mortality from EEHV. This is the first report from Thailand regarding EEHV infection in wild elephants, showing the importance of preventing disease transmission between captive and wild elephants. © 2021 The Authors.

U. Rajhans, G. Wankhede, B. Ambore, S. Chaudhari, N. Nighot, V. Dhaygude & C. Sonekar

Sero-diagnosis of tuberculosis in elephants in Maharashtra, India

J. of Threatened Taxa 13 (2021) 18713-18718

Abstract. Tuberculosis is a highly contagious zoonotic disease caused by *Mycobacterium* spp. A study was conducted to detect the presence of *Mycobacterium* in captive elephants. A total of 15 captive elephants were screened from various regions in Maharashtra. The blood and serum samples collected were subjected to rapid test kit, BacT/ALERT 3D system, Ziehl-Neelsen (ZN) staining and PCR. All the samples were found seronegative using rapid test kit and whole blood PCR. Whereas, all samples were signalled culture positive in BacT/ALERT 3D system which were further subjected to PCR, only one amplicon was produced of 176 bp of RD4 gene (*Mycobacterium bovis*) and no acid-fast organism was detected upon ZN. Due to the atypical nature of this organism, diagnosis of this disease in elephants using various tests is complicated unlike the diagnostic tests that are validated in domestic animals. Therefore, many tests have sub-optimal sensitivity and specificity in elephants. As TB is a zoonotic disease, transmission can occur between human-livestock-elephants interface. Therefore, the zoos and state forest authority should inculcate a protocol of periodic TB screening for mahouts and elephants in captivity along with protocol of elephant-visitor interaction, thus helping in conservation of this endangered species in India. © 2021 The Authors.

A.K. Schulz, J.N. Wu, S.Y.S. Ha, G. Kim, S. Braccini Slade, S. Rivera, J.S. Reidenberg & D.L. Hu

Suction feeding by elephants

Journal of the Royal Society Interface 18 (2021) e20210215

Abstract. Despite having a trunk that weighs over 100 kg, elephants mainly feed on lightweight vegetation. How do elephants manipulate such small items? In this experimental and theoretical investigation, we filmed elephants at Zoo Atlanta showing that they can use suction to grab food, performing a behaviour that was previously thought to be restricted to fishes. We use a mathematical model to show that an elephant's nostril size and lung capacity enables them to grab items using comparable pressures as the human lung. Ultrasonographic imaging of the elephant sucking viscous fluids show that the elephant's nostrils dilate up to 30% in radius, which increases the nasal volume by 64%. Based on the pressures applied, we estimate that the elephants can inhale at speeds of over 150 m/s, nearly 30 times the speed of a human sneeze. These high air speeds enable the elephant to vacuum up piles of rutabaga cubes as well as fragile tortilla chips. We hope these findings inspire further work in suction-based manipulation in both animals and robots. © 2021 The Authors.

C.S. Sepalage & R.S. Rajakaruna

Gastrointestinal helminth and protozoan infections of wild mammals in four major national parks in Sri Lanka

J. of Threatened Taxa 12 (2020) 17093-17104

Abstract. A cross-sectional, coprological survey of gastrointestinal (GI) parasites of wild mammals in four major National Parks in Sri Lanka: Wilpattu, Udawalawe, Wasgamuwa, and Horton Plains was carried out during November 2016 to August 2017. Fresh fecal samples were collected and analyzed using sedimentation technique, iodine & saline smears, and Sheather's sucrose flotation for morphological identification parasite eggs, cysts, and larvae. A modified salt flotation was carried out for egg counts. Seventy samples from 10 mammal species: Asian elephant, spotted deer, water buffalo, sambar, Indian hare, Asian palm civet, sloth bear, wild boar, grey langur, leopard, and four unknown mammals (two carnivores, one herbivore and one omnivore) were analyzed. Most were infected (94.3%) with more than one GI parasites. The highest prevalence of infection was recorded in Horton Plains (100%), followed by Wasgamuwa (92.8%), Wilpattu (90.4%) and Udawalawe (75.0%) with a significant difference among four parks (Chi square test; $\chi 2=35.435$; df=3; $p<0.001$). Nineteen species of GI parasites were recorded, of which *Entamoeba*, *Isospora*, *Balantidium*, *Fasciola*, *Moniezia*, *Dipylidium*, strongyles, *Toxocara*, *Trichiurus* and hookworms were the most common. Strongyles (62.1%) and *Entamoeba* (80.3%) were the most prevalent helminth and protozoan infections, respectively. Overall, there was no difference in the prevalence of protozoans (84.3%) and helminths (87.1%; $\chi^2=1.0$; df=1; p=0.317). In carnivores, *Entamoeba*, *Balantidium*, *Moniezia*, strongyles and *Strongyloides* were common and in herbivores, *Entamoeba*, strongyles, *Strongyloides* and *Toxocara* were common. The quantitative analysis showed strongyles (17.639 EPG) and Isospora (18,743 OPG) having the highest infection intensity among helminthes and protozoans, respectively. This study provides baseline information of GI parasites and their distribution in wild mammals in the four national parks. Although the prevalence of GI infections was high, their intensity shows that they could be incidental infections. When the prevalence of an infection is high but the intensity is low, it is unlikely to be a major health problem leading to the endangerment of a species. Parasitic diseases can not only affect conservation efforts, but they are also natural selection agents and drive biological diversification, through influencing host reproductive isolation and speciation. © 2020 The Authors.

T.T. Shameer, N.A. Mungi, B. Ramesh, S.V. Kumar & P.S. Easa

How can spatio-temporal overlap in mammals assist in maximizing biodiversity conservation? A case study of Periyar Tiger Reserve

Biologia 76 (2021) 1255-1265

Abstract. No permission to print abstract.

J.L. Siegal-Willott, P. Anikis, D.L. Neiffer, T. Barthel & L.R. Goodrich

Use of intracarpal interleukin receptor antagonist protein (IRAP) and hyaluronic acid in a multimodal therapeutic regime for os-

teoarthritis in an Asian elephant (*Elephas maximus*)
Journal of Zoo and Wildlife Medicine 52 (2021) 401-405
Abstract. An approximately 41-yr-old female Asian elephant (*Elephas maximus*) experiencing forelimb stiffness and decreased range of motion was diagnosed with bilateral carpal osteoarthritis (OA). Standing sedation combined with local anesthesia was used to deliver ultrasound-guided carpal articular injections of an autologous conditioned serum product, interleukin receptor antagonist protein, combined with hyaluronic acid. Within 2 mo of completing therapy, improved range and speed of motion were evident. Reduced inflammation was suggested by decreased carpal articular prostaglandin E2 levels. Subjectively improved clinical signs lasted approximately 5–6 mo, at which point carpal articular injections were repeated. Joint inflammatory markers were useful in gauging response to treatment and may provide guidance in the diagnostic and therapeutic approach to elephant OA. On the basis of the positive response noted, interarticular autologous therapy combined with hyaluronic acid should be considered for carpal OA in elephants. © 2021 American Association of Zoo Veterinarians.

R.J. Snyder, L.P. Barrett, R.A. Emory & B.M. Perdue
Performance of Asian elephants (*Elephas maximus*) on a quantity discrimination task is similar to that of African savanna elephants (*Loxodonta africana*)
Animal Cognition 24 (2021) 1121-1131
Abstract. No permission to print abstract.

S. Sripiboon, P. Dittawong, P. Meetipkit, W. Songsuwankit, A. Jaidee, N. Detcharoenyos, S. Phetdee, P. Santhitisaree, N. Thongtip & W. Tangjitjaroen
Asian elephant (*Elephas maximus*) suffering from lightning strike successfully treated by integrative veterinary medicine
Journal of Zoo and Wildlife Medicine 51 (2020) 1067-1071
Abstract. A captive female Asian elephant (*Elephas maximus*), approximately 30 yr old, was struck by lightning and displayed obtundation, dysphagia, drooling, and muscle weakness. A physical examination, hematologic test, blood gas analysis, and electrocardiogram were performed. Treatments included the administration of mannitol, dexamethasone, antibiotics, analgesics, vitamins, and intravenous fluid. Conventional therapy resulted in improvement but not complete resolution of clinical signs. Therefore, acupuncture was integrated into the treatment protocol. Electroacupuncture and laser acupuncture were administered every other day; aqua acupuncture was administered once a week. No complications were observed during acupuncture treatment. Acupuncture, a form of traditional Chinese veterinary medicine (TCVM), contributed to the resolution of clinical signs in this case and may be an effective adjunctive treatment for other neurologic disorders in elephants. © 2021 American Association of Zoo Veterinarians.

W. Sukmantoro, A. Suyitno, Mulyadi, D. Gunaryadi, A. Seno, A.I. Kusuma & Darwis
Population, distribution, and habitat of Bornean Elephant in Tulin Onsoi, Nunukan District, Indonesia based on dung counts
Biodiversitas 22 (2021) 311-319
Abstract. The survey on population, distribution, and habitat of Bornean elephants is very important because it reduces the information gap about Bornean elephants' population and distribution. In more detail, the study can be used for updating information and the needs of local government in a spatial plan based on biodiversity conservation. The survey of Bornean Elephant was conducted in Tulin Onsoi Subdistrict, Nunukan District, North Kalimantan Province, Indonesia, starting in February 2018 to May 2019. The survey area's scopes are Agison, Sibuda, Apaan, and Tampilon subwater catchment areas in 34 (5 x 5 km^2) grids with a total of 850 km^2. The occupancy method with perpendicular line transect was used in this study. In the survey, the number of traces was 52 finding points with a total of 241 traces. The elephant dung identified in the dung piles (one-time defecation) was in 29 finding points with a total of 38 dung piles (0.22 dung piles per km). Based on Distance 6.0 and involved the formula

of the elephant population's density with standard defecation and dung decay ratio, the elephant population density in the Tulin Onsoi is between 4.8–5.7 individuals/100 km^2. Minimum convex polygon (MCP)-qHull showed that the area of the elephant habitat is 253.12 km^2 in Tulin Onsoi sub-district. Generally, the habitat conditions for the location are old secondary forests (37 %). Meanwhile, other habitats included in the survey area are primary forest, shrubs, and plantations, including community agriculture and roads. In the strategy of managing the Bornean elephant, efforts to stabilize or increase population are important things to do. Conservation-based spatial planning and close monitoring for the protection of small populations of this species and its threats, are options that can be selected for present and future in North Kalimantan.

Y. Sun, Y. Chen, J.J. Díaz-Sacco & K. Shi
Assessing population structure and body condition to inform conservation strategies for a small isolated Asian elephant (*Elephas maximus*) population in southwest China
PLoS ONE 6 (2021) e0248210
Abstract. The Asian elephant (*Elephas maximus*) population in Nangunhe National Nature Reserve in China represents a unique evolutionary branch that has been isolated for more than twenty years from neighboring populations in Myanmar. The scarcity of information on population structure, sex ratio, and body condition makes it difficult to develop effective conservation measures for this elephant population. Twelve individuals were identified from 3,860 valid elephant images obtained from February to June 2018 (5,942 sampling effort nights) at 52 camera sites. Three adult females, three adult males, one subadult male, two juvenile females, two juvenile males and one male calf were identified. The ratio of adult females to adult males was 1:1, and the ratio of reproductive ability was 1:0.67, indicating the scarcity of reproductive females as an important limiting factor to population growth. A population density of 5.32 ± 1.56 elephants/100 km^2 was estimated using Spatially Explicit Capture Recapture (SECR) models. The health condition of this elephant population was assessed using an 11-point scale of Body Condition Scoring (BCS). The average BCS was 5.75 (n = 12, range 2–9), with adult females scoring lower than adult males. This isolated population is extremely small and has an inverted pyramid age structure and therefore is at a high risk of extinction. We propose three plans to improve the survival of this population: improving the quality and quantity of food resources, removing fencing and establishing corridors between the east and wet parts of Nangunhe reserve. © 2021 The Authors.

N. Suwanchatree, P. Thanakiatkrai, A. Linacre & T. Kitpipit
Discrimination of highly degraded, aged Asian and African elephant ivory using denaturing gradient gel electrophoresis (DGGE)
International Journal of Legal Medicine 135 (2021) 107-115
Abstract. No permission to print abstract.

T.M. Taher, T. Lihan, N.A.T. Arifin, N.F. Khodri, M.A. Mustapha, P.A. Patah, S.H.A. Razali & S.M. Nor
Characteristic of habitat suitability for the Asian elephant in the fragmented Ulu Jelai Forest Reserve, Peninsular Malaysia
Tropical Ecology 62 (2021) 347-358
Abstract. No permission to print abstract.

Z.M. Thant, R. May & E. Røskaft
Pattern and distribution of human-elephant conflicts in three conflict-prone landscapes in Myanmar
Global Ecology and Conserv. 25 (2021) e01411
Abstract. Human-elephant conflicts (HEC) are detrimental for both humans and elephants. A better understanding of HEC enhances effective mitigation strategies and promotes the well-being of humans and wild elephants. This study assesses the pattern and distribution of HEC in three different HEC hotspots in Myanmar and identifies local factors that contribute to HEC. A face-to-face questionnaire survey was performed in three HEC landscapes in 30 villages. Our study showed that larger croplands were more vulnerable to crop attacks. Crop damage was found more frequent and was more severe in the more deforested landscapes. The land-

scapes with higher human density and where local people frequently encountered elephants, were at higher risk to elephant attack. Our results indicate that distance to the forest reserves influenced the incidents of HEC most. We suggest the implementation of land-use plans in the potential elephant migration areas to mitigate HEC and improve the local resilience to economic vulnerability due to HEC. © 2020 The Authors.

J. Thapa, S.K. Mikota, K.P. Gairhe, S. Paudel, D.K. Singh, I.P. Dhakal, C. Nakajima & Y. Suzuki

Tuberculosis seroprevalence and comparison of hematology and biochemistry parameters between seropositive and seronegative captive Asian elephants of Nepal

Journal of Veterinary Medical Science 83 (2021) 1278-1283

Abstract. We conducted a tuberculosis (TB) serosurveillance program of captive elephants in Nepal and compared hematology and biochemistry parameters between seropositive and seronegative elephants. A total of 153 elephants (male=20, female=133) from four national parks were tested for TB using the ElephantTB STAT-PAK® Assay (ChemBio Diagnostic Systems, Inc., Medford, NY, USA). The mean reported age for 138 elephants was 38.5 years (range 2–71 years). Seroprevalence for TB was 21.56% (33/153). The majority of seropositive elephants were female (n=30) and from Chitwan National Park (n=29). The occurrence of TB seropositive cases in other more remote national parks suggests TB may be widespread among the captive elephant population of Nepal. Hematology and biochemistry analyses were performed on 13 and 22 seropositive elephants, respectively and, nine elephants from a seronegative TB herd for comparison. Hematology parameters (hemoglobin, packed cell volume, platelet, white blood cells, and erythrocyte sedimentation rate) were comparable between the two groups. Total protein, globulin, and lactate dehydrogenase were significantly higher in seronegative elephants, and bilirubin was significantly higher in seropositive elephants whereas blood urea nitrogen, creatinine, glutamic oxaloacetic transaminase/aspartate aminotransferase (GOT/AST), glutamic pyruvic transaminase/alanine aminotransferase (GPT/ALT), gamma glutamyl transferase (GT), and albumin were not significantly different. The range of biochemical parameters that were significantly different between seropositive and seronegative elephants had narrow ranges. Thus, the potential of these parameters as a direct biomarker for TB diagnosis is limited based on the findings in this study. We recommend including blood parameters in future TB surveillance studies. © 2021 The Japanese Society of Veterinary Science.

M. Tollis, E. Ferris, M.S. Campbell, V.K. Harris, S.M. Rupp, T.M. Harrison, W.K. Kiso, D.L. Schmitt, M.M. Garner, C.A. Aktipis, C.C. Maley, A.M. Boddy, M. Yandell, C. Gregg, J.D. Schiffman & L.M. Abegglen

Elephant genomes reveal accelerated evolution in mechanisms underlying disease defenses

Molecular Biology and Evolution 38 (2021) 3606-3620

Abstract. Disease susceptibility and resistance are important factors for the conservation of endangered species, including elephants. We analyzed pathology data from 26 zoos and report that Asian elephants have increased neoplasia and malignancy prevalence compared with African bush elephants. This is consistent with observed higher susceptibility to tuberculosis and elephant endotheliotropic herpesvirus (EEHV) in Asian elephants. To investigate genetic mechanisms underlying disease resistance, including differential responses between species, among other elephant traits, we sequenced multiple elephant genomes. We report a draft assembly for an Asian elephant, and defined 862 and 1,017 conserved potential regulatory elements in Asian and African bush elephants, respectively. In the genomes of both elephant species, conserved elements were significantly enriched with genes differentially expressed between the species. In Asian elephants, these putative regulatory regions were involved in immunity pathways including tumor-necrosis factor, which plays an important role in EEHV response. Genomic sequences of African bush, forest, and Asian elephant gen-

omes revealed extensive sequence conservation at TP53 retrogene loci across three species, which may be related to TP53 functionality in elephant cancer resistance. Positive selection scans revealed outlier genes related to additional elephant traits. Our study suggests that gene regulation plays an important role in the differential inflammatory response of Asian and African elephants, leading to increased infectious disease and cancer susceptibility in Asian elephants. These genomic discoveries can inform future functional and translational studies aimed at identifying effective treatment approaches for ill elephants, which may improve conservation. © 2021 The Authors.

B.R. Tripathy, X. Liu, M. Songer, L. Kumar, S. Kaliraj, N.D. Chatterjee, W.M.S. Wickramasinghe & K.K. Mahanta

Descriptive spatial analysis of human-elephant conflict (HEC) distribution and mapping HEC hotspots in Keonjhar Forest Division, India

Frontiers in Ecology and Evolution 9 (2021) e640624

Abstract. Escalation of human-elephant conflict (HEC) in India threatens its Asian elephant (*Elephas maximus*) population and victimizes local communities. India supports 60% of the total Asian elephant population in the world. Understanding HEC spatial patterns will ensure targeted mitigation efforts and efficient resource allocation to high-risk regions. This study deals with the spatial aspects of HEC in Keonjhar forest division, where 345 people were killed and 5,145 hectares of croplands were destroyed by elephant attacks during 2001–2018. We classified the data into three temporal phases (HEC1: 2001–2006, HEC2: 2007–2012, and HEC3: 2013–2018), in order to (1) derive spatial patterns of HEC; (2) identify the hotspots of HEC and its different types along with the number of people living in the high-risk zones; and (3) assess the temporal change in the spatial risk of HEC. Significantly dense clusters of HEC were identified in Keonjhar and Ghatgaon forest ranges throughout the 18 years, whereas Champua forest range became a prominent hotspot since HEC2. The number of people under HEC risk escalated from 14,724 during HEC1 and 34,288 in HEC2, to 65,444 people during HEC3. Crop damage was the most frequent form of HEC in the study area followed by house damage and loss of human lives. Risk mapping of HEC types and high priority regions that are vulnerable to HEC, provides a contextual background for researchers, policy makers and managers. © 2021 The Authors.

D. Vasudev, V.R. Goswamia & M.K. Oli

Detecting dispersal: A spatial dynamic occupancy model to reliably quantify connectivity across heterogeneous conservation landscapes

Biological Conservation 253 (2021) e108874

Abstract. Connectivity shapes species distribution, spatial population dynamics and genetic structure, and is critical for conservation. It is imperative to reliably identify factors that limit connectivity across heterogeneous, fragmented landscapes. Viewing connectivity as the persistence of movement in space from source to destination—along potential corridors simulated from correlated random walks—we adapt the dynamic occupancy modeling framework to present an approach to reliably quantify connectivity. This approach allowed us to estimate the probability of spatial persistence of movement along potential corridors, while accounting for imperfect detection of animal use of the matrix. We use simulations to test our model, and data from sign surveys of Asian elephant *Elephas maximus* space use in Garo Hills, Northeast India, as a practical application of the method. Distance to forests and ruggedness predominantly shaped elephant connectivity patterns. Negative effects of distance to forests were intensified at the onset of dispersal, and in the more disturbed part of our landscape. We mapped locations critical to maintaining connectivity in our study landscape. We demonstrate that the widely used occupancy modeling approach, when combined with appropriate field data collection, permits explicit assessment of matrix impacts on connectivity while accounting for imperfect detection of animal movement. In so doing, we highlight the value of the approach in enabling inference on where animals move, as well as why. Obtaining a reliable understanding of factors shaping con-

nectivity is central to understanding and predicting species responses to environmental change, thereby facilitating effective long-term conservation in fragmented landscapes. © 2020 Reprinted with permission from Elsevier.

G. Vibha, H.G. Lingaraju & G.V. Venktaramana

Effectiveness of solar fence in reducing human-elephant conflicts in Manchahalli village, Mysuru, Karnataka, India

Current Science 120 (2021) 707-711

Abstract. Human-elephant conflict is not a new issue in the state of Karnataka, India. Primary conflict involves loss of lives on both sides, loss of property and damage to crops. Solar fencing is considered to be the most effective way to mitigate the conflict between humans and elephants. An assessment on the effectiveness of solar-powered fencing was carried out in Manchahalli village, which is located adjacent to Bandipur National Park (BNP), Karnataka and is prone to frequent raids by elephants. Hence, this area was chosen as the study site. Field survey was conducted between March and April 2019, to estimate whether the installation of solar fencing had reduced the damage caused by elephants on the crops. During the survey, questions related to the following factors were considered: area of land owned by farmers, distance from the forest boundary to the croplands, types of crops grown, types of crops damaged, year of installation of solar fence, damage caused to the solar fence, methods used before the installation of solar fencing and the perceived effectiveness of the solar fence. Among the 30 croplands that were surveyed, majority were at less than 2 km from the forest, followed by others ranging between 1 and 1.5 km. Although solar fencing was not helpful in reducing the raids completely, it proved to be more effective than any other conventional method previously used.

T.C. Weisbrod, R. Isaza, C. Cray, L. Adler & N.I. Stacy

The importance of manual white blood cell differential counts and platelet estimates in elephant hematology: Blood film review is essential

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Abstract. Unique features of elephant hematology are known challenges in analytical methodology like two types of monocytes typical for members of the Order Afrotheria and platelet counts of the comparatively small elephant platelet. To investigate WBC differential and platelet data generated by an impedance-based hematology analyzer without availability of validated species-specific software for recognition of elephant WBCs and platelets, compared to manual blood film review. Blood samples preserved in ethylenediaminetetraacetic acid (EDTA) of 50 elephants (n = 35 *Elephas maximus* and n = 15 *Loxodonta africana*) were used. A Mann-Whitney test for independent samples was used to compare parameters between methods and agreement was tested using Bland-Altman bias plots. All hematological variables, including absolute numbers of heterophils, lymphocytes, monocytes, eosinophils, basophils, and platelets, were significantly different ($p < 0.0001$) between both methods of analysis, and there was no agreement using Bland-Altman bias plots. Manual review consistently produced higher heterophil and monocyte counts as well as platelet estimates, while the automated analyzer produced higher lymphocyte, eosinophil, and basophil counts. The hematology analyzer did not properly differentiate elephant lymphocytes and monocytes, and did not accurately count elephant platelets. These findings emphasize the importance of manual blood film review as part of elephant complete blood counts in both clinical and research settings and as a basis for the development of hematological reference intervals. © 2021 The Authors.

G. Wilson, R.J. Gray, R. Radinal, H. Hasanuddin, W. Azmi, A. Sayuti, H. Muhammad, A. Abdullah, B.S. Nazamuddin, H. Sofyan, H.S. Riddle, C. Stremme & A.A. Desai

Between a rock and a hard place: Rugged terrain features and human disturbance affect behaviour and habitat use of Sumatran elephants in Aceh, Sumatra, Indonesia

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