2021

Elephant Welfare Group: Ten Year Report to Defra

Photo Chester Zoo @Lizzie Webber

5/29/2021

Contents

1 EXECUTIVE SUMMARY 6
2 FOREWORD AND ACKNOWLEDGEMENTS 8
3 INTRODUCTION 9
Summary 9
3.1 Context for Assessing Captive Elephant Welfare 9
3.2 Global Concerns About Captive Elephant Welfare 10
3.3 Background to the EWG 10
3.3.1 Concerns about the welfare of elephants in UK zoos 10
3.3.2 Development of the EWG 12
3.3.3 Remit of the EWG 12
3.3.4 Broader Welfare Context 13
3.4 Scope of this report 13
3.4.1 Welfare indicators used previously, and concerns raised 14
3.4.2 Welfare indicators used by the EWG 15
3.5 Elephants in captivity in the UK 16
4 OVERVIEW OF ENGAGEMENT WITH EWG AND TOOL DEVELOPMENT 18
Summary 18
4.1 SSSMZP review and development of evidence-based recommendations 18
4.2 Stakeholder engagement with the EWG longitudinal welfare assessment tools 18
4.3 Elephant age categories 19
5 EWG REVIEW OF EVIDENCE ON CAPTIVE ELEPHANT WELFARE 20
5.1 Enclosure and husbandry changes from 2006-2020 21
Summary 21
5.1.1 Enclosure and Management Changes: Methods 21
5.1.2 Relatedness Coefficient: Methods 21
5.1.3 Enclosure and Husbandry Changes: Results 22
5.1.3.i Total enclosure size 22
5.1.3.ii Indoor enclosure area 22
5.1.3.iii Outdoor enclosure area 22
5.1.4 Indoor substrates 23
5.1.5 Elephant choice: Access to indoor and outdoor areas 23
5.1.6 Management by Keepers: Contact type 24
5.1.7. Relatedness Coefficient: Results 24
5.1.8 Overview of Management Changes over Time 26
5.2 REPRODUCTION AND SOCIAL BEHAVIOUR SUBGROUP 27

Summary 27
5.2.1 Reproduction and Social Behaviour Subgroup: Methods 27
5.2.1.i Reproduction data collection: methods 27
5.2.1.ii Bull social experience in early life and effects on reproductive success: methods 28
5.2.2 Reproduction and Social Behaviour Subgroup: Summary of published results 28
5.2.2.i Paper 1: Social behaviour between bulls in zoos in the UK (Wood, 2017) 28
5.2.2.ii Paper 2: Causes of reproductive failure in European zoo elephants (Hartley & Stanley, 2016) 28
5.2.2.iii Paper 3: Assessing risk factors for reproductive failure and associated welfare impacts in elephants in European Zoos. (Hartley, 2016) 30
5.2.2.iv Bull early life social experience: effects on reproductive success for European zoo males 33
5.2.3 Overview of results on reproductive outcomes 33
5.3A HEALTH SUBGROUP: LONGEVITY & MORTALITY RESULTS 34
Summary 34
5.3.1 Mortality and Longevity: Methods 34
5.3.1.i Survival analysis data collection 34
5.3.1.ii Cause of death data collection 35
5.3.2 Survival and Mortality: Results 35
5.3.2.i Survival and life expectancy 35
5.3.3. Cause of death 35
5.3.3.i Asian Elephants 35
5.3.3.ii African elephants 36
5.3.4 Overview of findings on longevity and mortality 36
5.3 B HEALTH SUBGROUP: FOOT HEALTH AND LOCOMOTION RESULTS 37
Summary 37
5.3.5 Foot health assessment in elephants 37
5.3.5.i Assessment of locomotion in elephants 38
5.3.5.ii EWG locomotion assessment protocol 38
5.3.6 Foot health: results 39
5.3.6.i EWG (2019) foot health data 39
5.3.6.ii Changes over time: 2015 to 2019 EWG foot health tool 39
5.3.6.iii Comparisons with Harris *et al.* (2008) 39
5.3.7 Locomotion results 40
5.3.7.i EWG gait data 40
5.3.7.ii Changes in gait over time: Comparisons with Harris *et al.* (2008) 41
5.3.8 Overview of results for locomotion and foot health in 2019 42

5.4 NUTRITION SUBGROUP 43
Summary 43
5.4.1 Body Condition Score (BCS): Methods 43
5.4.1.i EWG Body Condition Score protocol 44
5.4.2 Nutritional data collection 44
5.4.3 Calf growth rate data collection 44
5.4.4 Body Condition Scoring Results 45
5.4.4.i Body condition scoring sample sizes 45
5.4.4.ii Most recent EWG (2019) body condition score (BCS) data 45
5.4.4.iii Changes in body condition between 2015 and 2019: EWG BCS tool 45
5.4.4.iv Comparisons with Harris *et al.* (2008) 45
5.4.5 Nutritional information 45
5.4.6 Calf growth rate 46
5.4.6.i Growth rate comparisons between African and Asian calves 46
5.4.6.ii Growth rate comparisons between females and males 46
5.4.7 Overview of body condition, nutrition and growth 46
5.5 BEHAVIOUR AND ABNORMAL BEHAVIOUR SUBGROUP: WELFARE ASSESSMENT TOOLS 48
Summary 48
5.5.1 Individual Elephant Behaviour: Methods 48
5.5.1.i EBWAT (Elephant Behaviour and Welfare Tool) development 49
5.5.1.ii EBWAT protocol and implementation 49
5.5.2 Behaviour Subgroup: Results 51
5.5.2.i Assessments submitted 51
5.5.3 Behaviour overview 51
5.5.4 Stereotypical behaviour: Daytime 52
5.5.4.i EWG data from 2019 – daytime stereotypical behaviour 52
5.5.4.ii Changes in daytime stereotypical behaviour over time: 2015 to 2019 EWG EBWAT tool 53
5.5.5 Stereotypical behaviour: Night 53
5.5.5.i EWG data from 2019: night-time stereotypical behaviour 53
5.5.5.ii Changes in night-time stereotypical behaviour over time: 2015 to 2019 EWG EBWAT tool 53
5.5.6 Changes in stereotypical behaviour over time: Comparisons with Harris *et al.* (2008) 54
5.5.7 Stereotypical behaviour in elephants under 15 years old 55
5.5.8 Effect of the presence of young (<6yrs) elephants on group behaviour 55
5.5.9 Qualitative Behaviour Assessment (QBA) 56
5.5.10 Overview of results from behaviour subgroup 56
5.6 INTERACTIONS AMONG EWG WELFARE ASSESSMENT TOOLS 57

Summary 57
5.6.1 Comparisons between health and behaviour tools 57
5.6.2 Comparisons between behaviour tools 57
5.7 INTERACTIONS BETWEEN WELFARE TOOLS, ENCLOSURE VARIABLES AND GROUP COMPOSITION 59
Summary 59
5.7.1 Health data and enclosure variables 59
5.7.2 Behaviour and enclosure factors 60
5.7.2.i Stereotypical behaviour 60
5.7.2.ii Lying behaviour during rest 62
5.7.3 Interactions between behavioural welfare scores and group relatedness 62
6. DISCUSSION 64
6.1 Welfare indicators showing improvement over time 74
6.2 Welfare indicators showing little or no substantial change 75
6.3 For the future, the Elephant Welfare Group and its BIAZA hosts need to consider: 75
6.4 Future planning for elephants in zoos 76
APPENDICES 77
Appendix 3.1: Priorities and recommendations of the Zoos Forum (2010) 77
Appendix 4.1 Engagement with EWG tools over time 81
Appendix 5.3A. Survival and data on causes of mortality 82
Appendix 5.3B Foot Health and Locomotion 84
Appendix 5.4: Body condition scoring and nutritional information 87
Appendix 5.5 Behaviour and Abnormal Behaviour 92
REFERENCES 97

1 Executive Summary

The UK Elephant Welfare Group (EWG) is a multi-stakeholder group formed in response to concerns about compromised captive elephant welfare, raised by both external and Defra commissioned reports. Advice from the Zoos Expert Committee (at the time the Zoos Forum) to Defra ministers was to "*drive forward a programme of improvements, encourage co-ordination, develop and share husbandry advice and good practice, and monitor progress*" regarding elephant welfare. Ministers indicated that they would consider banning the keeping of elephants in UK zoos should improvements not be evident at the end of a 10-year work programme.

Welfare concerns identified included stereotypic and aggressive (abnormal) behaviour, obesity, lameness and joint disease, inadequate social groupings, poor reproductive success, calf mortality and reduced lifespan.

The Elephant Welfare Group is composed of zoo professionals, veterinarians, welfare scientists and academics who have undertaken programmes of research, data collection and analysis, and developed welfare assessment tools to allow evidence-based welfare auditing. The elephant population changed over the ten years of the EWG, tools developed during this period were novel, and these new tools require further refinement and application to assess their utility over time; thus direct comparisons with previous studies were not always possible. It is also important to note that the EWG has no enforcement powers whatsoever; implementation of the recommendations and the adoption of the EWG methodologies by elephant-holding zoos is entirely voluntary.

This report summarises the work and conclusions of the UK Elephant Welfare Group for 2011 – 2020.

Welfare Improvements Identified:

- The proportion of obese elephants has declined, with a major reduction in foot problems and lameness. These health advances result from improvements in facility design, husbandry and quality of nutrition. However, excessive weight remains a problem.
- With the exception of older elephants, the occurrence of stereotypical behaviour has decreased in most elephants, and is now less frequently seen in young elephants born in UK zoos.
- There has been a sustained move to improved and enlarged facilities allowing communal group space, with more appropriate, naturalistic substrates, less restraint and restriction, and greater 24-hour outdoor access. These moves have been associated with a shift to protected contact management, giving elephants greater choice over their daily activities.
- Group composition has changed for 50% of zoos, creating multi-generational family groups and holding multiple bulls. Along with facility and management improvements, this has enhanced social behaviour and learning, reduced aggression, increased affiliative behaviours and improved herd stability.

Remaining Welfare Concerns:

- Premature mortality and a short lifespan remain major problems, confounded by the identification and occurrence of Elephant Endotheliotropic Herpesvirus in Asian elephants. UK zoos have been significantly involved in investigating, treating and funding research on this disease.
- Improvement in the longevity of elephants who joined the UK population as adults has resulted in a substantial number of geriatric elephants. The specific needs of these animals must be addressed.
- The effects of high growth rates in young elephants, premature puberty and short inter-birth intervals in breeding groups are not well understood and potentially could have negative impacts on welfare and survival.
- Although there have been improvements in expression of abnormal behaviour, approximately one-third of UK zoos elephants were observed to express a stereotypy at some time.
- The enclosure size for elephants in UK zoos has increased, but their relatively small size still limits the potential for the expression of natural behaviours, especially social behaviour, and may facilitate aggression. Should zoos continue to keep elephants into the future, they should build or adapt enclosures of sufficient size to house multi-generational family herds, and multiple bulls. This will facilitate fission-fusion social behaviour, and enable elephant-based choice of space use, which are essential for positive welfare.

Recommendations:

- The EWG should continue into the future, providing ongoing advice to zoos in monitoring elephant welfare, and in addressing any current or future welfare concerns.
- Zoos should be required to use the welfare assessment tools developed by the EWG, and continue to submit these to the EWG, to allow for continued monitoring of elephant welfare, and generation off reliable long-term data sets to inform future advice from the EWG.
- The tools developed by the EWG provide a robust basis for gathering detailed evidence on elephant welfare; however, they should be further refined to detect and better understand the changes experienced by individuals in relation to their particular needs.
- Elephant welfare assessment must be further developed to reflect ongoing advances in assessing psychological welfare and mental well-being.
- UK elephants are managed as part of the European Ex-Situ Programme (EEP). Population management is fundamental to elephant welfare, but it is recognised that some of these aspects are outside the control of UK zoos. However, UK zoos should continue to work with the EEP to ensure that population management supports positive welfare of UK zoo elephants.

2 Foreword and Acknowledgements

The EWG would like to thank the following individuals and their affiliated organisations who have acted as Chair of the EWG at various times: Nic Masters (Zoological Society of London), Mark Pilgrim (Chester Zoo, North of England Zoological Society), Jon Cracknell (Cracknell Wildlife & Vet Services), Miranda Stevenson (BIAZA, retired), and Lisa Yon (University of Nottingham). The following acted as heads of various subgroups: Nic Masters (Zoological Society of London), Matt Hartley (Zoo & Wildlife Solutions Ltd), Lisa Yon (University of Nottingham), Andrea Fidgett (Chester Zoo), Sarah Chapman (Chapman Zoo Consultancy), and Ayona Silva-Fletcher (Royal Vet College, London).

Many institutions generously donated the time of their keeping and other staff to organise training sessions, to record data, and to attend EWG meetings. We thank all the zoos that responded to the requests for funding, data and staff time. We thank the elephant keeping zoos (Blair Drummond, Blackpool, Chester, Colchester, Dublin, Howletts, Knowsley, Noah's Ark, Twycross, ZSL Whipsnade) for engagement and financial support. The University of Nottingham supported Lisa Yon, Ellen Williams, Lucy Asher, Naomi Harvey, Giuliana Pacheco and Clare Ellis for conducting research and analysis which underpinned a major portion of this report; the University of Stirling supported Phyllis Lee; IFAW supported Cindy Milburn, RSPCA supported Ros Clubb. BIAZA provided logistical support and hosting facilities for meetings, and a website for dissemination, throughout the EWG's tenure. We also thank the members of BIAZA's original Elephant Welfare Group, and experts who provided advice to the EWG, especially David Field (Zoological Society of London) and Jake Veasey (Calgary) for their early input into understanding elephant welfare.

It is important to note that support does not equate to endorsement of the report or its findings by any of the institutions mentioned.

3 INTRODUCTION

Summary

- The Elephant Welfare Group (EWG) is a multi-stakeholder group (see Appendix 3.1), initially formed by the British and Irish Association of Zoos and Aquariums (BIAZA) in 2010 in response to concerns (particularly Clubb & Mason, 2002, and Harris *et al.*, 2008) about the welfare of elephants in captivity in the UK.
- BIAZA was tasked by Lord Henley, then Parliamentary Under Secretary of State at Defra, to extend and administer the EWG with the remit to "*drive forward a programme of improvements, encourage co-ordination, develop and share husbandry advice and good practice, and monitor progress*".
- As per this remit, the focus of this report is solely on the welfare of elephants in captivity in the UK. Although crucial to ongoing discussions, this report does not cover the ethics of elephant keeping, or the debate over the potential conservation, education or research roles of those elephants. The focus is rather on presenting evidence of any changes in UK captive elephant welfare that have occurred during the 10-year timescale of the Elephant Welfare Group, particularly in those highlighted as areas of concern in the Harris *et al.* report (2008) and the Zoos' Forum response (2010).
- The report contains the evidence-base for assessing whether there have been improvements in captive elephant welfare over the 10-year period of the EWG. We report on changes in facilities and management, on new tools for assessing foot health, body condition and locomotion, on longevity, survival and causes of mortality, on reproduction and its constraints, on the social dynamics, kinship and male associations of elephants in UK facilities, as well as a new tool for direct keeper observations of behaviour.

3.1 Context for Assessing Captive Elephant Welfare

In order to assess whether elephants in zoos are doing better or worse than one would expect at a population level, some sort of **benchmark or reference data** are required. The comparative context used throughout this report includes three populations: (a) wild elephant behaviour, lifespan and reproduction; (b) studies from extensive management regimes (e.g. timber camps) where foraging and reproduction are not controlled by keepers; and (c) captive studies in the UK, Europe (as the UK elephants form part of the European managed population), and North America, where recent studies on zoo elephant welfare have highlighted elements of concern as well as best practice.

As an example of comparators, when considering infant mortality rates in captivity, it is important to know what is typical for the species. One can look at data gathered in the wild, but animals in zoos are not subject to the food or water shortages or predation experienced by those in the wild, and they have veterinary treatment on hand when they become unwell or injured. The most suitable reference populations with available data are therefore well protected wild populations, or captive animals in other settings. Such comparators can allow us to assess "whether zoo elephants are faring as well as one would expect given that they are well-provisioned, protected from danger, and receive veterinary treatment" (Mason and Veasey, 2010a). At an individual level, data collected before and after an intervention can be used to measure the impact on that individual. Thus, elephants can serve as their own benchmark against which scores are compared over time to look for improvements or decrements in welfare. Understanding individual elephants in their captive context provides us with the ability to assess their welfare compromises and improvements over time.

Understanding what matters to elephants and how this can be used to inform the provision of positive welfare in captivity nonetheless requires consideration of their evolutionary ecology (Lee and Moss, 2009). We briefly highlight here some notable aspects of wild elephant life, with emphasis on experiences likely to be associated with positive mental states, to provide a baseline context for how elephants are cared for in captivity. Examining whether zoos provide for the physical and psychological needs of elephants requires thoughtful consideration of these animals as whole beings, in the context of the rich natural world in which they have evolved and thrived - from the intellectual challenge

that comes from negotiating an ever-changing physical and social landscape, to the joy generated by playing with lifelong friends and family.

The two genera of elephants (African, *Loxodonta africana* and Asian, *Elephus maximus*) share social and ecological traits, although there are subtle differences in behaviour and social structure (e.g. de Silva and Wittemyer, 2012). Therefore the EWG stresses the general applicability of elephant "needs" across the genera, both of which are kept in UK zoos.

Elephants have rich, deep and complex social lives acted out over a potential lifespan of 70+ years. They exhibit multi-level sociability with fission and fusion, where groups form and dissolve on a minute to minute or day to day basis (Archie *et al.*, 2006; Nandini *et al.*, 2018). For elephants, knowledge, memory and active choice are all involved in how elephants form groups. Sociability is more than a measure of time spent with others; it reflects tolerance of others' nearness, positive responses to approaches and contacts with others (including via vocalisations), and friendly concern and care for others' infants.

Space sustains elephant sociality, allowing aggregation and avoidance – fission-fusion – and normative diverse activities over a 24-hr period. Movement across home ranges that span tens to tens of thousands of square kilometres is determined by both social and ecological factors. Travelling over a mixed terrain, between habitats with seasonal variability, maintains foot health and body condition, offers variation in sensory input and provides opportunities to experience the unexpected (leading to arousal and possibly to higher affect intensity).

Elephants monitor their world using a variety of modalities – scent, sound, touch – and they apply this knowledge to responses to social and environmental challenges. Elephants make decisions about when and where to move between areas, habitats and companions (avoiding noise, being able to keep warm or cool, seeking or avoiding other individuals, engaging with keeper activities such as training).

3.2 Global Concerns About Captive Elephant Welfare

The significant welfare problems experienced by elephants kept in zoos has been the subject of much debate, research and campaigning around the world, particularly over the past 10 to 20 years. Serious scrutiny of the issue began in the UK after the death of three elephant keepers, and a lawsuit over poor treatment of elephants during 'taming' of elephants destined for export to European zoos (reported in Clubb and Mason, 2002; Gore *et al.*, 2006; Hutchins and Keele, 2006). These incidents contributed to The Royal Society for the Prevention of Cruelty to Animals (RSPCA) commissioning a study by Oxford University researchers, Ros Clubb and Georgia Mason. Born primarily from concerns about the impact of intensive management and hands-on training and handling of elephants in zoos (Atkinson, 2009), the review aimed "*to identify welfare problems associated with keeping elephants in captivity; to scientifically identify relationships between such problems and elements of elephant husbandry; and to make sound, ethically based recommendations for improving welfare of captive elephants*". The resulting report (Clubb and Mason, 2002) and follow-on scientific publications (Clubb *et al.*, 2008, 2009) identified several serious welfare issues based on a review of the literature and analysis of the European Ex-situ Species Programme (EEP) Elephant Studbooks. These issues included high mortality rates, low reproductive rates, lameness (and other health issues), and abnormal behaviours (stereotypies, high levels of aggression). This work contributed to the animal-based welfare measures identified in Table 3.1. The studies also identified welfare concerns relating to the way in which elephants were housed and cared for, and these are included in Table 3.2.

The wider issues of ethics of elephant keeping, explored by the Zoos Forum (2010), have been raised and discussed by members of the EWG. While these were agreed as being outside the remit of the current report, it is hoped that a consideration of ethical issues will form part of the evaluation by ZEC and the Minister for Animal Welfare.

3.3 Background to the EWG

3.3.1 Concerns about the welfare of elephants in UK zoos

Following publication of the RSPCA-commissioned report in 2002, elephants were a discussion point at several Zoos Forum meetings. A decision was made to examine the situation in UK zoos in detail, explore some of the research suggestions made by Clubb and Mason (2002) and identify factors associated with elephant welfare (Zoos Forum, 2010; see Appendix 3.2). A project steering group was formed by the co-funders: Defra, the RSPCA, IFAW and BIAZA, and a research tender agreed and issued. The tender was

awarded to Dr Moira Harris, Dr Chris Sherwin and Professor Stephen Harris, of the University of Bristol. Results of this independent research carried out in 2006 by Harris *et al*., were published in the report 'The welfare, housing and husbandry of elephants in UK zoos' in November 2008.

Reporting on visits to all elephant holding zoos in the UK, Harris *et al.* (2008) collected data on housing, behaviour, and health, and obtained faecal samples to measure faecal glucocorticoid metabolites (FGMs). Based on data collected during three visits to each facility over an 18 month period, Harris *et al.* (2008) cited a number of specific welfare concerns, including: 81.4% of elephants had some type of foot health problem; 82.1% had an abnormal gait; 75% were overweight; 55% of elephants were observed performing stereotypical behaviour during the day, and 49% performed stereotypical behaviour during the night. Findings are further detailed in Tables 3.1 and 3.2.

Table 3.1: Animal-based welfare indicators highlighted historically and by Harris *et al.* (2008) as a cause for concern, in UK and/or European zoos, leading to the EWG being tasked with their current remit.

Welfare indicator	Significant findings for zoo elephants
Survivorship	Significantly lower than reference populations, especially in elephants born in zoos.
Lifespan	Lived, on average, half as long as reference populations.
Infant mortality	2-3 times higher than reference populations. High rates of stillbirths, infanticide and calf rejection.
Fecundity and birth rates	Birth rates far lower, and stopped earlier, than reference populations. High rates of abnormal reproductive cycling. Skew to male births.
Sustainability of zoo population	Not self-sustaining due to low fecundity and survivorship.
Body condition	Three out of four elephants were overweight.
Lameness and joint problems	High prevalence of lameness.
Foot health	High prevalence of foot problems.
Stereotypical behaviour	High prevalence of stereotypic behaviours.
Aggression	Aggression-related elephant deaths reported but aggression infrequently observed. Aggression towards humans reported and handler deaths.
Cortisol measures	Unclear welfare implications of findings from faecal cortisol metabolite (FGM) measurements.
Circulatory Problems	Most common cause of death in non-infants.
Elephant Endotheliotropic Herpes Virus (EEHV)	Increasingly implicated as a cause of mortality in young Asian captive elephants and stillbirths. High mortality rate.
Tuberculosis	Known in zoo population. Zoonotic so can be passed to humans and cases reported in keepers.

Table 3.2: Resource-based welfare indicators highlighted historically and by Harris *et al*. (2008) as a cause for concern, in UK and/or European zoos, leading to the EWG being tasked with their current remit.

Welfare indicator	Significant findings for zoo elephants
Social Groupings and group composition	Smaller groups, atypical group composition (age and sex) and fewer relatives compared with reference populations. Most zoos with males had only one.
Transfers between zoos	Transfers frequent. Associated with lower survivorship. Most elephants transferred alone and at a young age.
Early weaning	Zoo-born elephants removed from their mothers and transferred to other zoos in infancy.

Time confined indoors	Confined indoors for half to three-quarters of the 24hr day, on average. Only two (of 16 facilities) provided freedom of choice for movements.
Space available	Average indoor space available to each elephant was 165.9m^2 (range 17.9 to 560m^2). Average outdoor space available to each elephant was 8,713m^2 (range 280 to 22,514m^2) in winter and 11,326m^2 (range 280 to 36,422m^2) in summer.
	Smaller spaces associated with poor welfare from health and behavioural indicators.
Restraint	Chaining was common practice including overnight.
Handling system	Most elephants handled in free contact (60.5%); few (14.5%) in protected contact.
Substrate	Hard unyielding substrates in all but two indoor enclosures. Associated with foot and joint problems.
Mature bulls	Lack of adequate facilities, or a coherent strategy for housing mature bulls into the future as young bull calves aged.
Diet	Most diets were deficient in various vitamins and minerals and had an excessive fat content. Grazing was not available in nine out of 10 zoos.
Climate	Colder, wetter climates may be linked to foot and joint problems, and result in elephants being kept indoors for up to 24 hours in winter.

3.3.2 Development of the EWG

Defra's Zoos Forum (now the Zoos Expert Committee) subsequently published a response to the Harris *et al.* (2008) report, reviewing the documented concerns for UK zoo elephants, and they invited input from interested parties. The Zoos Forum examined these welfare 'costs' in the context of the reasons given for keeping elephants in zoos (the potential 'benefits') before developing a series of recommendations for the way forward (Zoos Forum, 2010). They concluded that "*There is a need for concerted and vigorous efforts to tackle the health and welfare issues discussed … and, if zoos wish to keep elephants into the future, to tackle the sustainability issues also. In view of the importance of these issues, clear progress needs to be made and this will need to be monitored*" (Zoos Forum, 2010). They also made the point that "*considerable improvement upon the present situation*" is required if zoos are permitted to continue keeping and breeding elephants into the future. They proposed the establishment of an independent Elephant Advisory Group "*to advise upon, encourage, and monitor progress … and that there should be a comprehensive review of progress in ten years' time.*" Notably, five members of the Zoos Forum favoured an alternative to the independent Elephant Advisory Group, namely an expansion of BIAZA's newly established Elephant Welfare Group (Zoos Forum, 2010). The latter option was taken forward by the Minister.

The Zoos Forum report (2010) provided further detailed guidance on the remit of the proposed Advisory Group (see Appendix 3.2) which included:

- planning and driving a programme of welfare improvements;
- development of husbandry advice where needed;
- encouraging and monitoring coordination between zoos in progress towards improved welfare; and
- monitoring overall progress.

3.3.3 Remit of the EWG

Subsequently, in January 2011, Lord Henley, then Parliamentary Under Secretary of State at Defra, wrote to BIAZA "*to request your help in stepping up action to tackle the serious welfare problems found in elephants in UK zoos as set out in the 'Bristol' report.*" Lord Henley asked BIAZA to extend their new Elephant Welfare Group to take on a new remit (i.e. work with Defra, and bring on board external experts and non-BIAZA zoos) to "*drive forward a programme of improvements, encourage co-ordination, develop and share husbandry advice and good practice, and monitor progress. I agree with the Forum that a ten year period for this is reasonable, with a review after five years. I expect there to be evidence of improvements within this timescale.*" (Letter from Lord Henley to BIAZA, January 2011). Lord Henley also stated *"I should say that such is my concern about the welfare of elephants in UK zoos that I have*

not ruled out the option of looking at the scope for phasing out the keeping of elephants in the UK in the future if there is little or no evidence of improved welfare". Similarly, Lord Gardiner of Kimble was quite explicit in his speech at an elephant stakeholder meeting in February 2017 that a phasing out of elephants from UK zoos was a possibility if improvements were not evident after the 10-year period, in January 2021.

It should be noted that the EWG's role was to provide information, guidance and recommendations to zoos, and to monitor progress in elephant welfare over time. It was not and is not within the control of the EWG to ensure that these recommendations are followed, nor to ensure that improvements in elephant welfare are made. Rather this responsibility lies with the elephant-keeping zoos themselves, as well as those enforcing the Zoo Licensing Act 1981.

At the time of this report, the EWG consisted of 18 members, including academics, Defra-appointed representatives, welfare scientists, zoo directors, zoo veterinarians, elephant keeping staff and other elephant behaviour and welfare experts. From 2019, the group was chaired by Dr Miranda Stevenson OBE, with Dr Lisa Yon as Vice Chair. Composition of the group over the 10-year period can be found in Appendix 3.1.

The terms of reference, based on the tasks for the group identified by Lord Henley and agreed by the EWG, were:

1. To take vigorous and concerted action to ensure that UK collections maintain their elephants to the highest standards based on current knowledge. This should include: planning and driving a programme of improvements, development of husbandry advice where needed, encouraging and monitoring coordination between facilities keeping elephants and monitoring progress.
2. To ensure strategic research is carried out to advance knowledge relating to the husbandry, health and welfare of elephants to support Objective 1.

The EWG includes four subgroups dealing with husbandry issues raised by Harris *et al.* (2008):

- Social and reproductive management
- Feeding, nutrition and body condition
- Health, foot care and locomotion
- Behaviour and abnormal behaviour

3.3.4 Broader Welfare Context

In an ideal world, this report would consider elephant welfare in the context of both providing for elephants' basic needs - keeping them alive, healthy and breeding - and also considering their psychological welfare, and taking a holistic life-time look at their experiences, with the aim of giving them a 'good life' (FAWC, 2009). This wider work has started and needs to be ongoing; however at the time the group was initiated there were no existing baseline measures of positive mental states and experiences of the UK zoo elephant population from which to measure progress. The EWG recognises the importance of the experience of positive mental states and experiences as critical components of wellbeing and the EWG's new tools should provide a foundation for ongoing future study and a holistic assessment of zoo elephant welfare.

OIE Definition of Animal Welfare

Animal welfare means the physical and mental state of an animal in relation to the conditions in which it lives and dies.

An animal experiences good welfare if the animal is healthy, comfortable, well nourished, safe, is not suffering from unpleasant states such as pain, fear and distress, and is able to express behaviours that are important for its physical and mental state.

Good animal welfare requires disease prevention and appropriate veterinary care, shelter, management and nutrition, a stimulating and safe environment, humane handling and humane slaughter or killing. While animal welfare refers to the state of the animal, the treatment that an animal receives is covered by other terms such as animal care, animal husbandry, and humane treatment."

3.4 Scope of this report

This report summarises the work and conclusions of the Elephant Welfare Group conducted with UK elephant-holding zoos during the period 2011 – 2020. It provides evidence of changes in UK captive elephant welfare and husbandry that have occurred during the 10-year timescale of the Elephant Welfare Group's activities. The ethical aspects of elephant keeping are not explored in this report.

The work presented here focuses on the specific welfare and husbandry concerns highlighted by

Harris *et al.* (2008) and in the Zoos' Forum report (2010) as noted above (see Tables 3.1 and 3.2). Section 6: *Discussion* brings together the EWG's findings in an attempt to examine the holistic life-time experience of elephants living in UK zoos today based on what we currently know, and identifies areas of ongoing and future work needed.

3.4.1 Welfare indicators used previously, and concerns raised

Prior to the work of the EWG, a number of welfare indices had been described by researchers investigating elephant welfare (particularly in the report by Harris *et al*., 2008), and it is on these that the EWG focused. These are summarised in Table 3.3 and can be broadly categorised as measures of: reproduction, mortality, health, and behavioural indicators of welfare. Apart from behavioural indicators, these measures represent an assessment of conditions associated with compromised welfare, but most do not enable an assessment of positive welfare. Elements of positive welfare (sociality, play, affect) are examined in new behavioural assessment tools (EBWAT).

It is always recommended that a suite of welfare indicators should be used rather than a single test in isolation; thus the complex construct of welfare is best assessed through multiple measures, as they can each help with interpretation of the other data collected, and can provide a more holistic evaluation of welfare (Hill and Broom, 2009; Mason and Veasey, 2009).

Survivorship, longevity and reproductive fitness have been measured in zoo elephants. Poor survivorship in adults and infants, low median lifespan, poor conception rates, long inter-birth intervals and early cessation of reproductive competence were reported in Clubb and Mason (2002). Each of these issues may well be associated with adverse welfare. Failure to reproduce may be an indicator that welfare is compromised, although there are complex factors contributing to reproductive failure (Moberg, 2000). Additionally, the impact of having non-breeding females in a group may have welfare implications which are not yet fully understood. Mason and Veasey (2010) explored the role of fecundity, acyclicity, stillbirths and infant mortality from population level (studbook) data to examine the utility of these measures as welfare indices. They concluded that low fecundity, premature reproductive senescence, acyclicity and high stillbirth rates could be indicative of poor welfare, but that the evidence was not yet clear due to the complex physiological processes involved. Successful reproduction in captive elephants is not necessarily an indication that an animal is experiencing good welfare, but reproductive failure could certainly be used to indicate compromised welfare. In addition, very early reproductive onset seen in captivity (see 5.2), especially during rapid growth phases, may impact long-term health and fitness, but this has yet to be fully evaluated. These issues are also a concern when considering the future of elephants in captivity, if there is a goal of establishing a self-sustainable population that does not require further importation of animals from the wild, which is itself a major welfare concern (Hutchins and Keele, 2006; CITES, 2019).

Health has previously been assessed through the presence or absence of a range of conditions, including lameness, poor foot health, obesity, skin lesions, EEHV and tuberculosis (Clubb and Mason, 2002; Harris *et al.*, 2008). The experience of such compromised health is likely to represent a significant welfare issue, as may the intensive treatment regimes that are sometimes required (e.g. EEHV).

The **physiological** welfare assessment measure explored in Harris *et al.* (2008) was the non-invasive measurement of glucocorticoids (from faecal or urine samples). Glucocorticoids are a group of hormones produced following activation of the hypothalamic-pituitary-adrenal axis, as an excitatory response to arousing stimuli (not always associated with stress). Measurement of glucocorticoids in faecal samples has been previously identified as a potential measure for assessment of welfare in elephants (Mason and Veasey, 2009). However, glucocorticoids can increase in a variety of situations unrelated to stress (Ralph and Tilbrook, 2016): e.g. during feeding, reproductive activity, social excitement, and through diurnal variations in secretion (e.g. Menargues *et al.*, 2012). Moreover, in situations of chronic stress, levels of glucocorticoids can actually decrease below baseline levels (Wong *et al.*, 2018). Thus, interpretation of glucocorticoid levels in relation to welfare can be quite complex and it is important to assess other welfare indicators alongside them, such as behaviour, in order to interpret them accurately.

Behavioural welfare indicators have primarily focused on the measurement of undesirable behaviours, such as high levels of elephant-to-elephant aggression, and stereotypical behaviour

(Clubb and Mason, 2002; Harris *et al.*, 2008; Mason and Veasey, 2009; Mason and Veasey, 2010). However, as with other measures of welfare, caution must be used in interpreting the expression of stereotypies, as their expression can persist beyond the presence of the initial stimulus/stressor that triggered their development, so the observation of this abnormal behaviour may not reflect the animal's current welfare status (Mason and Latham, 2004). Nevertheless, looking at the expression of aggression and stereotypies in young animals may indicate whether there are current environmental factors contributing to their development, or whether these highlight an historical welfare problem. Regardless, the presence of such behaviour should always be considered as a red flag indicating that current welfare may be compromised, and measures should be taken to identify and address possible underlying causes, which may require long-term interventions (Swaisgood and Shepherdson, 2005). The performance of stereotypies is also associated with poor foot health, and elephants are reported to interact less with the environment and with other elephants when performing stereotypies, reducing opportunities for experiencing positive welfare through appropriate interactions with their physical and social environment.

In addition to these animal-based measures, it is also beneficial to look at the ways in which elephants are housed and cared for in order to build a picture of their overall welfare state. Although resource-based measures, like diet and enclosure size (see Table 3.2), do not directly tell us how an animal feels, they can nevertheless be informative, particularly when the link with welfare is underpinned by strong evidence from a suite of animal-based measures (Mellor, 2016). Minimum standards for such resource-based measures are embodied in zoo guidelines (BIAZA) and legislation (Secretary of State Standards for Modern Zoo Practice or SSSMZP), with compliance determined by: (1) regular audits (BIAZA) and (2) during inspections (SSSMZP) to ensure compliance under the Zoo Licensing Act.

3.4.2 Welfare indicators used by the EWG

For clarity, the tables below summarise welfare measures considered by the EWG and provide signposts to the relevant sections where these are discussed. Indicators are categorised into animal-based measures (Table 3.3) and the resource-based measures (Table 3.4), discussed in the previous section.

Table 3.3: Animal-based welfare indicators used by the EWG and the sources of data.

Welfare indicator	Data source	Results section
Survivorship	Studbooks (UK)	Section 5.3A
Lifespan	Studbooks (UK)	Section 5.3A
Causes of death	Pathology and specimen reports (UK)	Section 5.3A
Infant mortality	Questionnaire responses from UK and European Zoos	Sections 5.2 & 5.3A
Fecundity and birth rates	Questionnaire responses from European Zoos	Section 5.2
Body condition	Keeper reports – new EWG BCS tool	Section 5.4
Lameness and joint problems	Keeper reports – new EWG locomotion tool	Section 5.3B
Foot health	Keeper reports – new EWG foot health tool	Section 5.3B
Stereotypic behaviour	Keeper reports – new EBWAT tool	Section 5.5
Aggression	Keeper reports – new EBWAT tool	Section 5.5
Other behavioural parameters (feeding, affiliative, interaction with environment, rest lying)	Keeper reports – new EBWAT tool	Section 5.5

Qualitative Behavioural Assessment (QBA)	Keeper reports – new EBWAT tool	Section 5.5

Table 3.4: Resource-based welfare indicators used by the EWG and the sources of data.

Welfare indicator	Data source	Results section
Social groupings and group composition	BIAZA audit and reports from zoos	Sections 5.1 & 5.2
Time confined indoors	BIAZA audit and reports from zoos	Section 5.1
Space available	BIAZA audit and reports from zoos	Section 5.1
Restraint	BIAZA audit and reports from zoos	Section 5.1
Handling or management system	BIAZA audit and reports from zoos	Section 5.1
Substrate	BIAZA audit and reports from zoos	Section 5.1
Diet	BIAZA audit and reports from zoos	Section 5.4

The assessment of changes in welfare, as made here, are within the context of the community of UK elephant keeping zoos, where clear compromises were previously shown. In this regard, the collection of long-term data over many years is crucial in order to monitor changes in the welfare status of elephants and elucidate how welfare is affected by aspects of their management in captivity, as well as whether changes in management predicted to have positive welfare impacts have actually led to welfare improvements.

3.5 Elephants in captivity in the UK

This report concerns elephants kept in captivity in the UK. As shown in Table 3.5, as of 31 December 2019 there were 52 elephants, comprising 28 Asian elephants (5 males and 23 females) and 24 African elephants (10 males and 14 females), held in 12 UK collections. This represents a reduction in elephant numbers by around a third since 2006 (Harris *et al.*, 2008) and about half since 2001 (Clubb and Mason, 2002). Between 2006 and 2019, four zoos stopped keeping elephants, while two began holding elephants. All but two elephants are held in licensed zoos; these are two Asian elephants held at a multi-faith monastic community in mid Wales, licensed under the Dangerous Wild Animals Act 1976. All UK zoos holding elephants are members of EAZA and the majority are also members of BIAZA (10 zoos, 26 Asian elephants and 11 African elephants).

There were three facilities breeding African elephants and three breeding Asian elephants in 2010; two of these had ceased holding elephants by 2019, one had commenced breeding and one had the potential for future breeding. Of these facilities, only four were breeding naturally with a male; the rest used artificial insemination.

All UK zoo elephants are part of the European Association of Zoos and Aquariums' (EAZA) Ex situ Programme (EEP) for either Asian or African elephants, overseen by EAZA's Elephant Taxon Advisory Group (TAG). The EEPs make population management decisions for the European-level zoo population of that species, including breeding and movement recommendations, based on the genetic and demographic requirements of that population.

Table 3.5: Captive UK elephant population from 2006 to 2019

Collection (African elephants [Af] or Asian elephants [As])	Number of elephants: total (male, female)		
	2006 Harris	**End of 2010**	**End of 2019**
Belfast Zoo (As)	4 (0,4)	4 (0,4)	2 (0,2)
Blackpool Zoo (As)	4 (0,4)	3 (0,3)	6 (1,5)
Blair Drummond Safari Park (Af)	3 (0,3)	3 (0,3)	1 (0,1)
Chester Zoo (As)	9 (2,7)	9(3,6)	6 (2,4)
Colchester Zoo (Af)	7 (3,4)	4 (1,3)	4 (1,3)
Howlett's Wildlife Park* (Af)	13 (2,11)	14 (3,11)	13 (5,8)
Knowsley Safari (Af)	8 (2,6)	7 (1,6)	0
Longleat Safari Park (As)	0	0	1 (0,1)
Noah's Ark Zoo Farm (Af)	0	0	3 (3,0)
Paignton Zoo (Af) Paignton Zoo (As)	1(0,1) 1 (0,1)	1 (0,1) 0	0 0
Port Lympne Safari Park* (Af) Port Lympne Safari* (As)	0 7(1,6)	4(2,2) 0	0 0
Skanda Vale* (As)	1 (0,1)	1 (0,1)	2 (0,2)
Twycross Zoo (As)	4 (0,4)	5 (1,4)	0
West Midland Safari Park (Af)	4(2,2)	3 (1,2)	3 (1,2)
ZSL Whipsnade Zoo (As)	9(1,8)	9 (3,6)	6 (1,5)
Woburn Safari Park (As)	3 (1,2)	4 (1,3)	5 (1,4)
TOTALS African Asian	**78 (14, 64)** **37 (9, 28)** **41 (5, 36)**	**71 (16, 55)** **36 (8, 28)** **35 (8, 27)**	**52 (15, 37)** **24 (10, 14)** **28 (5, 23)**

*non-BIAZA members

4 Overview of engagement with EWG and tool development

Summary

- The Elephant Welfare Group has been able to contribute to the development of welfare and husbandry standards used during the inspection of those zoos keeping elephants. The Secretary of State's Standards for Modern Zoo Practice incorporates specific elements derived from the EWG's activities (SSSMZP-Appendix 8, May 2017).
- Part of the EWG's activities were the development of novel tools which were used to gather evidence about any changes in welfare status, and to provide mechanisms for the ongoing monitoring of captive elephant welfare into the future. Each of the tools is discussed in detail in the following sections. Here we present an overview of engagement on the part of zoo stakeholders with the tools.
- Descriptive information on terminology used for categorising elephants by age is presented to contextualise further discussions.

4.1 SSSMZP review and development of evidence-based recommendations

In 2012, BIAZA and Defra updated the Secretary of State Standards for Modern Zoo Practice (Appendix 8 – elephants), which are critical to the licensing of zoos. These initial changes were driven by the publication of Clubb and Mason (2002), Harris *et al*. (2008) and the Zoo Forum 2010 reviews which identified compromised welfare. The EWG provided input into specific guidelines for elephants in a subsequent version (between 2016 and 2017, and again in 2019). In 2013-2014, as part of a Defra-funded research project (Asher *et al.*, 2015), the Behaviour Subgroup undertook a detailed review of published evidence and expert opinion to make evidence-based recommendations on revisions to Appendix 8 of the SSSMZP guidelines. In this project, the physical and social resources important to elephants were identified through two sources: published literature (including peer reviewed research, grey literature and review/opinion papers), and stakeholder opinion gathered through focus group teleconferences (for more detail see Asher *et al*., 2015; Chadwick *et al.,* 2017). The identified resources were then ranked, in terms of their importance to captive elephant welfare, by attendees at a stakeholder workshop (which included keepers, managers and veterinarians from 11 British and Irish elephant-holding zoos, as well as representatives from animal welfare NGOs, and University academics specialising in animal behaviour and welfare). The project's External Advisory Panel (EAP) and the Project Team reviewed the current SSSMZP guidelines for elephants. In light of the resources of importance identified during the project, and the weight of evidence for each resource, suggestions were made for revisions to the existing SSSMZP guidelines. Many of these suggestions informed the updated guidelines released in 2017 (see Table 4.1).

4.2 Stakeholder engagement with the EWG longitudinal welfare assessment tools

Four distinct and novel welfare assessment tools were developed and adopted by the EWG. These tools were related to key issues of compromised health, husbandry and welfare identified by Harris *et al.* (2008) as set out in Tables 3.3 and 3.4 (above). They covered individual behaviour, foot health, locomotion and gait, and body condition. Collections were required to complete these tools quarterly for each elephant held at that collection. These were submitted to the EWG and the results are summarised in following sections.

The proportion of expected assessments (four per year per elephant, adjusted for export, import and death, and inclusive of all elephants from one year of age for calves) that were submitted by each collection averaged between a third and a half. Response rate increased for all tools over time from a low of 5% to a high of 90% (Appendix 4.1). However, engagement with protocols varied by collection and some zoos have had a poor uptake due to differences in keeper availability, training and turn-over, although engagement has improved substantially

over the 10 years of the EWG's tenure. The number of responses for different monitoring tools is presented in the appendices associated with the relevant analyses.

Table 4.1: Changes to SSSMZP guidelines (Appendix 8) for zoo elephants adopted in 2017, based on EWG input

Section	Nature of change
8.8.3	30-year management plan now required.
8.8.4	Individual Welfare Plan (including health care, diet, training, welfare monitoring, exercise) required.
8.8.8	Minimise elephant transfer between facilities.
8.8.9	Breeding only within stable matriarchal herds. Calves raised in maternal herd; cows remain in maternal herd for life. Social opportunities for bulls (presence of older bull).
8.8.10	Cows and bulls must have opportunities for social interaction; 16 out of 24-hour unrestricted social access.
8.8.12	Female elephants must have social contact with other elephants at all times. Male and female elephants also have option to get away from other elephants (visual or physical barriers in enclosure).
8.8.14	Bulls must have options for social contact with other elephants (either family herd or other bulls).
8.8.18	Elephant choice of indoor and outdoor space.
8.8.19	Provide a complex and variable enclosure.
8.8.20	Indoor facilities ≥300 m^2 (≤4 elephants). Increase by 80m^2 for each additional elephant. Indoor facilities for bull ≥160 m^2.
8.8.22	Deep sand (≥1m) or natural substrates.
8.8.23	Outdoor area minimum 3,000 m^2 (aim for ≥20,000 m^2 if possible). Flexible enclosures; space for elephants to get away from others.
8.8.26	Opportunities for bathing in both inside and outside enclosures; include variety (e.g. pool, dust bath, mud wallow, sprinklers/showers).
8.8.34	Food presentation to maximise foraging time and provide cognitive stimulation, with an emphasis on browse. Unpredictable timing/intervals , placed throughout enclosure to maximise movement.
8.8.36	Use of welfare monitoring tools required; includes overnight cameras to monitor individuals.
8.8.37	Social, cognitive, physical, sensory and food enrichment, with a goal driven plan (aims and evaluation method) required.
8.8.47	Elimination of most uses of physical restraint (chaining) (not ≥1 out of 24 hours).

4.3 Elephant age categories

Due to the extended period of development in elephants, terminology for distinguishing between immature and adult elephants is complex. In the following sections, calves are considered to be nutritionally dependent on their mothers (0-3 years), juveniles are socially dependent but weaned, while adolescents / subadults are reproductively immature, and adults are sexually mature. Specific age categories are defined in each of the sections, since the age cut-off varied depending on the objective of the particular analysis. To enable comparisons with the Harris *et al*. 2008 report, animals under or over 10 were distinguished in some analyses.

5 EWG Review of Evidence on Captive Elephant Welfare

5.1 Enclosure and husbandry changes from 2006-2020

Summary

Enclosure size and access

- Total enclosure size in UK collections increased between 2010 to 2019.
- The total amount of space available for each elephant increased over this time from 4,014m^2 in 2010 to 6,406m^2 in 2019.
- The average amount of indoor space per elephant has increased from 130m^2 in 2010 to 259m^2 in 2019.
- Indoor space per elephant has also increased compared to that available during Harris *et al.*'s (2008) study, from 59.3m^2 to 259 m^2.
- Elephant choice, on a 24/7 basis, of access to indoor and/or outdoor enclosures was available for at least part of the year for females groups in 50% of zoos in 2019 (6/12 collections) and for part of the year for all elephants (cows, calves and bulls) in 42% (5/12) of zoos.

Substrate

- In 2019, the majority of collections (76.9%) used softer and/or more natural materials such as sand, rubber or bark chips as substrates for at least part of their indoor enclosures.

Management type

- There has been a significant change in management, specifically in the system used for contact between keepers and elephants, over the last ten years. By 2019, 79.2% of elephants were managed using protected contact (with a physical barrier between keepers and elephants), representing a major shift from 48.5% of elephants that were managed this way in 2010.

Relatedness – kinship and generations within groups

- Mean family group relatedness coefficient in 2019 (n= 48, excluding bulls >6yrs) was 0.05, which was a slight decrease from 0.067 in 2010, due to inter-zoo transfers and mortality.
- Mean bull (6yr+, n= 7) relatedness coefficient with other group members in 2019 was 0.048, an increase from 0.08 in 2010.

5.1.1 Enclosure and Management Changes: Methods

Enclosure and husbandry (enclosure size, indoor substrate and access) information was obtained from the 2010 and 2014 BIAZA elephant audits, made available to the EWG with permission from the zoos. Comparative data for 2019 were obtained by request from the EWG to each zoo directly. Descriptive data show trends in enclosure size separately for the indoor and outdoor enclosures and for total enclosure size, as well as for the substrate used indoors and whether elephants had unrestricted 24/7 access to both indoor and outdoor enclosures for at least part of the year.

Space per elephant was calculated based on the number of elephants at the collection, divided by the amount of space at the zoo. This calculation does not account for actual access to different enclosure areas but enables an estimate of enclosure size that takes account of the number of elephants held.

5.1.2 Relatedness Coefficient: Methods

Relatedness coefficients were determined by examining genetic relationships (both maternal and paternal) between elephants, using UK zoo elephant studbook data to quantify individual, collection and overall UK zoo population relatedness for 2010 and 2019. Relatedness was explored here for two key purposes: 1) to assess whether elephants were being kept in family groups of grandmothers, mothers, daughters, and sisters as we see in the wild; and 2) to determine whether breeding age bulls were being housed with related or unrelated breeding age females, in order to assess the potential for inbreeding; high relatedness could result in males breeding with their kin (mothers, sisters), resulting in inbred, and ultimately less healthy, offspring.

The average relatedness coefficient for each period, 2010 and 2019, was based on the average (mean) for all elephants at each collection, with each elephant's individual relatedness calculated. All

calculations were based on all elephants at that site, regardless of whether they could physically access each other. Relatedness was calculated as the percentage of shared genes (50% [0.50] mother-offspring, siblings 25% [0.25] without shared father, 50% with shared father, grandmother- grandchild 25% [0.25] and so on). The information presented below is the average percentage across all group members.

We considered 6yrs to be the youngest possible age of breeding for both sexes and calculated relatedness coefficients for 2010 and 2019 separately for each of the following groups:

- **Bulls 6yrs+** this includes only the coefficients of any bull aged 6yrs and over (on 1st Jan of 2010 and 1st Jan 2019), to assess their relatedness to the other bulls and to the breeding age females that they were housed with (i.e. male of any age or female aged 6yrs and over (on 1st Jan of 2010 and 1st Jan 2019). Bull relatedness to females was only considered with respect to potentially reproductive females (assumed to be those aged 6yrs and over).
- **Main group** - this was calculated as the sum of the individual relatedness of each female (of any age) to each of the other group members, including male offspring <6yrs (on 1st Jan of 2010 and 1st Jan 2019).

Lone elephants (all of which were female) were included in the main group calculations; average relatedness coefficients for groups without lone elephants are shown in the footnote of Table 5.1.2).

5.1.3 Enclosure and Husbandry Changes: Results

5.1.3.i Total enclosure size

Average total enclosure size increased from 16,375m^2 (±4,020m^2) in 2010 to 18,982m^2 (±5,425m^2) in 2019. The total amount of space available per elephant also increased over this time from 4,014m^2 (±917m^2) in 2010 to 6,406m^2 (±1,648m^2) in 2019 (Figure 5.1.1).

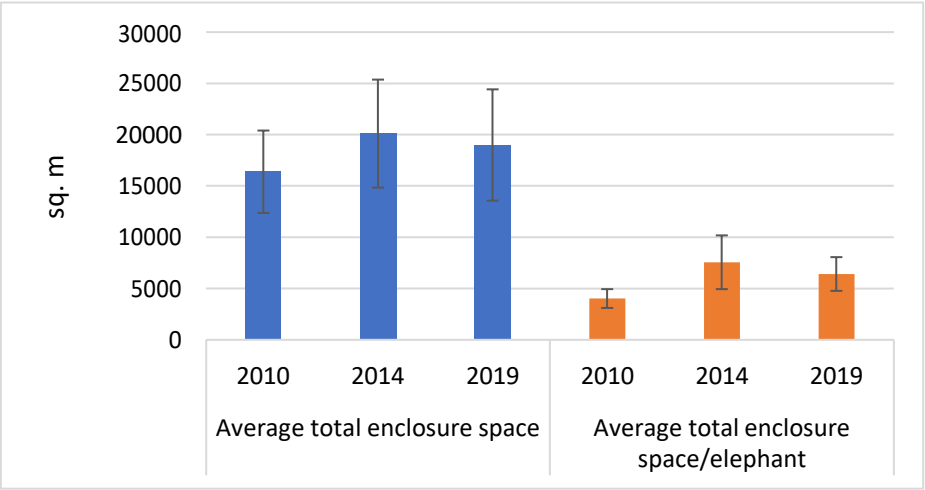


Figure 5.1.1: Average total enclosure size and the average total enclosure size divided by the number of elephants (space/elephant) at each site (2010 = 69 elephants at 14 collections, 2014 = 65 elephants at 16 collections, 2019 = 53 elephants at 13 collections). Error bars show Standard Errors.

5.1.3.ii Indoor enclosure area

Average indoor enclosure size increased from 515m^2 (±105.3m^2) in 2010 to 716m^2 (±105.4m^2) in 2019. The amount of space available per elephant also increased over this time, from 130m^2 (±23.9m^2) in 2010 to 259m^2 (±63.2m^2) in 2019 (Figure 5.1.2).

5.1.3.iii Outdoor enclosure area

Average outdoor enclosure size increased from 15,860m^2 (±4,027m^2) in 2010 to 18,266m^2 (±5,428m^2) in 2019. The space available per individual elephant in the outdoor enclosure also increased over this time, from 3,885m^2 (±918m^2) in 2010 to 5,740m^2 (±1,651m^2) in 2019 (Figure 5.1.2).

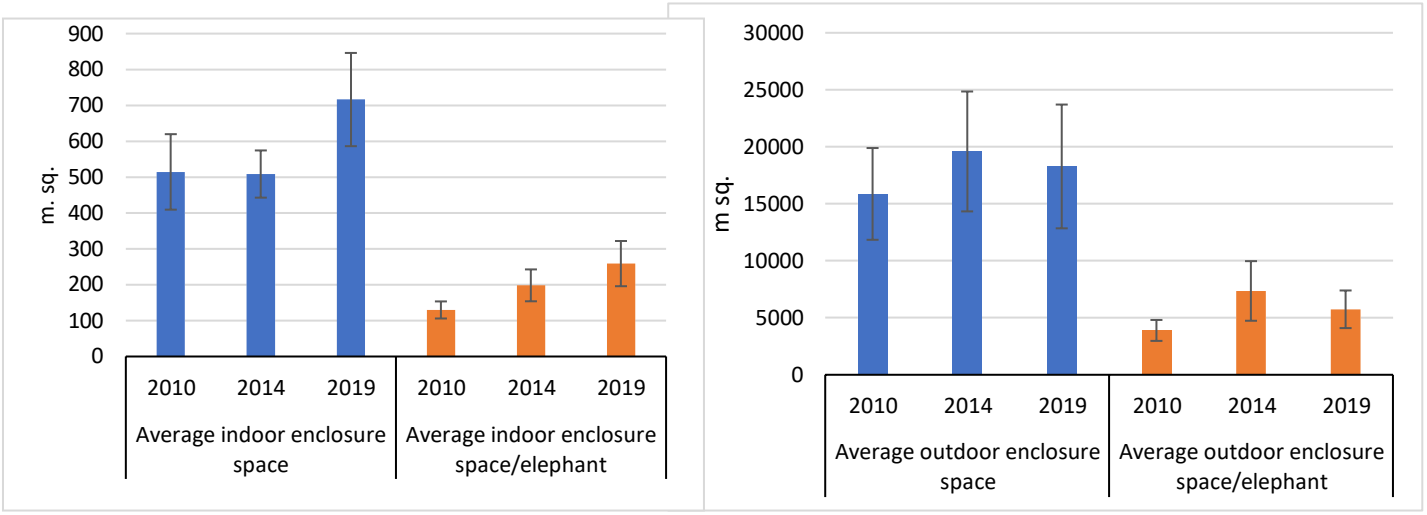


Figure 5.1.2: Average indoor and outdoor elephant enclosure size and average space per elephant, from 2010 to 2019 (2010 = 69 elephants at 14 collections, 2014 = 65 elephants at 16 collections, 2019 = 53 elephants at 13 collections). Error bars show Standard Error.

5.1.4 Indoor substrates

Indoor substrate shifted from a frequent use of 'hard' substrates in 2010 to 'softer' substrates by 2019 (Figure 5.1.3). In 2010, six collections provided only hard substrates (42.9%) in the indoor area. This decreased to just one collection (7.7%) in 2019 and the majority of collections (76.9%) provided softer substrates indoors.

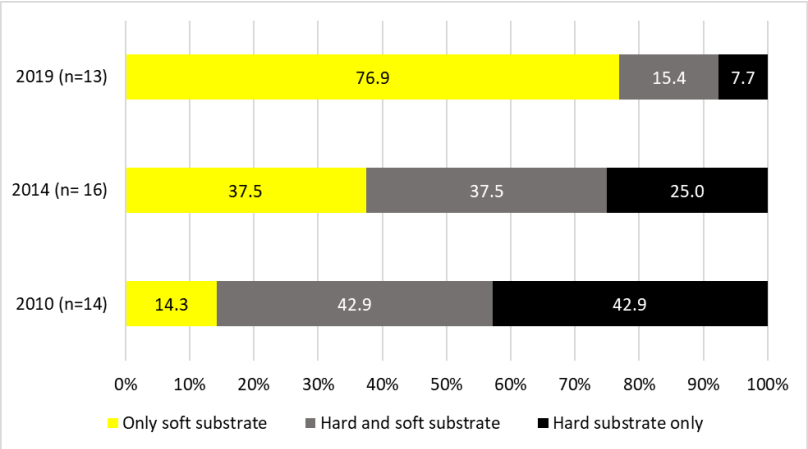


Figure 5.1.3: Substrate used indoors at UK zoo elephant houses. Soft = any substrate with 'give', including sand, chipped bark, rubber. Hard = substrates with no 'give', including concrete and tile floors. (N = number of zoos represented each year).

5.1.5 Elephant choice: Access to indoor and outdoor areas

Information on access to indoor / outdoor areas was not collected in the 2010 BIAZA elephant audit, so these data were only available for 2014 and 2019. There was an increase in the number of collections facilitating 24/7 indoor to outdoor access for the elephants (from 25% in 2014 to 50% in 2019, n=12 collections). However, 24/7 access was limited for many facilities, as zoos indicated that they restricted access in the colder winter months due to health concerns related to extremes of weather conditions and temperatures. By 2019, 50% of females (6/12) had free indoor/outdoor access throughout the year, although one associated male did not have this free choice. Thus 5/12 zoos (42%) provided full

elephant choice of indoor or outdoor access for all of their elephants.

5.1.6 Management by Keepers: Contact type

There has been a major change in how elephants are managed in terms of the type of contact between keepers and elephants over the last ten years. As of 2019, the majority of elephants (79.2%) are now managed under protected contact (physical barriers between keepers and elephants, and training of elephants for procedures) rather than free contact between keepers and elephants (Figure 5.1.4). Protected contact management by 2030 has now been mandated for all zoos who are members of the European Association of Zoos and Aquaria (EAZA).

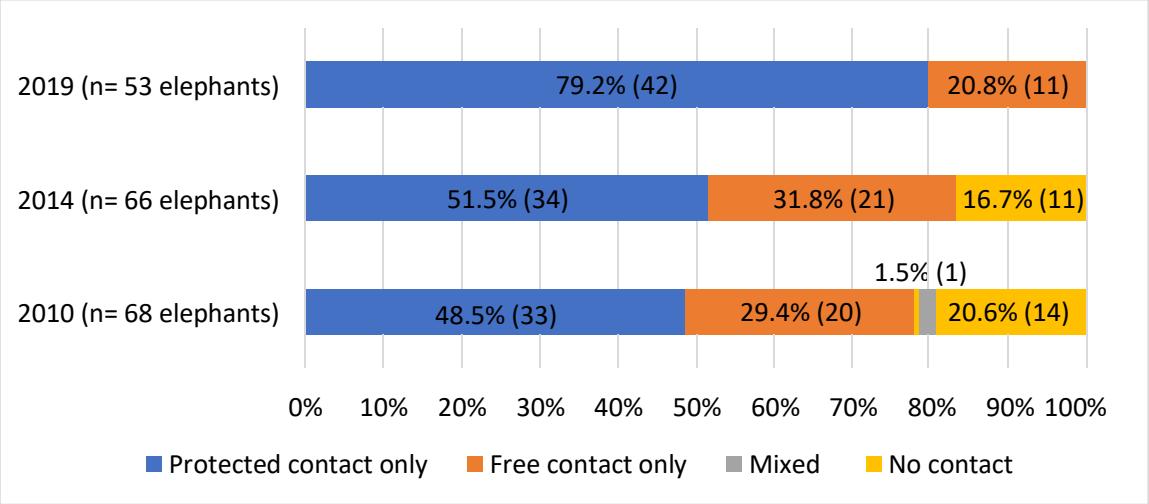


Figure 5.1.4: Management (contact) type for UK zoo elephants, as reported in the BIAZA audits in 2010 and 2014 and through EWG contact in 2019 (n represents number of elephants in the UK, and included in the data, for each year).

5.1.7. Relatedness Coefficient: Results

A key welfare concern was the lack of appropriate kin structuring to captive groups. Among wild elephants, several generations of female kin may live together for most of their lifespan. Thus, higher relatedness of females indicates greater kin structuring of a group, which is considered positive for elephant welfare as it emulates natural social structures, and there is some evidence that this encourages more positive social interactions (Harvey et al., 2019). Conversely, when reproductively mature males co-reside with mothers, sisters or reproductive-aged daughters, there is a potential that these relatives may breed with each other, resulting in inbred, potentially less healthy, offspring. In this case, a lower degree of relatedness is desirable between that bull and those reproductive-aged females at that collection.

Of 13 collections housing elephants on 1st January 2019, the mean family group relatedness coefficient for 48 elephants (excluding bulls 6yrs+) was 0.052, which was a decrease from 0.072 on 1st January 2010. The 2019 data included three lone elephants; excluding these lone elephants resulted in a relatedness coefficient similar to that of 2010, of 0.067 from 45 elephants at 10 collections (Table 5.1.1). In 2010, six facilities had groups with kin structuring. By 2019, evidence of kin structuring was found in three additional facilities, while two of those with previously high degrees of relatedness were no longer keeping elephants.

Bull (6yr+) relatedness in 2019 was 0.048 for seven bulls housed at five collections, representing an increase from 0.008 in 2010. Inbreeding is therefore not a current consideration due to male movement prior to breeding age.

There were nine movements of bulls out of six facilities between 2010-2020, all of which were over 4 years of age.

Table 5.1.1: Relatedness coefficient of elephants housed in UK zoos in 2010 and 2019

	Main group relatedness coefficient - excludes bulls 6yrs+		Bull (6yrs+) relatedness coefficient in relation to all other elephants*	
	2010	**2019**	**2010**	**2019**
Mean group relatedness (standard error)	0.072 (±0.034)	0.052 (±0.019)	0.008 (±0.008)	0.048 (±0.031)
Number of zoos sampled	13	13	8	5
Zoos with lone elephants	0	3	No lone bulls	No lone bulls
Number of elephants sampled	59	48	8 bulls	7 bulls
Number of individual bulls (6yrs+) with relatedness to herd (coefficient above 0)	n/a		1	4
Number of collections with bulls 6yrs+ with scores above 0	n/a		1	2
**Sites with no bull aged 6yr+ were not included in breeding bull data (2010, 5 zoos had no bull; 2019, 8 zoos had no bull,)*				

Table 5.1.2: Relatedness coefficient, by collection and overall, for family groups (all elephants except bulls >6 years) in 2010 and 2019. Data are based on elephants held at collection on the 1st January for either period.

Groups – without bulls >6 years				
Collection number	2010 relatedness	Number of elephants (excluding breeding bulls)	2019 relatedness	Number of elephants (excluding breeding bulls)
1	0	4	0	2
2	0	3	0.05	5
3	0	3	0	1
4	0.09	7	0.13	5
5	0	3	0	3
6	0.12	12	0.07	10
7	No elephants in 2010		0	1
8	No elephants in 2010		[Bachelor group]	n/a
9	0	2	0	1
10	0	1	0	2
11	0	2	0.17	3
12	0	2	0.06	5
13	0.05	7	0.10	6
14	0.50	2	No elephants in 2019	
15	0.10	5	No elephants in 2019	
16	0.08	5	No elephants in 2019	
Mean relatedness	**0.07**		**0.05**	
Excluding lone elephants	**0.07**		**0.06**	

Table 5.1.3: Relatedness coefficient, by collection and overall, for bull elephants (relatedness between any female elephant ≤6 years old and any aged male) in 2010 (8 males ≤6 years) and 2019 (5 males ≤6 years). Data are based on elephants held at collection on the 1st January for both years. Collections lacking bulls in both years are not shown.

Breeding BULL (>6 years) relatedness to females 6yrs+ and any other males				
Collection number	2010 relatedness	Number of elephants (females 6yrs+, males any age)	2019 relatedness	Number of elephants (females 6yrs+, males any age)
4	0	7	0	4
5	0	3	0	3
6	0.07	8	0.15	12
8	No elephants in 2010		0	Bachelor group
11	0	3	No bulls >6yrs	
12	0	3	0	4
13	0	7	0.08	7
14	0	3	No elephants in 2019	
16	0	6	No elephants in 2019	
Mean relatedness	**0.01**		**0.04**	

5.1.8 Overview of Management Changes over Time

- Since 2002, management changes (coinciding with the first major overview of zoo elephant welfare) commenced and these have accelerated recently, at least in part due to the influence of the EWG.
- There has been a major shift towards elephant-led management, removing keepers from direct physical contact, and allowing elephant choice of which enclosures they use on a 24/7 basis.
- Total enclosure size increased overall by 16%. Smaller areas of indoor space have increased by 39%, while outdoor size increased by 15%, in comparison to 2010.
- While it is recognised that the absolute size of indoor or outdoor enclosures may be of reduced importance for the expression of natural behaviours by elephants, limited space remains a welfare concern; these areas are still orders of magnitude smaller and less diverse than those used by elephants in the wild.
- Due to changes in transfer strategies (fewer moves of single elephants), and greater breeding success in some facilities, levels of kinship have increased over time in several facilities. Demographic events over time will contribute to variations in relatedness.

5.2 Reproduction and Social Behaviour subgroup

Summary

- Natural reproduction for elephants remains challenging in captive environments.
- In Asian elephants, the age of the cow and reproductive pathology were the primary risk factors for both acyclicity and failure to conceive.
- In African elephants, acyclicity was highest in those animals that had remained at the same facility with the same herd mates for a long period of time, especially when there was a marked dominance hierarchy.
- Limited access to natural day-night cycles was identified as a risk factor for reproductive failure and remains an important area for future research on elephant reproduction.
- Lack of access to a mature bull elephant during oestrus was the most important factor in reproductive failure. This could be caused by a lack of bull in the herd, incompatibility between the bull and cow, separation overnight, or restricted access which was controlled by keepers.
- In Asian elephants, older primiparous cows were found to be at most risk of dystocia. High calf birth weight was also an important contributor to reproductive failure.
- Maternal or allomothering experience was a vital influence on reducing poor maternal behaviour and increasing calf survival.
- In Asian elephants, herd stability increased calf survival.
- For Asian elephants, calves removed from their maternal herd before the age of 5 years had double the mortality risk compared to those that left the herd after reaching the age of 5 years.

5.2.1 Reproduction and Social Behaviour Subgroup: Methods

Reproductive and maternal behaviour in elephants promotes positive welfare by encouraging social interaction, herd cohesion and an increased repertoire of diverse behaviour including mating and calf caretaking. Successful reproduction in captive elephants is not, however, an indication of high welfare standards on its own, while investigating reproductive failure could potentially identify causes of compromised welfare. Dystocia (birth complications: Flugger *et al.,* 2001; Murray *et al.,* 1996), stillbirth, acyclicity (Brown *et al.;* 2004; Proctor *et al.,* 2010), reproductive pathology and neonatal morbidity and mortality (Taylor and Poole, 1998; Mar *et al.,* 2012) have all been reported in zoo elephants. For the UK population, few prior studies have examined either the consequences of captive breeding or the problems associated with lack of breeding (Dale, 2010); poor breeding success and high mortality has resulted in a concern that captive populations are unsustainable, especially in comparison to wild or timber camp elephants (Clubb *et al.,* 2008, 2009).

5.2.1.i Reproduction data collection: methods

The Reproduction and Social Behaviour EWG sub-group conducted a qualitative risk analysis using standardised techniques to assess risk factors which negatively impacted reproductive activity in elephants housed in European zoos. The European population was used to generate a sufficient sample size for analysis (as using the UK population alone could not achieve this). Furthermore, key factors were identified which influenced the likelihood of a live calf being born that was maternally reared to independence. This latter question is fundamental both to successful captive breeding, involving the behaviour of both males and females, and to the establishment of appropriate kinship and male groups supporting high quality social dynamics.

The work undertaken by this sub-group also used data from European studbooks to compile individual elephants' life histories (i.e. where born, transferred to, where died), to assess their previous social, reproductive and maternal experience (Wood, 2017). In addition, elephant management information was collected through two detailed questionnaires (Hartley and Stanley, 2016). These data were explored alongside peer reviewed and grey literature, and expert opinion collected through structured

facilitated workshops; robust statistical correlational analysis was then performed to produce a risk assessment for reproductive failure (Hartley, 2016). Following this, a preliminary study was undertaken to investigate social interactions of bull elephants, and provide recommendations for bull elephant management to support positive welfare and improve reproductive activity (Hartley, Wood & Yon, 2019).

5.2.1.ii Bull social experience in early life and effects on reproductive success: methods

To explore the impact of the early social environment on later reproductive success (RS) in bulls, Bacon (2019) used 2011 and 2016 European studbook data for 98 Asian elephant bulls. The bulls (n= 56) were grouped by whether or not they had experience of being housed with a reproductively successful bull prior to their first successful breeding events (or prior to reaching 12 years old where they had not bred). A Mann-Whitney-U test was used to assess differences between reproductive success (number of calves born, where the bull could have sired a calf) as a function of these early life experiences. This same assessment should be done for African bulls in the future, to understand the impact of early social environment on their reproductive success.

5.2.2 Reproduction and Social Behaviour Subgroup: Summary of published results

5.2.2.i Paper 1: Social behaviour between bulls in zoos in the UK (Wood, 2017)

At the time of the study, the UK had nine bulls of breeding age (5 African, 4 Asian), defined as males over the age of 10. Of these, six (2 African, 4 Asian) were housed in a herd and able to mate naturally with females during the females' oestrous periods. There were a further six (5 African, 1 Asian) juvenile (<5 years) and adolescent (5-9 years) males which were housed in family groups, together with a mature breeding male, and one adolescent African bull elephant which was housed only with females. There was one bachelor herd composed of two (and then three) African elephant bulls. The creation of more naturalistic opportunities for association, for males born into families and for sexually mature males, is essential for improving welfare among male elephants, shifting away from isolation and constant transfer (Hartley *et al.* 2019).

As shown for wild elephants, the UK zoo males were highly, and positively, social and expressed this by the time spent close to – within a body length – other elephants. Breeding-age adult bull elephants spent 22.4% (Standard Deviation ±17.9%, n = 12) of their free-choice time within one body length of another elephant, and less than half of their time (49.7% ±19.9%) alone. The bachelor pair of elephants spent 21.7% (±7.6%) of their time within one body length of the other pair member, and 47.6% (±11.1%) alone. Juvenile males (under 5 years) spent 71.1% (± 17.7%) of their time within one body length of another elephant, and only 8.1% (±8.2%) alone, when given choices about social companions. The percentage of time spent alone increased with male age, but males of all ages retained a strong social element to their lives.

When adult bulls were in social groups where individuals were less than one body length apart, 65.3% (±5.5%) of groupings also included a young animal (of either sex), while 21.9% ±10.1% of close bull groups included only the bull and youngsters, without an adult female in close proximity. Juvenile bulls also grouped together regularly, and another youngster was the most likely neighbour (37.7% ±7.5% of time). As juvenile males in family groups became increasingly independent from their mothers, they spent more time close to other young males and adult bulls when available. Sons of subordinate cows spent more time socializing with other animals and more time away from their mothers than did the sons of matriarchs.

Similar to their wild counterparts, juvenile and adolescent bulls at UK zoos increasingly spent more time playing and socializing with other bulls rather than with females as they aged. Although much of this interaction was with other adolescent bulls, young bulls also sought some social contact with an adult bull if one was present; this male was not necessarily their father. Time spent at a distance of greater than 30m away from other elephants increased with age, but subadult bachelor males still spent approximately half of their time in close proximity to each other (under 30m) and half alone.

5.2.2.ii Paper 2: Causes of reproductive failure in European zoo elephants (Hartley & Stanley, 2016)

Reproductive success in captivity is low, and only a total of 161 calves have been successfully born to the European population of 87 captive females of

both genera over the last 20 to 30 years. Using a simplistic expectation of one calf produced every 5 years, between 300-500 calves might have been expected from this number of females. Only about half of reproductive aged females (6-45 years) show normal hormonal cycles, and only between 4-17% of females are able to choose to access a breeding male over the 24 hours when she is in oestrus. The various causes of reproductive failure of European zoo elephants are summarised from Hartley and Stanley (2016) in Table 5.2.1 below.

It is clear from the analysis of risk factors, both for successful conception and for a subsequently successful birth, that lack of access to a male, lack of previous experience with a calf, and unstable groups creating marked hierarchies among females (and the potential for aggressive interactions) all reduce the likelihood of successful conception and birth events. Hartley and Stanley (2016) concluded that lower rates of reproductive problems such as stillbirth or dystocia were found in their sample compared to previous studies, suggesting recent management changes have improved reproductive outcomes. However, they proposed that creating more naturalistic stable group structures, with opportunities for cows to gain experience with calves, and observing maternal behaviours, would create significantly more opportunities for successful reproduction – from conception to birth.

Tables 5.2.1 – 5.2.3 summarise findings of Hartley and Stanley (2016) and describe the survey findings regarding causes of reproductive failure in European zoo elephants. It should be noted that the UK population was included in these assessments, and thus the tables highlight issues in reproductive failure that remain to be addressed in the UK captive populations.

Table 5.2.1: Summary of potential causative factors in relation to failure to conceive by genus. (Samples sizes)

Factor	African	Asian
Hormones monitored	71% (34/48)	56% (22/39)
Reproductive tract pathology	23% (11/48)	43% (17/39)
Abnormal reproductive cycle	60% (29/48)	51% (19/39)
Acyclic	10% (5/48)	3% (1/39)
Irregular reproductive cycle	4% (2/48)	14% (5/39)
Unknown reproductive cycle	75% (36/48)	36% (14/39)
Mean Age at Puberty	9.2 years (n=5)	5.5 years (n=5)
Other health issues	17% (8/48)	5% (2/39)
Unstable herd hierarchy	8% (4/48)	26% (10/39)
Changes to herd composition	63% (30/48)	46% (18/39)
Cow refuses to allow bull to mate	50% (17/35)	21% (6/28)
Bull refuses to mate the cow	11% (4/35)	21% (6/28)
Cows only mixed with bull when in oestrus	17% (8/48)	18% (7/39)
Cow never mixed with bull housed at the same zoo	17% (8/48)	5% (2/39)
No bull housed at the zoo	10% (5/48)	23% (9/39)
Lack of overnight access to the bull	4% (2/48)	17% (7/39)

Table 5.2.2: Summary of potential causative factors for reproductive failure from the time of conception to birth at population level. [conceptions = 67 for 48 African elephants; 122 for 39 Asian elephants; live births = 48 for African elephants (over 31 years); 83 for Asian elephants (over 21 years)].

Factor	African	Asian
Abortion rate	7.5% (5/67)	3.2% (4/122)
Twinning rate	1.4% (1/67)	1.6% (2/122)
Dystocia rate	11.9% (8/67)	16.4% (20/122)
Stillbirth rate	11.9% (8/67)	12.3% (15/122)
Cow failed to immediately accept calf and allow to feed	13.4% (9/67)	22.9% (28/122)
Cow failed to accept calf but went on to rear it successfully	7.5% (5/67)	14.8% (18/122)
Dam aggressive to calf	4.4% (3/67)	9% (11/122)

Infanticide by mother	1.5% (1/67)	2.5% (3/122)
Killed by another herd member	0%	1.6% (2/122)
Number of calves attempted to be hand-raised	5.9% (4/67)	3.3% (4/122)
Number of calves removed and hand-raised successfully	1.5% (1/67)	0%
Survival rate overall (including abortions and stillbirths)	71.6 % (48/67)	68.0% (83/122)
Survival rate of live births	81.3% (48/59)	81.4% (83/102)
Mortality rate to infectious disease	2.9% (2/59)	9.8% (10/102)

Table 5.2.3: Summary of potential health, social and husbandry causative factors for reproductive failure or success at birth by genus.

Factor	African	Asian
Reproductive tract pathology diagnosed	0% (0/67)	7% (4/57)
Hormones monitored during pregnancy	26.8% (18/67)	41.8% (51/122)
Cow developed ventral oedema during pregnancy	16.4% (11/67)	7.4% (9/122)
Cow in free contact at birth	38% (26/67)	38.5% (47/122)
Cow in protected contact at birth	13.4% (9/67)	29.5% (36/122)
Cow in no contact at birth	47.7% (32/67)	0%
Changes in herd composition in preceding 6 months	26.9% (18/67)	48% (59/122)
Cow in unstable herd	23.8% (16/67)	24.5% (30/122)
Other health issues	13.4% (9/67)	3.3% (4/122)
No contact with other elephants at time of birth	1.5% (1/67)	4.1% (5/122)
Visual contact with other elephants at time of birth	25.4% (17/67)	38.5% (47/122)
With selected other elephant at time of birth	11.9% (8/67)	27.0% (33/122)
In whole herd at time of birth	11.9% (8/67)	29.5% (36/122)
Unknown contact with other elephants	49.2% (33/67)	4.1% (5/122)
Cow chained for birth	11.9% (8/67)	33% (41/122)

5.2.2.iii Paper 3: Assessing risk factors for reproductive failure and associated welfare impacts in elephants in European Zoos. (Hartley, 2016)

The tables below (5.2.4 – 5.2.11) present the risk assessment and uncertainty ratings, as described in Hartley (2016). These tables indicate the key problems, and specified as risks, associated with reproductive and maternal failure among the European zoo elephant population. Risks for each genus are based on detailed peer reviewed papers from the citations in Hartley (2016). The results are ranked from a high risk to a low risk. As with the previous analysis of health and husbandry factors contributing to reproductive failure, the UK population contributed to these risk assessments, and the tables thus highlight the specific risks for reproductive failure that remain to be addressed in the UK captive populations. Uncertainty ratings reflect the level of agreement in peer-reviewed papers or questionnaire responses relating to the extent of risk.

A high risk of occurrence is shown in bold, while a high risk of occurrence, plus a low uncertainty (noted in red) suggests a reproductive risk of concern.

Table 5.2.4: Risk assessment for the impact of identified risk factors on the likelihood of acyclicity in European zoo elephants.

Risk Factor	Risk Assessment		Uncertainty	
	African	Asian	African	Asian
Less access to daylight	**High**	**High**	**High**	**High**
Older age of cow	Low	**High**	Medium	Low
Higher hierarchical position	**High**	Low	Low	Low
Lack of change in social group	**High**	Low	Low	Medium
Immune activation inflammatory disease	**High**	Low	Medium	Low
Reproductive tract pathology	Low	High	Medium	Low
Obesity	Medium	Medium	Medium	Medium
General stress	Medium	Medium	**High**	**High**
Lack of stimulation from bull	Medium	Low	**High**	Low

Table 5.2.5: Risk assessment for the impact of identified risk factors on the likelihood of European zoo elephant cows not having access to a bull.

Risk Factor	Risk Assessment		Uncertainty	
	African	Asian	African	Asian
Cows not given access to bulls overnight	**High**	Medium	Low	Low
Incompatible Behaviour	**High**	Low	Low	Low
Access only given when in oestrus	Medium	Medium	Low	Low
No bull housed	Medium	Low	Low	Low

Table 5.2.6: Risk assessment for the impact of identified risk factor on the likelihood of European zoo elephants failing to mate.

Risk Factor	Risk Assessment		Uncertainty	
	African	Asian	African	Asian
Lack of choice of bull	**High**	**High**	Low	Low
Young age of bull	**High**	Medium	Low	Low
Cow refuses to stand to be mated	**High**	Medium	Low	Low
Bull refuses to mate cow	Low	Medium	Low	Low
Lack of previous experience of bull	Low	Low	Low	Low
Lack of previous experience of cow	Low	Medium	Low	Low

Table 5.2.7: Risk assessment for the impact of identified risk factors on the likelihood of European zoo elephants failing to conceive.

Risk Factor	Risk Assessment		Uncertainty	
	African	Asian	African	Asian
Reproductive pathology	Low	**High**	Medium	Medium
Age of cow	Low	**High**	Low	Low
Unproven bull	**High**	Low	Low	Low
Young age of puberty	Low	Medium	Medium	Medium

Table 5.2.8: Risk assessment for the impact of identified risk factors on the likelihood of dystocia in European zoo elephants.

Risk Factor	Risk Assessment		Uncertainty	
	African	Asian	African	Asian
Separation of Cow from other Elephants	**High**	**High**	Low	Low
Stress from chaining cow	Low	**High**	Medium	Low
Excessively large calves	Low	**High**	Medium	Low
Primiparous cow	Low	**High**	Medium	Low
Position of calf	Low	**High**	Low	Low
Obesity	Medium	Medium	Medium	Medium
General stress	Medium	Medium	**High**	**High**
Age of cow at parturition	Low	Medium	Medium	Low
Reproductive pathology	Low	Low	Medium	Medium
Oedema	Low	Low	Medium	Medium
Hypocalcaemia	Low	Low	Low	Low
Reproductive monitoring	Low	Low	Low	Low
Twins	Very Low	Very Low	Low	Low
Congenital Abnormality of Calf	Very Low	Very Low	Low	Low

Table 5.2.9: Risk assessment for the impact of identified risk factor on the likelihood of stillbirth in European zoo elephants.

Risk Factor	Risk Assessment		Uncertainty	
	African	Asian	African	Asian
Dystocia	**High**	**High**	Low	Low
EEHV	Low	**High**	Low	**High**
Cow Pox	Low	Medium	Low	Low

Table 5.2.10: Risk assessment for the impact of identified risk factors on the likelihood of poor maternal behaviour in European zoo elephants.

Risk Factor	Risk Assessment		Uncertainty	
	African	Asian	African	Asian
Primiparous cow	**High**	**High**	Low	Low
Lack of experience of calves	**High**	**High**	Low	Low
Separation from other elephants at birth	Medium	**High**	**High**	Low
Chaining of cow at birth	Medium	**High**	**High**	Low
Maternal aggression	Low	Low	Low	Low
Aggression from other herd members	Low	Low	Low	Low
Placentitis/metritis	Very Low	Very Low	Low	Low
Maternal agalactia	Very Low	Very Low	Low	Low

Table 5.2.11: Risk assessment for the impact of identified risk factors on the likelihood of European zoo elephants failing to rear a calf to 5 years old.

Risk Factor	Risk Assessment		Uncertainty	
	African	**Asian**	**African**	**Asian**
Failed hand-rearing	**High**	**High**	Low	Low
Separation of cow from other elephants at birth	Medium	**High**	**High**	Low
Chaining of cow at birth	Medium	**High**	**High**	Low
Primiparous cow	Medium	**High**	Low	Low
Lack of maternal experience	Medium	**High**	Low	Low
EEHV	Low	**High**	Low	Low
Herd stability	Low	**High**	Medium	Medium
Separation from mother <5 years of age	Low	**High**	Medium	Medium
Short Inter-calving Interval	Medium	Low	**High**	**High**
Infanticide	Low	Low	Low	Low
Killed by other elephant (Not Mother)	Low	Low	Low	Low
Other infectious disease	Low	Low	Low	Low

5.2.2.iv Bull early life social experience: effects on reproductive success for European zoo males

Bull future reproductive success was found to differ for elephants that had prior social experience with successfully reproductive males (median 0.2 calves/year), compared to bulls without that early social experience (median 0 calves/year) and this difference was significant (W= 831.5, p= 0.035, n= 56) (Bacon, 2019).

These results emphasise the importance of allowing young males to experience both the mating activities of other active males and the signalling of females. Learning to interpret the signals of oestrus and then how to respond is difficult for both male and female elephants and requires exposure to behaviour of others when mating occurs (see for example Bates *et al*., 2010; Moss, 1983).

5.2.3 Overview of results on reproductive outcomes

- There have been advances in the successful breeding of elephants as a result of promoting natural breeding behaviour, as well as due to management changes which allow females to give birth within the herd, without restraints and on appropriate substrates.
- EWG studies have evidenced the positive effects of the creation of multi-generational family herds which allow for herd experiences of the birth process and looking after calves, enabling involvement of the group in calving events, and facilitating allomothering care of calves.
- Facilitating the complex social behaviours of bulls has advanced, with no bulls being held alone in UK zoos, and enclosure developments allowing for the integration of bulls into herds during the day and at night.
- EWG studies of the social needs and optimal management of males, which includes the provision of appropriate access to females for mating, and to immature and mature bulls for social learning, have increased the probability of producing calves in breeding groups.
- Management of males has been shown to be more nuanced and complex than previously thought, requiring considerable additional long-term planning and resourcing.
- The findings of the EWG studies, among others, on reproduction and social behaviour have influenced policy changes at the European level, resulting in limits on the early transfer of juvenile male elephants from their maternal herd, improved management of cows during parturition and creation of a more natural herd composition.

5.3A Health Subgroup: Longevity & Mortality Results

Summary

Survival and longevity analysis

- Average lifespan from 2006 – 2019 among the elephants born into the UK population remains low at ~17 years, similar to previous estimates for the European zoo population. No appreciable progress has been made in ensuring longevity among the cohort of UK zoo-born elephants.
- Calves <1 year die at a high rate in captive born African elephants (64%) while 51% of juvenile Asian elephants die before 5 years.
- For elephants already in the UK population who survived to at least 20 years of age, some progress has been made in ensuring that these older individuals survive to a more typical lifespan of ~50 years.
- Given improvements in the survival of older individuals, longevity across all UK elephants is higher than in 2008 (Asian survival = 40.4 years vs. 17 years, African survival= 33.8 years vs. 16.9 years).
- There are no significant differences between the genera in mean or median longevity.

Causes of Mortality

- Mortality data from 2006 to 2019 indicated that there were 27 Asian elephant deaths and 23 African elephant deaths with known causes of death.
- Causes of death where known were varied; however, more Asian elephants died due to infection, while more African elephant deaths were perinatal.

5.3.1 Mortality and Longevity: Methods

Longevity, the average lifespan achieved at birth (i.e. how long that animal should live if current death rates remain the same), has historically been expected to increase for animals kept in zoos due to reduced threats to survival such as starvation and predation; however, a long-lived, slow to reproduce species with low mortality in the wild (such as elephants) may not always live longer in zoos (Tidière *et al.*, 2016). European zoo elephants have been highlighted as being at risk of dying at younger ages than Asian elephants at timber camps in Asia or wild African elephants (Clubb *et al.,* 2008), suggesting they were experiencing some aspect(s) of compromised welfare leading to premature death. Moreover, death rate in calves (first year of life) was also higher for European zoo elephants in comparison to wild elephants or those managed at timber camps (Clubb *et al.,* 2008). The EWG Health sub-group set out to explore causes of mortality and statistical life expectancy for the UK zoo population, with the added goal of determining a baseline for these data to enable future comparative reviews.

5.3.1.i Survival analysis data collection

Population (births and deaths) data were provided to the EWG from UK zoos for elephants present (living in 2006) in the period from 2006 to 2019. There were 114 elephants included in the survival analysis, with 59 deaths during this period. There were 50 elephants, with known cause of death between 2006-2019, which were included in the detailed analysis of causes of death.

Longevity, assessed via survival analysis as the expectation of lifespan from birth, was explored using a Kaplan Meier proportional hazards model, and analysed separately for African and Asian elephants. Sexes were not separated due to the very small sample sizes for adult males. Data were right-censored since some animals were still living at the time of analysis. Survival analysis accounts for these still living individuals, and produces an average (mean, standard error and median with 95% confidence interval) survival age or expectation of life from birth – this is the age at which half the sample has died and half the sample is still alive. Average longevity was also calculated by birth location, as 'captive born' or 'non-captive born'. Only eight elephants in the sample of captive-born individuals who were alive in 2006 could potentially have reached 25 years of age, and just one in this sample could have survived past 30 years of age. For some comparisons, the sample sizes were too small to enable the calculation of median values, so mean values are reported. These limitations in sample sizes

and censoring suggest that the results for longevity should be interpreted with care.

5.3.1.ii Cause of death data collection

If truncated longevity is an indicator of compromised welfare (e.g. Clubb *et al.* 2008, 2009), then understanding the mortality trends in the UK population is vital. Mortality data were not reported in Harris *et al.* (2008), and no published work has yet described causes of mortality in UK zoo elephants, so the Health sub-group sought to address this gap in knowledge. Pathology and specimen reports were obtained through the European elephant Taxon Advisory Group (TAG) veterinary advisors, since UK zoos are part of this TAG. Where necessary, zoos were contacted directly to obtain their records. The following data were then extracted from these records for each individual elephant between 2006 and 2019 (this timeframe was selected to follow on from Clubb *et al.* 2008): global identification number; genus; sex; date of birth; origin (wild / unknown origin, captive born in UK); date of death; age at death; age category; cause of death category; cause of death notes; and pathology notes by body system (gross, histopathological). These data were first examined for life expectancy (n = 114) and then for cause of death (n = 50 out of 59 deaths). Age categories, cause of death categories and survival statistics are presented in Appendix 5.3.1. Descriptive summaries of causes of mortality are presented here and, where possible, considered in relation to demographic factors such as age, sex, and genus.

5.3.2 Survival and Mortality: Results

5.3.2.i Survival and life expectancy

Between 2006-2019, of the 114 elephants in UK zoos, average lifespan was 31.7 years (59 died by the end of 2019). Average lifespan differed considerably between those elephants born into captivity in the UK (average = 17.3 years, n = 76) and those who were already in the population in 2006 (born elsewhere and survived or wild caught, imported and survived, average = 46.5 years, n = 38). These two populations are distinct, and comparisons between them are less informative than are the trends within each group (Appendix 5.3A).

The captive-born sample available for survival analysis started with births in 1987, and thus the maximum age that could be attained by a captive born elephant by 2019 was 34 years. It is critical to note that the average captive born elephant in UK zoos only survives to half this age. Although African elephant calves appear to survive less well in the first year of life, trends in overall longevity are not statistically different between the genera due to small sample sizes.

Excluding deaths during the first year of life, the mean longevity for the captive born sample of African elephants was 27.1 years (mean male=24.9 years, female=26.6 years). Excluding deaths during the first year of life for the Asian captive born elephants, mean longevity in this sample was 16.4 years (mean male = 14.1, female = 18.1 years). While more African elephant calves died as neonates or in the first year of life (13/23), Asian elephant calves were dying before or at the average age of weaning (~5 years, 4.7% of 39 calves), and both genera thus converged on 15-17 years as an average lifespan overall. Such a short average lifespan is similar to that found in 2008 by Clubb *et al.* for the European population, suggesting that survival to those born in zoos has not markedly improved over the past 10 years, and many elephants are still showing a compromised lifespan.

Among the elephants who were already in the population as adults in 2006 (following on from Clubb *et al.*, 2008), we can compare longevity between genera. Differences in longevity between Asian (48.2 years) and African elephants (44.6 years) were not statistically significant (Appendix 5.3A). UK zoos are now doing better at keeping their pre-existing individuals alive until 40-50 years of age. While females >50 years can successfully breed and lead families in the wild, they are still considered past-prime, and in UK zoos they may need special care. Maximum lifespan remains unknown, for any population – captive or wild – although one female in the UK population is over 65.

5.3.3. Cause of death

5.3.3.i Asian Elephants

Between 2006 and 2019, 27 Asian elephant deaths were recorded. Most individuals died early in life (Appendix 5.3A). During this 14 year period, 24 calves were born and 15 (0-3yrs) died. Three died at less than one year of age. Post mortem findings are presented in Appendix 5.3A; the most common cause of death was infection.

Elephant Endotheliotropic Herpes Virus (EEHV) was the cause of 44.4% of Asian elephant mortality, affecting thirteen immature elephants aged 1-3 years old (one survived treatment) and having a huge

impact on the size and age composition of the captive population. EEHV has also been reported in wild elephants, although its prevalence is unknown. It is understood to be carried by most elephants without clinical signs, like herpes viruses in other species, and may be pathological under conditions of stress. Historically EEHV cases were simply found dead or presented with very significant clinical signs which were too severe to respond to treatment. However, in recent years, a number of clinical cases have now been treated successfully worldwide and research is ongoing into the production of a vaccine – it is hoped one will be developed in the coming years. UK zoos have contributed significantly to research and clinical developments associated with EEHV diagnosis and treatment, including funding of PhD work and collaboration with European and other international research groups.

5.3.3.ii African elephants

Between 2006 and 2019, 23 African elephants died in UK zoos. Again, young individuals made up a large proportion of these deaths. Many deaths were categorised as perinatal although a range of other causes were described (Appendix 5.3A). Of the 20 calves born in the UK between 2006 and 2019, eight died within their first year of life (40% of births). This is significantly higher than calf mortality in wild African populations subject to drought and predation, which is around 10% of births (Clubb *et al*., 2008). Causes of death included maternal neglect or abuse, stillbirth due, in some cases, to oversized or abnormal calves, and there was also one set of twins with only one surviving.

5.3.4 Overview of findings on longevity and mortality

- Among the existing UK population, older non-captive bred elephants now live a longer life compared to previous reports.
- Among the existing UK population, those born into captivity still experience an atypically short lifespan, compared to reference populations.
- Early death remains a problem due to a variety of causes: disease in juvenile Asian elephants, and multiple causes (including maternal neglect) in calves < 1 year among African elephants.

5.3B Health Subgroup: Foot Health and Locomotion Results

Summary

Foot health

- From 2015 to 2019, from data which was collected by zoo staff using the EWG foot health tool, population level foot scores were mostly under 5, reflecting no or minor issues (e.g. cracks to nails).
- Asian elephants and older elephants of both genera had higher (i.e. poorer health) foot scores.
- There was no obvious difference between fore and hind feet scores, unlike Harris *et al.* (2008), which reported marked variation between hind and fore foot scores among individuals.
- A similar percentage (26%) of the population had no foot issues (0 score) in 2019 compared to Harris *et al.* (2008) (27%).
- There were fewer elephants with 'severe' foot health issues (10%; 5/50) in 2019, compared with Harris *et al.* (2008) (52%; 40/77).
- Six elephants with severe foot issues left the UK population before 2019; severity had reduced for four, but two were euthanised due to foot / joint ill health.
- Of the 26 elephants with data in both Harris *et al.* (2008) and EWG 2019, three were scored as severe (revised scoring system) on both occasions (all were 36 yrs or older), and a further five went from a score of zero (no issues) in 2006 to mild issues in 2019. No differences were found for the remaining elephants between studies.

Locomotory health

- Between 2015 and 2019, population level locomotion scores were mostly under 5; this included scores ranging from no issues (0 score) on any leg, to all four legs showing minor stiffness (4 score).
- A larger proportion of the UK zoo elephant population were free from locomotory abnormalities in 2019 (73.7% of 28 elephants had scores of 0), in comparison with 17.4% of 69 elephants in Harris *et al.* (2008).
- Asian and African elephants did not differ in scores allocated for locomotory health using the EWG tool.

5.3.5 Foot health assessment in elephants

Foot related problems have been reported as a contributing factor in euthanasia decisions for captive elephants (Ollivet-Courtois *et al.*, 2003; Luikart and Stover, 2005) and were also found to be problematic in the UK zoo elephant population in 2008 by Harris *et al.* Harris *et al.* (2008) reported that 81.4% of UK zoo elephants that had some type of foot health problem and 82.1% of the same population exhibited an abnormal gait. Therefore, the EWG Health sub-group developed two tools for regular assessment by keepers of foot health and of locomotion in zoo elephants, to enable long-term monitoring.

The EWG Health sub-group felt it was important to develop a more detailed method for scoring elephant foot health, as the method used by Harris *et al.* (2008) was prone to over- or under-estimation of foot health problems. The foot health scoring system used by Harris *et al.* (2008) assigned minor problems a score of '1' and major problems a score of '2' for each foot. With Harris's methodology, which involved a simple summation of the scores from each foot, it was possible for four minor problems to be scored as equivalent to two major problems (e.g. abscesses in two feet, each scoring '2', summing to an overall score of 4). The same score could also be achieved if there was minor overgrowth of the cuticle (score = 1) observed in all four feet, totaling an overall score of 4. Furthermore, Harris *et al.* (2008) did not provide any visual examples or detailed descriptions of the problems that they defined as minor or major, making it difficult in practice to use or implement their scores consistently, or to evaluate the validity of their methods. The Head of the EWG Health Subgroup worked with the Elephant Sub-Group of BIAZA's Mammal Working Group (ESG), with other zoo professionals, and with postgraduate veterinary

and biology students, to develop a novel method for routinely scoring the health of captive elephants' feet (see Table 5.3.1).

This was a category-based, outcome-oriented (providing actions to follow from any given score) protocol and included a visual chart for ease of use by elephant keeping staff (Appendix 5.3B).

Table 5.3.1: Foot health scores and associated descriptors.

Score allocated per foot	Severity descriptor	Description
0	Healthy	No lesions.
1	Mild	Cracked, disfigured or overgrown nails, and/or overgrown foot pads, soles or nail cuticles.
5	Moderate	Conditions where the underlying tissue was exposed.
21	Severe	Where deeper tissue was exposed or where the problem had persisted for at least eight weeks or reoccurred up to three times in 12 months.

5.3.5.i Assessment of locomotion in elephants

Poor movement and limited ability to walk without the appearance of pain were significant welfare issues noted by Harris *et al.* (2008); these issues were related to a high prevalence of arthritis and other chronic causes of reduced mobility in captive elephants, affecting their longevity and fitness. Foot health can also be compromised if an individual's gait is abnormal, due to inappropriate weight-bearing on the toes, potentially leading to abscesses/sores; this link between poor foot health and abnormal gait contributes negatively to the overall welfare of the individual. To address concerns about reliability of gait scores between assessors and across elephants using the locomotion measurement tool of Harris *et al.* (2008), because interpretation was subjective and the assessments used were not specific to elephants as a taxon, the subgroup developed a new tool for assessing an elephant's gait, with clearer scoring criteria. The new method assigned scores for each leg based on locomotion observed on a variety of substrates, allowing for detailed monitoring of improvement or deterioration over time (Turner, 2012).

5.3.5.ii EWG locomotion assessment protocol

Scores were made from video footage, taken from four angles for each elephant (in front, behind, from the left and right sides), observing them walking at least ten paces in one direction (see Appendix 5.3B for further details). Gait was measured for each leg in relation to three possible gait abnormalities: stiffness (score of 1), abnormal tracking (score of 5) and reluctance to bear weight (score of 25; see Table 5.3.2). Where no issues were observed, the leg was scored zero. Therefore, each leg was given a score between 0 and 31. Each elephant was also given an overall locomotion score, summing results for all four legs, which therefore ranged from 0 to 124. When an elephant had more than one observation per year, the median score for the year was used in the analysis.

When statistical testing was undertaken, the results of the Mann-Whitney U test and probability values are presented.

Table 5.3.2: Locomotion was scored from video footage using the below criteria for each leg.

Score	Issue	Guidance provided
0	Normal	• Unable to discern any locomotor abnormalities • No 'stiffness', no 'abnormal tracking', no 'reluctance to weight bear' • Normal conformation
1	Stiffness	• Reduced flexion / extension of any joint in the limb • Likely to be most visible in the left and right views
5	Abnormal tracking	• Limb does not track entirely in longitudinal plane • Likely to be most visible in the front and behind views
25	Reluctance to bear weight	• Weight is not distributed entirely evenly across both front or both hind feet • Likely to be most visible during walking as less time spent on that limb (unless bilateral problem)

5.3.6 Foot health: results

Foot health scores were submitted for 60 individual elephants from 2015 to 2019 (see Appendix 5.3B). The number of elephants sampled each year varied, but only three elephants in the UK in 2019 had no EWG foot health records, and all three were younger than three years of age at the start of 2019. The proportion of elephants that were African or Asian varied with each sampling year, as did the sex ratio of sampled elephants (more females than males were sampled in each year as fewer males were available).

5.3.6.i EWG (2019) foot health data

The population median foot health score in 2019 was 2 (IQR 6, min 0, max 12), indicating that up to two feet had a mild (superficial) abnormality. There was no difference in foot scores between male (med 1, IQR 2, n= 13) and female (med 2, IQR 3, n= 37) elephants in 2019 (U= 183.5, z= -1.3, p= 0.193). Asian elephants had higher (worse) foot health scores (med 2, IQR 3, n=25) compared to African elephants (med 1, IQR 2, n= 25) and this difference was statistically significant (U = 193.5, z= -2.382, p= 0.017). While a visual trend was observed towards poorer foot health scores in older elephants, it was not possible to test for a statistically significant change over time, as measures were not comparable due to the use of a novel tool (see Appendix 5.3B).

5.3.6.ii Changes over time: 2015 to 2019 EWG foot health tool

Fifteen elephants had foot health scores reported for each of the five years sampled by the EWG, and these scores did not change over this time (X^2 (df, 4) =1.029, p= 0.905). These included nine Asian and six African elephants, were mostly females (n=12) and represented diverse age ranges.

5.3.6.iii Comparisons with Harris *et al.* (2008)

In order to compare between the Harris *et al.* (2008) report and the current study, the foot scores were revised to reflect relative prevalence from none to severe (Table 5.3.3). Revised foot health scores were available for 26 elephants with data from both Harris *et al.* (2008) and 2019 EWG. There was no significant difference in foot health scores (revised) between the two time points (z = -1.470, p= 0.142, n= 26). However, of those 26 elephants, three (aged 36 years or older in 2019) that were scored either as mild or severe in Harris *et al.* (2008), had foot health scores categorised as severe in 2019. And five elephants (aged 13 – 49 years in 2019) that were scored as 'none' by Harris *et al.* in 2008, were scored as 'mild' (revised) in 2019, suggesting that they had developed foot problems in the years since the Harris report.

Six elephants had a score of 'severe' allocated by Harris *et al.* (2008) and also had EWG data in the years of 2016, 2017 and 2018, but were no longer in the UK population in 2019. Examination of their revised EWG scores indicates that four of these elephants had improved foot health scores at time of departure from the UK or at the time of death. The other two elephants still had 'severe' foot health scores at their time of death. Both of these elephants were euthanised – decisions that were made partly due to concerns over chronic joint issues and lameness.

A larger proportion of the population had reduced

severity of foot health scores in 2019 by comparison with Harris *et al.* (2008) (Figure 5.3.1). Harris *et al.* (2008) reported differences in foot health between the fore and hind feet, with the fore feet being scored as 'severe' more frequently (22.1% of 68 elephants at the last visit) than the hind feet (13.2% of 68 elephants at last visit). In 2019, using the EWG foot health tool, there was no apparent difference between the fore (8% scored as severe, 4/40 elephants) and hind feet (6% scored as severe, 3/50 elephants).

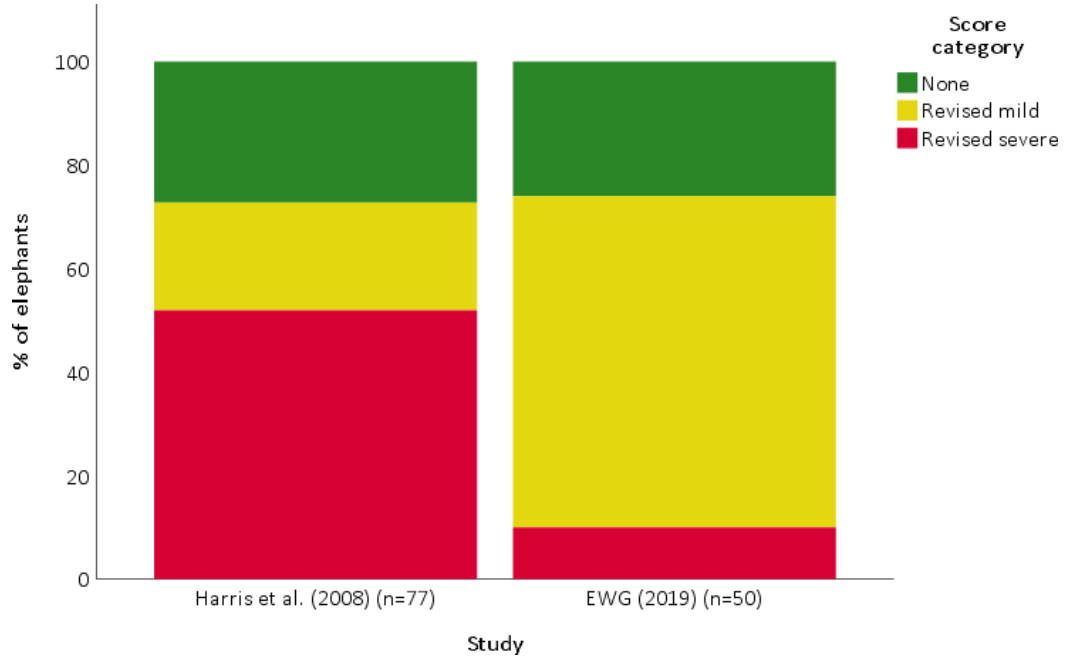


Figure 5.3.1: Population level comparisons of revised foot health scores between all elephants observed in Harris *et al.* 2008 (*n*= 77) and those with foot scores in 2019 EWG dataset (*n*= 50). A traffic light system indicates absence of foot health issues (green / none) to escalating foot health concerns (yellow / mild (1 in Harris *et al.* and 1 – 4 in EWG), red / severe (≥2 in Harris *et al.* and ≥5 in EWG)).

Table 5.3.3: Revised foot health scores to enable comparisons between Harris *et al*. (2008) and the EWG foot health data.

Original score Harris *et al.* (2008)	Original score EWG foot health tool	Revised score	Revised score description
0	0	No issues 0	Healthy foot, no issues
1	1-4	Revised mild 1	Minor scratches or overgrowth of the nail, pad or cuticles or uncomplicated nail cracks
≥2	≥5	Revised severe 2	At least one foot with a lesion that is exposing underlying tissue

5.3.7 Locomotion results

Locomotion scores were submitted for 65 individual elephants from 2015 to 2019. The number of elephants sampled each year varied, and again more females were sampled than males in each year (Appendix 5.3B).

5.3.7.i EWG gait data

The median score assessing whether elephants had compromised locomotion in 2019 was 0 (IQR 3.3, min 0, max 38); half the individuals had no gait abnormalities. Male (0, IQR 0) and female (0, IQR 7) locomotion scores were similar. Scores for Asian (0,

IQR 1) and African (0, IQR 9) elephants were again low and not statistically significantly different, (U = 173.5, z = 0.710, p = 0.59).

A trend was apparent for higher (i.e. poorer) locomotion scores in older elephants in 2019, with 30-39 year old and 50-59 year old age categories having higher median scores; however, it was not possible to test for a statistically significant difference due to small sample size at each age.

Over the five years of data submitted, a trend towards slightly lower scores, indicating less compromised locomotion, was seen over the time between 2010 and 2019 (Appendix 5.3B). Sixteen elephants had locomotion scores for each of the five years sampled and these scores did not differ significantly over time ($p > 0.05$), indicating that their locomotion scores were stable over the five years studied. These elephants were mostly females (13) and Asian (12) elephants.

As was found for the overall 2019 sample, the majority of elephants in each separate year had scores of 'zero', indicating no gait abnormalities. Four elephants (all female; two Asian and two African elephants) scored over 24 (at least one leg scored as 'reluctant to bear weight') over the five years. For three of these elephants, all of their submitted locomotion observations were scores of >24. For the fourth elephant, 20% of her locomotion observations were scored >24 and the remaining scores ranged from 10 to 24. Three of these elephants were aged 37 years or older; the fourth was 31 years old, known to be arthritic, and was euthanised four months after the single locomotion observation recorded using the EWG tool was made.

5.3.7.ii Changes in gait over time: Comparisons with Harris *et al.* (2008)

To enable comparisons between periods, the locomotion scores from 2006 and 2019 were both adjusted so that any reported issue was now scored as 1, while 0 remained as an indication of no issues seen.

Of the 23 elephants with data available from both 2006 and 2019, more elephants (65.2%) had a normal gait (no locomotory abnormalities) in 2019, compared with just 13% with a normal gait in 2006. This was a significant reduction in the prevalence of gait problems over time (X^2 (df, 1) = 8.64, p= 0.002).

When looking at all the elephants studied at both time points, a larger proportion of the 2019 population had a normal gait (76.3% n=38 sampled out of 53 total) in comparison to the 2008 data (17.4% n=69 sampled out of 77 total) (Figure 5.3.2).

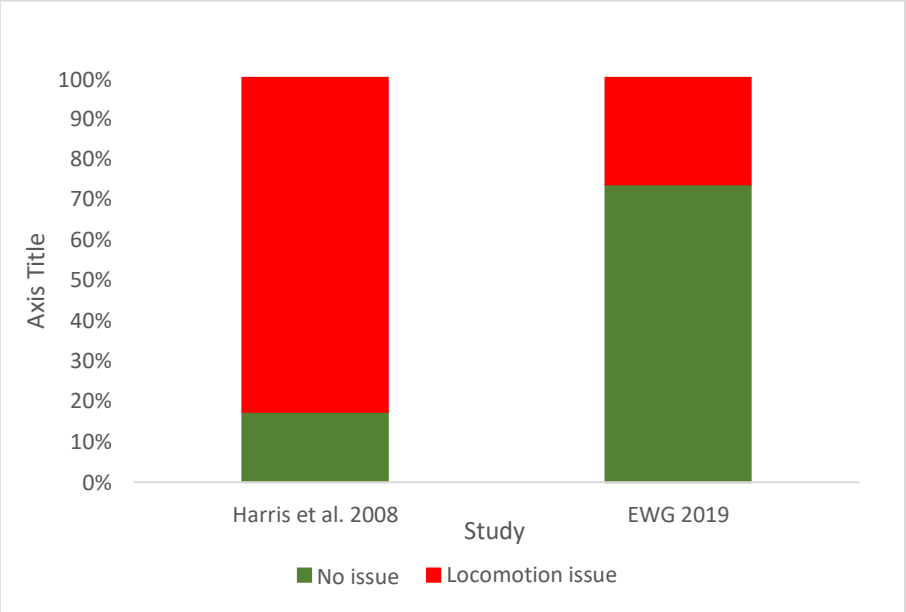


Figure 5.3.2: Population level comparisons of revised locomotion scores between all elephants observed in Harris *et al.* 2008 (*n*= 69) and those with locomotion scores in 2019 EWG dataset (*n*= 38).

5.3.8 Overview of results for locomotion and foot health in 2019

- Foot health has improved for the majority of elephants, with most now having no or very minor issues.
- Population level gait scores have also improved, due in part to the euthanasia of a small number of severely compromised individuals in recent years and the birth of young animals who do not currently have significant foot or locomotory compromises.
- Improved management and larger enclosures are additional factors thought to be contributing to better foot and locomotor health.

5.4 Nutrition Subgroup

Summary

Body condition (BCS)

- Between 2015 and 2019, population level body condition scores, using the new EWG methods, were mostly 7 or 8 out of 11, indicating the higher end of the 'normal' range or lower end of 'over condition'.
- It was not possible to make direct comparisons with Harris *et al.* (2008) due to inconsistent data from that study and the use of a new, validated tool.
- No statistically significant differences were observed between BC scores for either sex or genus.

Nutritional analysis

- Nutritional provision analysis proved challenging from the data obtained, given the lack of reporting of roughage quantities provided and the challenges of extracting actual consumption data from group fed animals.
- The average first year growth rate for 20 calves born between 2004 and 2018 was 0.94 ±0.154 Kg/d.

5.4.1 Body Condition Score (BCS): Methods

A Body Condition Score (BCS) is an established method of weight monitoring in elephants and other animal species, using a visual assessment of subcutaneous body fat; the scores are highly correlated to other morphometric measurements such as shoulder height and back length. At least six anatomical landmarks on an elephant's body must be visually inspected and scored to obtain a reliable score (Wemmer *et al.*, 2006). Harris *et al.* (2008) reported scores based on a single photograph, ordinarily taken from the hind end of the animal. Two researchers scored four anatomical points from this single photograph, and an overall score was assigned, with higher numbers indicative of thinner animals. The authors did not publish detailed descriptions or comprehensive illustrations of the criteria for each score, and therefore it is difficult to establish the reliability or validity of their methods. Harris *et al.* (2008) appeared to use the same method to score both African and Asian elephants, as no distinction was made between the scoring system used for the two different genera.

The EWG adopted a body condition scoring scale described by Wemmer *et al.* (2006) following a thorough review of published BCS systems available for elephants. The BCS system used by the EWG was selected because it was judged to be the least subjective and most user-friendly method (see Fig. 5.4). Scoring was trialed by Partington *et al.* (2012) and guidance developed for zoo staff. The Wemmer *et al.* (2006) BCS tool was developed for Asian elephants, but as the EWG tool was being used in both genera, we tested this alongside a tool previously developed by Howletts Wild Animal Park for use in African elephants.

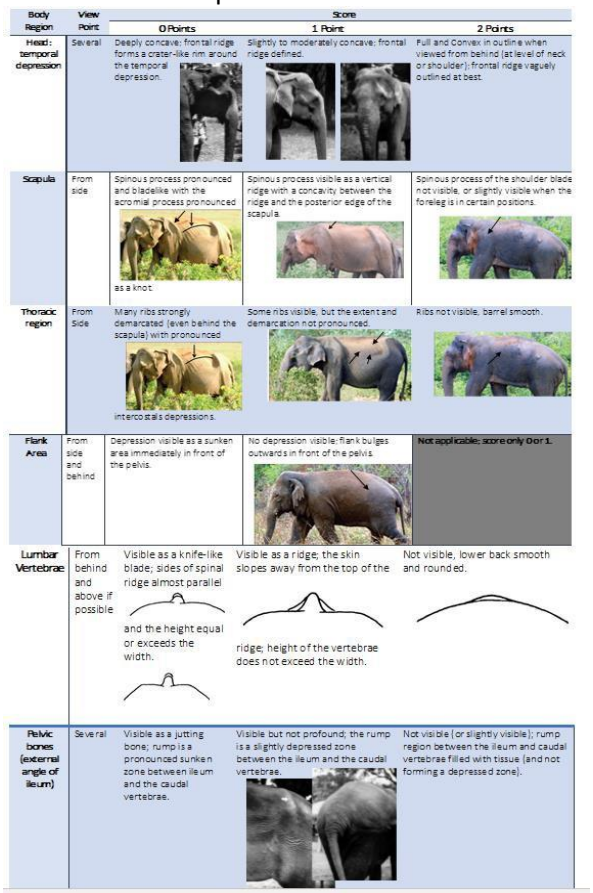


Figure 5.4. EWG body condition scoring system

While the two tools used slightly different scales, (the Howletts tool produced scores out of a possible total of 20; the EWG tool out of a total of 11), both methods ranked the 13 elephants in the same order (i.e. lower scores equated to poorer condition, higher scores indicated higher levels of adiposity; see Appendix 5.4). The scores from both tools had a strong, positive correlation with each other (r_s= 0.861, $p < 0.001$), providing some validation for using the EWG scoring method in African elephants.

5.4.1.i EWG Body Condition Score protocol

Keepers had to view the animal from multiple angles, with a minimum of assessment of both left and right sides, as well as front and rear. Scores were assigned to six body regions (head, scapula, thoracic region, flank area, lumbar vertebrae and pelvic bones), based on the visual prominence of key skeletal structures, and the amount of fat and muscle covering each area. Each region was allocated a score (0, 1 or 2, with the exception of the flank area which could only be allocated a score of 0 or 1, giving a potential maximum of 11). For each area, a score of zero indicated that bones were more prominent at that site (as would be seen if the animal were underweight), one indicated bones were moderately covered by fat and/or muscle (as would be the case in an animal of healthy condition) and two indicated bones were well covered by fat and/or muscle at that site (as would be the case if the animal was overweight); scoring was done using descriptive and pictorial guidance (Table 5.4.1). Keepers were also asked to record the elephant's weight (kilograms), if possible, at roughly the same time as the BCS was completed. Data analysis was based on weight data with the summed score for all six body regions (minimum 0, maximum 11). A score of 5-7 would indicate an elephant in optimal condition (Wemmer *et al.,* 2006; Fernando *et al.*, 2009; Ramesh *et al.*, 2011). Appendix 5.4 provides sample sizes for BCS for genus for each year. As with all sampling, more females contributed to the data than did males, due to availability in the population.

5.4.2 Nutritional data collection

Dietary data were sought from zoos by email (via a BIAZA request in 2018). Completed diet sheets were available for 9 out of 13 collections. Nutritional components were considered in relation to estimated average daily consumption by a non-pregnant, non-lactating average-sized adult female, based on food provided; this may not represent actual consumption, due to group housing, competition or wastage. Information on diet composition is presented in Appendix 5.4.

5.4.3 Calf growth rate data collection

Good nutrition is an essential part of good health and welfare. Zoo elephants must be provided with food that meets all of their macro and micro-nutrient requirements and an appropriate amount of dietary energy to ensure growth and maintenance. Nutrition is particularly important for young calves, as welfare can be compromised through ill health when immune function and infectious diseases challenge calves during their rapid early growth period (Ritskes-Hoitinga and Strubbe, 2016). In UK zoos, mother-reared elephant calves receive maternal colostrum soon after birth and have continuous access to milk from the mother on demand. Bottle-reared calves have specific problems with growth faltering, supressed immune function and digestive disorders (Takehana *et al.*, 2020). Calf growth is also influenced by any solid food that the calf learns to eat in addition to mother's milk. In the wild, elephants live in multi-generational family groups, and the calves learn to eat solid food by observations of their mother and other group members feeding (Lee, 1987; Perera *et al.*, 2018). There has been an effort to replicate this in the group feeding regimes now used in UK zoos, which seeks to support social learning of feeding behaviour by the calves. Social feeding encourages the calf to start eating solid food from an early age, to supplement the nutrition obtained from their mother's milk. Sustained lactation also contributes to maternal contact which has shown to have a positive effect on both growth rate and welfare in calves of dairy cows (Meagher *et al.,* 2019). Therefore, calf growth rate may reflect maternal nutrition required to support lactation, as well as a calf's independent nutrient intake, which are both essential components of good welfare for mother and calf.

Data were requested from zoos (by BIAZA) in 2018, for analysis by the EWG. Information on calf weights was requested for elephants born between 2004 to 2018, and this was received from four of the six zoos with calves during that period. Calf growth rate was calculated for calves ≤ three years of age (1095 days), as the growth rates between birth and 3 years of age should be linear. The following data were collected about each calf:

- date of birth
- birth weight (at or within a week of birth)

- date when weighed (over the first 3-year period)
- weight in kg
- sex
- whether the calves were alive or dead in 2018

Average weight gain and birth weight data were checked to determine if they were normally distributed before statistical analysis was undertaken. The average gradient of weight over time for each calf was calculated using linear regression. The slope of the trendline gave the growth rate in kg/day. Sex and genus differences in weight were compared using Mann-Whitney U tests.

5.4.4 Body Condition Scoring Results

5.4.4.i Body condition scoring sample sizes

BCS reports were submitted for 63 individual elephants between 2015 and 2019. The number of elephants sampled each year varied, as did the proportion of elephants that were African or Asian, and the sex ratio of sampled elephants (see Appendix 5.4). As with all data, there were more females than males sampled in each year, reflecting the greater availability of females.

5.4.4.ii Most recent EWG (2019) body condition score (BCS) data

Distribution of BCS for males and for females was similar (males med 7, IQR 2, n= 13 and females med 7, IQR 3, n= 37) and were not statistically significantly different from each other (U = 237, z = -0.079, p= 0.94). Distribution of BCS for Asian and for African elephants was also similar (Asian median 8, IQR 2, n= 25; African median 7, IQR 2, n= 25; U = 234, z = -1.557, p = 0.120). BCS varied across age groups for elephants sampled in 2019 (n = 50) (Appendix 5.4), with higher average scores for individuals aged 40-49yrs and 0-9yrs. However, it was not possible to test for a statistically significant difference due to small sample sizes for the age groups.

5.4.4.iii Changes in body condition between 2015 and 2019: EWG BCS tool

Twenty-six elephants had a BCS recorded in each of the five years sampled; the scores were not statistically significantly different over time (X^2 (df, 4) = 4.135, p=0.388) (see Appendix 5.4), indicating that BCS scores have been stable in the UK elephant population for this five year period.

5.4.4.iv Comparisons with Harris *et al.* (2008)

It was not possible to make direct comparisons with the Harris *et al.* (2008) study for several reasons. The raw data from the 2006 study were difficult to interpret, numbers were not provided on how many elephants were scored as normal, over- or under-condition in 2006, nor were any individual elephant's BCS available. However, only 6/69 individuals were reported to be underweight or average in the Harris *et al*. (2008) study, compared with 26 out of 50 elephants with an average score in 2019.

5.4.5 Nutritional information

Analysis of diet sheets from 9 out of 13 collections showed that all collections offered hay and browse as the main source of forage in the diet. One or two collections listed grass, straw and 'Giraffe sticks' (left-over branches from browse fed to giraffes at that collection) as well. The non-forage (commercial food/ fruit/vegetables) components included specialist elephant cubes and elephant rolls, high fibre pellets, apples, bananas, a variety of vegetables, bran, linseed oil, dog biscuits, and feed supplements such as biotin and prebiotics (see Appendix 5.4 for food lists). All collections provided roughage (hay and/or browse) all year round. Timing of feeding varied in the different collections, but at all zoos, food was offered using feeding devices and at multiple feeding stations in an effort to ensure roughage provision for elephants throughout the 24 hour period. All feeds were also offered on a group basis for adult females and calves living in family groups. Appendix 5.4 details the different levels of crude protein, crude fibre etc. in common elephant dietary items offered in the UK.

Based on data from a single collection, the forage component was estimated as 88% of the total diet, in agreement with recommendations (BIAZA guidelines; Ullrey, Crissey & Hintz, 1997). However, for many collections it was impossible to estimate what percentage of the diet consisted of forage, and further study is clearly required. This information is essential in order to determine the energy provided by the diet, as compared against the energy requirements of individual elephants, especially as almost half of UK zoo elephants were considered over-conditioned.

5.4.6 Calf growth rate

A total of 10 female and 10 male calves born between 2004 and 2018 were included in the analysis of weight. Birth weights ranged from 90 -156 Kg (121.8 +/- 20.78). In 2018, only nine of those previously weighed calves were alive. The deaths of the other eleven calves occurred when they were between 11 months – 3 years of age. The birth weights were generally above the mean birth weight for Asian calves in timber camps in Myanmar (74-95 kg, Clubb *et al.,* 2009) and for a facility in Sri Lanka (male 83.1 ± 4.6 kg; n = 14; female 82.8 ± 8.4 kg; n = 6: Pushpakumara *et al*., 2016).

All calves showed similar trends in growth over time, with high linearity. R^2 value for weight for age were 0.99 +/- 0.015 (n=20). The average growth rate for all the calves was 0.94 +/- 0.154 kg/d, similar to that reported by Abbondanza *et al*. (2013) for captive Asian elephants in North American zoos. Figure 5.4.4 shows an example of one calf's growth for the first 3 years of its life.

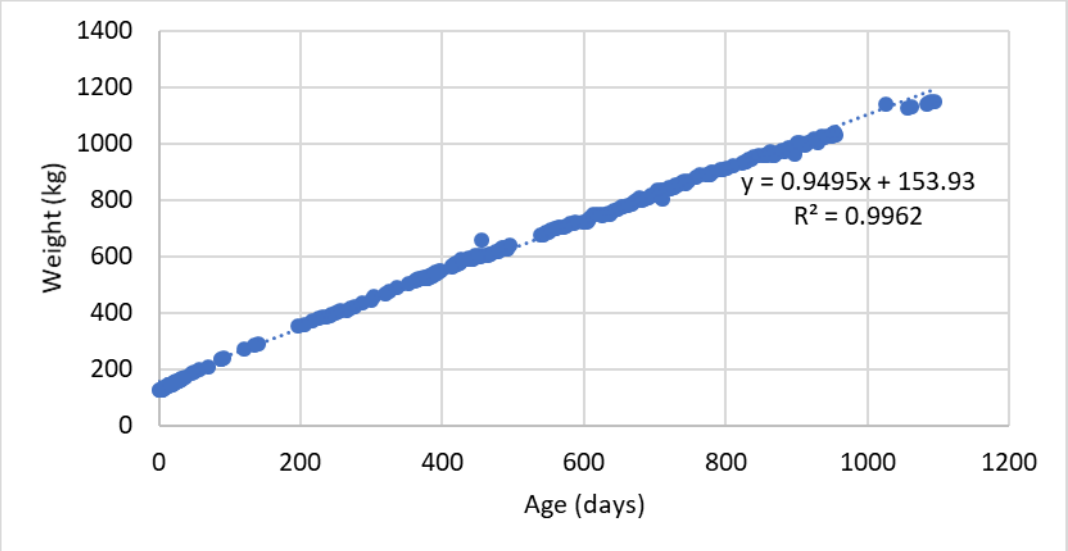


Figure 5.4.1: Growth (kg/day) for one calf from 0-3y of age, showing the linear trend and equation.

5.4.6.i Growth rate comparisons between African and Asian calves

Growth rates were compared between African and Asian calves. The African calf growth rate was 0.84 +/- 0.40 kg/day (n=3) which was significantly lower than the Asian elephant calf growth rate of 0.96 +/- 0.15 kg/day (n=17; Mann-Whitney U test p=0.003). Growth of 0.59 kg/day was previously reported for 11 mother-reared captive African elephants in the San Diego Wildlife Park, USA (Miller and Andrews, 2013).

5.4.6.ii Growth rate comparisons between females and males

All 0-3y growth rates were categorised by sex, and the results of comparisons are shown in Figure 5.4.5. The average female calf growth rate of 0.93 +/- 0.11 kg/day (n=10) was not significantly different from the male growth rate of 0.96 +/- 0.19 kg/day (n=10; Mann-Whitney U test, p=0.443).

Growth rates suggest that both male and female elephants, whether African or Asian, were not suffering growth deficits associated with early mortality. However, it was not possible to determine if growth rates were above the optimum for physical development and long-term health at this stage, as suitable benchmarks are lacking.

5.4.7 Overview of body condition, nutrition and growth

- Median body condition scores have remained generally stable in recent years; 24/50 elephants were still at the higher end of the range (above average / overweight) with 9 (18%) scored as obese, suggesting a need for further monitoring, further changes in feeding practices and provision of more opportunities for physical activity.
- Assessing and managing nutritional intake to maximise calf growth and optimise body mass and condition remains problematic, especially in group-feeding contexts where individual intakes can neither be controlled nor assessed.

- However, where group feeding occurs in the presence of calves, opportunities now exist for the calves in these collections to engage in the social learning of feeding behaviours.
- Calf growth rates are high in comparison to non-zoo populations. Long term consequences of rapid growth, and being above average or overweight, on reproductive activity, musculoskeletal health, and survival need further monitoring.

5.5 Behaviour and Abnormal Behaviour Subgroup: Welfare Assessment Tools

Summary

Daytime behaviour

- Feeding and foraging were the most frequently recorded daytime behaviours, and represented a large proportion of recorded night-time behaviour.
- Elephants commonly engaged in their own activities independently of keeper routines, or approached other elephants when given opportunities to do so.
- Social interactions were rarely observed, but the majority were positive affiliative behaviours.
- Older elephants (≥6 years) showed more frequent daytime affiliative behaviour when housed with young elephants (≤6yrs old).

Night-time behaviour

- 46 of 49 elephants with overnight observations in 2019 were seen to rest lying down; only three were never observed in lying rest.
- 58.7% of 46 elephants were observed in lying rest near another elephants.

Qualitative Behaviour Analysis (QBA)

- Although few elephants overall were rated as having a playful demeanour on their QBA scores, younger elephants (0-9 years) were rated as more playful than older elephants (specifically those aged 30-39 years).

Abnormal behaviour

- Agonistic behaviour, mild or extreme, was very infrequent (seen in only 8/48 elephants).
- Overall stereotypies reduced, with 33% (17/51) of elephants showing stereotypies at least once during the day in 2019, compared to 55% (42/77) of elephants reported by Harris *et al*. (2008).
- However, in 2019 stereotypies were still seen frequently in 20% (10/51) of all elephants.
- There was a significant increase in the frequency of day and night stereotypies with increasing age. In 2019, no elephants under ten years old were observed performing daytime stereotypical behaviour. Three elephants with the most frequent occurrence of stereotypies during the day were all over 40 years old.
- 24% (12/49) of elephants performed stereotypies overnight in 2019. This compares to 49% (20/41) reported by Harris *et al.* (2008)
- Asian elephants were significantly more likely to display night-time stereotypies compared to African elephants.
- There was a decrease in proportion of time spent stereotyping at night in 2019, compared to Harris *et al.* (2008) for females (2006 = 8.8%, 2019 = 3.5%) and for African elephants (2006 = 4.4%, 2019 = 0.7%).
- There was a small increase in proportion of time spent stereotyping at night in 2019, compared to Harris *et al.* (2008) for males (2006 = 4.8%, 2019 = 6.5%) and for Asian elephants (2006 = 6.6%, 2019 = 7.1%).
- 1/20 (5%) of elephants less than 15 years old had reported occurrences of stereotypical behaviour, and this was only at night. By contrast, Harris *et al.* (2008) reported 6/29 (21%) of elephants less than 15 years old performed stereotypical behaviours during the day, with three of them also displaying the behaviour at night.

5.5.1 Individual Elephant Behaviour: Methods

Direct comparisons of behaviour presented in Harris *et al.* (2008) were not made. Their methods provided only an instantaneous record of a restricted subset of behaviours important for assessing welfare, but at the same time were too detailed and time consuming for regular assessment by zoo keepers. A validated behavioural welfare assessment tool

(described below) was developed for routine use by zoo keepers (see Yon *et al*., 2019).

Harris *et al.* (2008) assessed stereotypy frequency, providing a snapshot of stereotypies expressed over a limited duration of time, and used a method of behavioural observation which resulted in some elephants being represented more than others in the data. In light of difficulties with methodologies in Harris *et al.* (2008), The Behaviour and Abnormal Behaviour subgroup developed a validated method that could be used by keepers to behaviourally assess welfare, so that zoos could monitor and assess their elephants in a routine and ongoing way. The EWG strongly felt that collection of behavioural data in a standardised way, on an ongoing basis by each zoo (through the use of the new Elephant Behavioural Welfare Assessment Tool), would be more robust, repeatable and consistent, and would include a much broader range of behaviours, all of which are relevant to welfare (see Tables 3.1 & 3.2). Zoos thus have ready access to welfare-related information and can determine possible impacts of husbandry and management changes on elephant welfare.

5.5.1.i EBWAT (Elephant Behaviour and Welfare Tool) development

The EBWAT was developed through a review of published literature, together with detailed focus group interviews with relevant stakeholders (including keepers, veterinarians, curators, animal behaviour and welfare scientists and those working with free living elephants) (Chadwick *et al.*, 2017; Williams *et al.*, 2018), to identify elephant behavioural welfare measures. These were reviewed by an expert Advisory Panel, which considered the evidence for and feasibility of the suggested measures. The behavioural welfare tool was designed to take approximately sixty minutes in total to complete for each elephant (to be performed over a few days in one week, four times a year). A prototype version of the tool, containing a suite of 76 measures, was tested at five UK zoos alongside more detailed behaviour observations (every 3 minutes), enabling the concurrent validation of measures. Additionally, reliability (inter- and intra-rater, and internal consistency of grouped measures) was assessed during two trials of the initial suite of measures as evaluated by both researchers and elephant keepers. For the section on Qualitative Behaviour Assessment, construct validity was assessed through the correlation between variables predicted to correlate (see Asher, Williams and Yon 2015, Chadwick *et al.* 2017, Williams *et al.* 2018, Yon *et al.,* 2019 for detailed description of the generation of the suite of measures, and reliability and validity testing). Following validation testing, a finalised version of the EBWAT was developed and distributed to the UK elephant keeping zoo community for routine use (Yon *et al.*, 2019).

5.5.1.ii EBWAT protocol and implementation

Observations were made across three days and one night in one week. Each elephant's behaviour was assessed individually. For consistency, one keeper was required to complete all of the behavioural observations and associated scoring for each section of the EBWAT tool (QBA, daytime and night-time).

Section 1 involved QBA (Qualitative Behavioural Assessment), in which the keeper observed the elephants for one minute, during each of four time periods spread across the day, i.e. between: 1) 09:00 – 11:00; 2) 11:00 – 13:00; 3) 13:00 – 15:00; and 4) 15:00 – 17:00). For each of those observations, the observer recorded their assessment of the elephant's demeanour at that point in time, using a visual analogue scale for each of eight adjectives (Table 5.5.1).

In Section 2, the keeper observed daytime behaviour (19 items), on three different days. Each day included four five-minute periods of behavioural observations, again with one observation in each of the four time periods described above. During each observation period, the observer noted the behaviours seen using a checklist of possible behaviours. At the end of the final observation on the third day, the observer then answered a series of questions about the presence or absence of a number of key behaviours seen over the past three days including: stereotypies, wallowing, feeding and foraging, interaction with the environment, affiliative behaviour, agonistic behaviour and play with conspecifics. These questions involved a combination of Likert scale (1-3 and 1-7 point scales), visual analogue scales and descriptive responses. Additional questions on more general impressions of that elephant covered how the elephant reacted to any new or unexpected situations, and any vocalisations the elephant made along with the context in which they were made. The observer was then asked their opinion on the general physical, mental and overall welfare for that elephant using a visual analogue scale.

For Section 3, night-time observations, keepers reviewed overnight video footage from 21:00 – 09:00 and noted the performance of selected behaviours at 30-minute intervals. The ethogram included seven behaviours (see Table 5.5.2) and keepers could record any other behaviours observed (not included in the brief ethogram) or if the elephant was out of view on the cameras. Keepers then scanned the entirety of the night-time footage to identify and record any incidence of agonistic behaviour, regardless of when it occurred.

Table 5.5.1: EBWAT procedure and behavioural variables measured during keeper observations.

	Type of observation	Time period of observations	Information Gathered / Content of Questions
Section A	Live	**One day** Four 1-minute observations, spread across day	Content^, Relaxed^, Uncomfortable^, Agitated^, Tense^, Frustrated^, Wary, Playful
Section B	Live	**Three days** On each of 3 days, conduct four 5-minute observations, spread across the day (make daily notes, complete questionnaire end of third day)	Stereotypies, Wallowing, Feeding, Activity, Social and Environmental Interactions, Response to Unexpected Situations, Vocalisations, Welfare Ratings (mental and physical health, and overall welfare)
Section C	Video footage	**One night** Record behaviours observed for each elephant every 30 minutes throughout night period. Plus continuous sampling for any instances aggression in night.	Stereotypies, Lying down (and with whom or if alone), Feeding/foraging, Interacting with the Environment, Comfort (self-maintenance), Social behaviour, any instances of aggression (time, behaviour, elephants involved)
Table adapted from **https://doi.org/10.1371/journal.pone.0210783.t007**; Behavioural welfare assessment tool for captive elephants PLOS ONE February 6, 2019			
^ QBA grouped variables following Principal Component Analysis at development stage, composite score 'at ease in the environment'.			

Table 5.5.2: Behaviours reported on the EBWAT (Sample sizes are reported in Appendix 5.5)

Behaviour	Description	Interpretation of score
Stereotypical behaviour	Repetitive behaviour with no obvious purpose	-ve
Interacting with the environment	Investigating or interacting with things in the environment (other than food or another elephant)	+ve
Affiliative	Any positive or neutral interaction with another elephant	+ve
Agonistic	Any negative social behaviour with another elephant	-ve
Lying down alone	Lying down on their side; more than two body lengths from another elephant	+ve*

Lying down with others	Lying down on their side; within two body lengths of another elephant	+ve
Feeding	Night-time feeding	(neutral)
Comfort	Dusting, mud splashing, water spraying or other self maintenance	(neutral)
*Lying rest is important for good welfare; however, where group housed, lying down alone may indicate that the focal elephant may not have a close social bond with the rest of the group.		

5.5.2 Behaviour Subgroup: Results

5.5.2.i Assessments submitted

Daytime behaviour observations were submitted for 65 elephants and night-time observations were submitted for 60 elephants between 2015 and 2019. However, the number of submitted reports for each elephant varied from 1 to 16 (mean 6.5, SE ±0.46) in this time period, meaning that few elephants had data available for the entire period of 2015 to 2019. The number of elephants sampled each year varied (Appendix 5.5). Gaps in reports on overnight behaviour occurred when there was no CCTV footage available (no video cameras). Two of the elephants were observed at night but not during the day. The proportion of elephants that were African or Asian varied with each sampling year, as did the sex ratio, with more females than males sampled, reflecting the sex ratio in the population. In Table 5.5.3, the sample sizes for each analysis are presented. It should be noted that sample sizes varied for each analysis as a function of elephant and keeper availability as well as observation conditions (day / night).

5.5.3 Behaviour overview

Feeding was the most frequently reported behaviour. For the majority of elephants (52.9%, 27/51) feeding or foraging was recorded almost every time they were observed (see Appendix 5.5). Elephants were also described as spending a high proportion of time engaged in foraging (mean score 7.8/10; SE 0.24). Of potential importance to welfare, but far less common than feeding, were the rarer behaviours: elephants spent time interacting with physical aspects of their environment (med = 4 or "Less than half the times I have looked at them", IQR 2, min 1, max 7), time engaged in social affiliative interaction (med = 4 "less than half of the times observed", IQR 3, min 1, max 7), and in agonistic behaviours (med = 0 "never observed", IQR 0, min 0, max 2) (Appendix 5.5). Activities initiated by the elephants that were independent of keeper routines or husbandry practices (mean score 8.15/10; SE 0.196) or approaching other elephants (mean score 7.26/10; SE 0.33, n= 48) were common when elephants had the opportunity to perform these behaviours.

At night, elephants were also observed spending a larger proportion (34%) of their time feeding in 2019, in comparison to time engaged in any other recorded behaviours (Figure 5.5.1). Lying rest/sleep was also a common night-time behaviour. The population average (mean) of proportion of time in lying rest at night was 29% in 2019, and lying rest was observed at some point during the night in 93.9% of the 49 elephants. Of the 46 elephants observed in lying rest, 58.7% were observed lying near another elephant at some point during observations; however, on average elephants spent similar amounts of their time sleeping alone as they did sleeping with others (Figure 5.5.1). Two elephants were never observed in lying rest; they had minimal data submitted, but there were some commonalities. Both were female and were located at the same facility, where the indoor area available to these elephants was mainly concrete, with smaller areas of sand (partial coverage of only 1m deep sand; 84.6 m^2 for one elephant and 112m^2 for the other). These two elephants spent 50% and 80% of their night-time observations feeding. Other elephants housed at this zoo did rest lying down for an average of 13% (± 9%) of overnight observations.

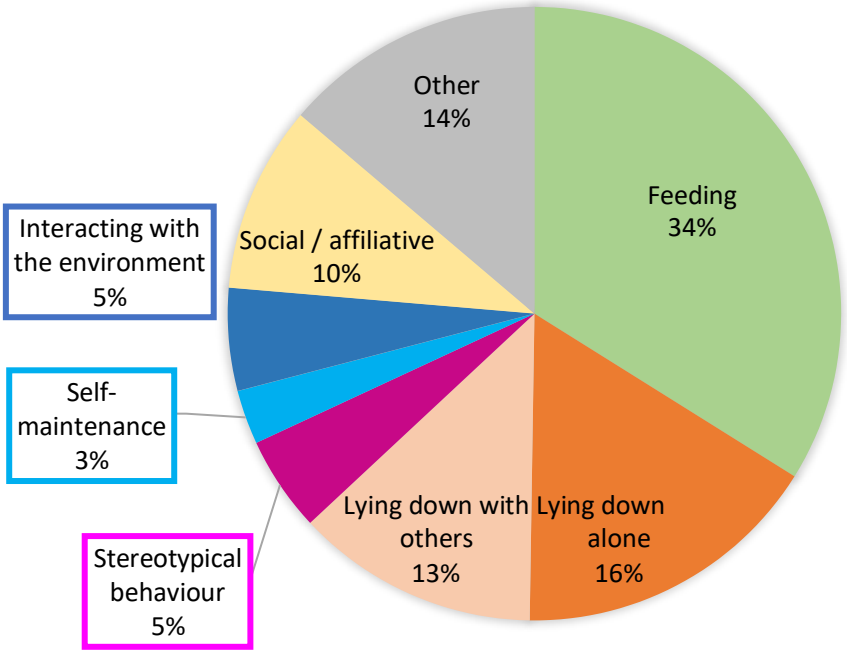


Figure 5.5.1: Percentage of time spent in different behaviours overnight for 49 elephants in 2019.

5.5.4 Stereotypical behaviour: Daytime

5.5.4.i EWG data from 2019 – daytime stereotypical behaviour

Of the 51 elephants observed in 2019, ten elephants (19.6%) displayed stereotypical behaviour on more than one occasion during the day (Figure 5.5.2). A further seven elephants were observed performing stereotypical behaviour during the day at least once (from the four assessments made across a total of 12 days) that year. Stereotypical behaviour was thus seen at least once in a third of the population (17/51) in 2019. Across all elephants however, the population median daytime stereotypical score in 2019 was 0 (never) (min=0, max=4, where 4='very frequently or virtually every hour').

There appeared to be little association between genus (p= 0.075) and none with sex (p= 0.707) and the expression of stereotypies during the day. However, age was a significant factor in daytime frequencies, and younger elephants had a lower expression of stereotypical behaviour (Cohen's d= 0.631, p= 0.001, n= 51) (Figure 5.5.2).

Six different types of stereotypical behaviours were described in the 17 elephants that displayed stereotypies during the day in 2019. The most commonly reported stereotypical behaviour was pacing (7/17), followed by swaying/weaving (4/17), rocking back and forth (2/17), bobbing up and down (2/17), bar biting (1/17) and leg swing (1/17).

Stereotypies were seen at all times of day:

- 'after 12 until late afternoon' (7/17)
- 'between 8am and 12pm' (5/17)
- 'multiple times throughout the day' (4/17)
- 'only prior to keeper arrival' (1/17)

Keepers reported that anticipation of events or times of resource provisioning seemed to be associated with the timing of stereotypies for 7/17 elephants, two of which were also said to perform stereotypical behaviour near entry points to indoor enclosures in response to poor weather.

.

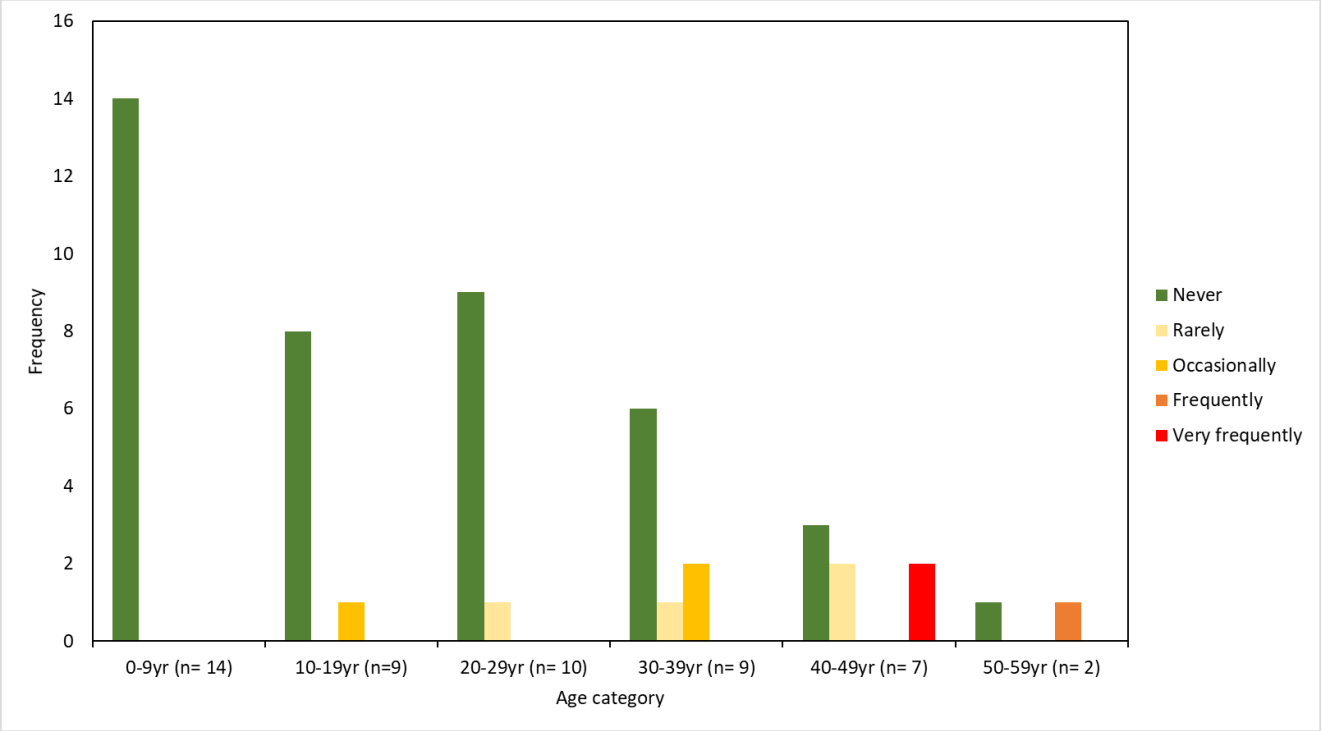


Figure 5.5.2: Daytime stereotypical behaviour scores for 51 elephants by age category.

5.5.4.ii Changes in daytime stereotypical behaviour over time: 2015 to 2019 EWG EBWAT tool

Daytime stereotypical behaviour scores showed a trend towards decreasing across the five years they were measured, from 2015 to 2019, although only six elephants were assessed over all six years. For a subsample of 24 elephants with behavioural data available from 2016 to 2019, no significant change in the frequency of daytime stereotypical behaviour was found over time (X^2 (df 3)= 3.582, p= 0.310).

5.5.5 Stereotypical behaviour: Night

5.5.5.i EWG data from 2019: night-time stereotypical behaviour

There were 49 elephants with overnight observations in 2019, and 12 were observed performing stereotypical behaviour (24.5%). Male elephants spent somewhat more time performing stereotypical behaviours overnight compared with females (males 6.5%, females, 3.5%) although this was not significantly different (p=0.509). While 78.6% of the 14 males housed in UK zoos were sampled, the overall sample size of male behaviour was very low due to their small numbers in the UK, and limited CCTV available in bull houses (which resulted in no data for three bulls in 2019).

Asian elephants spent more time engaged in stereotypical behaviour overnight (7.1%) compared to African elephants (0.7%) (Figure 5.5.3), although the time spent could not be compared directly due to limited sample sizes. In general, however, Asian elephants were more likely to display a night time stereotypy compared to African elephants (χ2(df 1)= 8.59, p= 0.006).

As age increased, elephants were more likely to spend more time engaged in stereotypical behaviour overnight (r_s= 0.423, p= 0.002) (see Appendix 5.5), with the highest night-time observations among the 50+ year old animals.

5.5.5.ii Changes in night-time stereotypical behaviour over time: 2015 to 2019 EWG EBWAT tool

There was a slight trend towards decreasing frequency of night-time stereotypical behaviour from 2015 to 2019. However, there were only five elephants with repeated observations over the entire five-year period. Data were available for 23 individuals observed across 2017, 2018 and 2019; for these elephants there was no significant difference in the frequency of night-time stereotypical behaviour over that period (X^2= 2 (df 2), p= 0.368; Appendix 5.5).

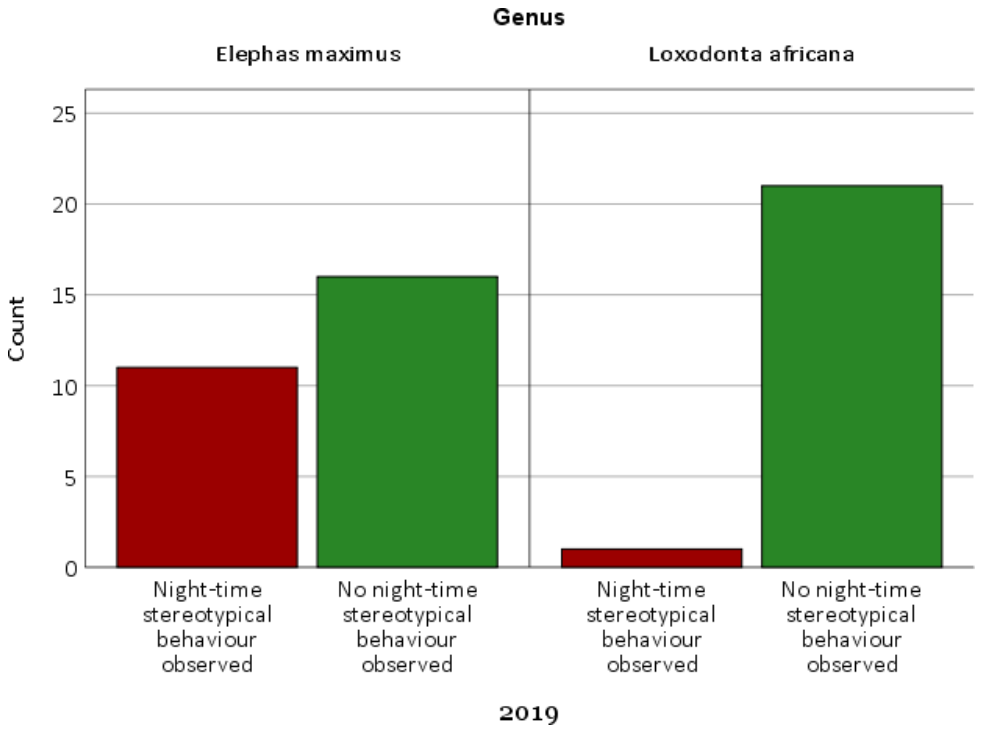


Figure 5.5.3: Frequency of elephants observed performing stereotypical behaviour overnight in 2019, by genus (27 Asian and 22 African elephants).

5.5.6 Changes in stereotypical behaviour over time: Comparisons with Harris *et al.* (2008)

Fewer elephants showed stereotypical behaviour during the day or at night in 2019, compared to the frequency reported by Harris *et al.* (2008). In 2006, stereotypical behaviour was seen during the day in 55% (42/77) of elephants; by 2019, this had declined to 33% (17/51). At night, stereotypical behaviour was seen in 49% of elephants (20/41) in 2006; this decreased to 24% (12/49) of elephants in 2019.

Because the methods used by Harris *et al.* (2008) were substantially different to those used by the EWG, it was difficult to compare the frequency of daytime stereotypical behaviour by sex or genus. However, comparisons were possible between Harris *et al.* (2008) and EWG data for night-time stereotypical behaviour. Although the differences in methodology between Harris *et al.* (2008) and the EWG data precluded statistical testing, by 2019 there was an apparent decline in the proportion of time spent stereotyping during the night for females and for African elephants. However, there was an increase in proportion of time spent stereotyping in 2019 for males and for Asian elephants (Table 5.5.3).

Table 5.5.3: Proportion of time observed performing stereotypic behaviour in UK elephants from Harris *et al.* (2008) and most recent EWG EBWAT (2019).

	Daytime		Night time	
	2006 (Harris *et al*. 2008)	EWG EBWAT 2019	2006 (Harris *et al*. 2008)	EWG EBWAT 2019
	Mean % time observed	Median score (IQR, n)	Mean % time observed	Mean % of time observed
African	1.0 (n= 36)	0 (IQR 0, n= 25)	4.4 (n= 17)	0.7 (n= 22)
Asian	5.7 (n= 41)	0 (IQR 1, n= 26)	6.6 (n= 24)	7.1 (n= 27)
Female	3.4 (n= 62)	0 (IAR 0, n= 37)	8.8 (n=32)	3.5 (n= 38)
Male	3.5 (n= 15)	0 (IQR 0, n= 14)	4.8 (n= 9)	6.5 (n= 11)
All elephants sampled	3.5 (n=77)	0 (IQR 0, n= 51)	5.7 (n= 41)	0.4 (n= 49)
Minimum	0	0	0	0
Maximum	31.8%	4	53.2%	2.8%

5.5.7 Stereotypical behaviour in elephants under 15 years old

Examining younger elephants who were born after recent (over the past 10-15 years) changes in management and husbandry allows us to assess whether stereotypies represent a legacy of historically compromised welfare or are more likely to be a response to currently stressful conditions. In order to determine if young elephants (less than 15 years, e.g. Harris *et al.* 2008) were expressing stereotypies, a separate analysis was undertaken, focusing on this age group.

In 2006, six out of 29 (20.7%) elephants aged <15 years old performed stereotypical behaviours during the day, with three of them also displaying the behaviour at night (four Asian, two African). Five of the six were males aged between 10 and 14 years. The one Asian female displaying stereotypical behaviour in both the night and day was eight years old.

Of the 20 elephants under 15 years old on the 1st January 2019, only one of them (5%) was reported to express stereotypical behaviour. This was only recorded at night for this male Asian elephant aged 4 years, whose mother had died the year before.

5.5.8 Effect of the presence of young (<6yrs) elephants on group behaviour

Elephants housed with young elephants (less than 6yrs old) showed more frequent daytime affiliative behaviour (med=3.5, IQR 3), than did elephants housed without young elephants (n= 9, med=1, IQR 2, M-W U= 204.5 z= 2.355 p= 0.019) (Figure 5.5.9). However, separate analysis of three affiliative behaviours found no significant difference between elephants housed with young elephants or those housed without young elephants, most likely due to small sample sizes, ('amount of time engaged in play behaviour with a conspecific' (M-W U= 152, z= 0.702, p= 0.588); 'spend time near or approach other elephants every time it is free to do so' during the day (M-W U= 184, z= 1.844, p= 0.068); and proportion of time spent lying down at night that was spent lying with other elephants (M-W U= 117, z= 1.196, p= 0.268)).

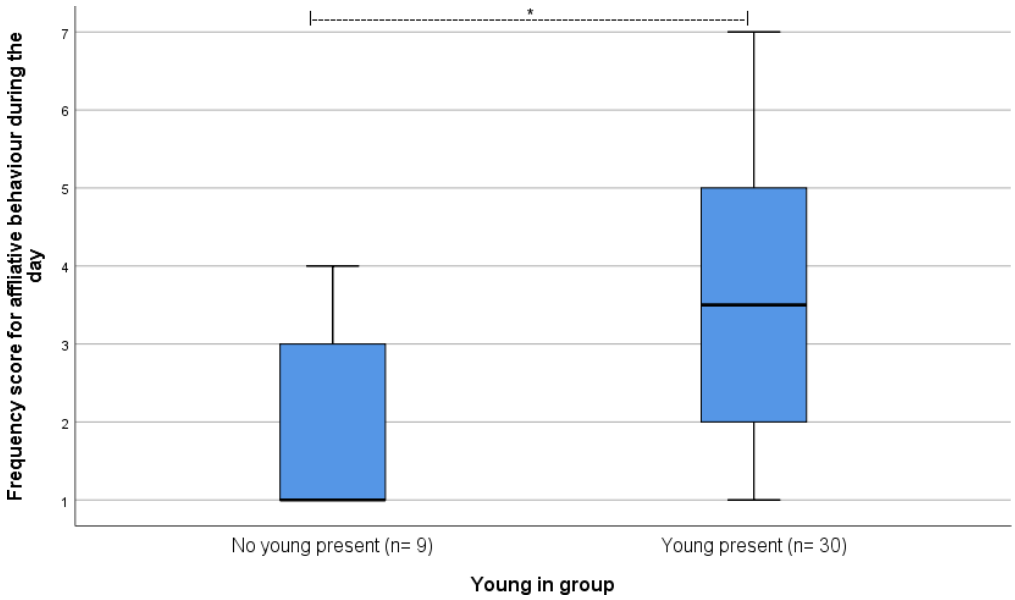


Figure 5.5.4: Frequency score (1 – 7 Likert scale, 7 = more frequently observed) for all affiliative behaviour (approaching, contacts, play and lying with) observed during the day for 39 elephants with or without a young elephant (<6yrs old) present in the group. * $p < 0.05$

5.5.9 Qualitative Behaviour Assessment (QBA)

Average QBA scores in 2019 for the composite score 'at ease in the environment' (mean=9.35, SE± 0.07) and the single item 'not wary' (mean=9.4, SE± 0.1) both scored on the high end of the scale; the single item playful (mean=2.2, SE± 0.31) by contrast was low scoring.

There were no differences in QBA scores between the genera or between the sexes for most scores in 2019. However, females had a higher average QBA score for 'not wary' (med = 10) than did males (med = 9: M-W U= 162.5, z=-2.141, p=0.032).

Similarly, most QBA scores were similar across the age categories in 2019 although younger elephants (0-9 years) were rated as significantly more playful than were some older elephants (specifically those aged 30-39 years) (X^2(df 5)=14.53, p=0.013) (Appendix 5.5).

5.5.10 Overview of results from behaviour subgroup

- Foraging and feeding were observed across the 24-hour period, rather than being focused during a single "feeding time".
- Play, lying rest (especially with others), and low levels of aggression were all part of the normal repertoire of behaviours seen.
- Social interactions between elephants, in the daytime or at night, were only observed infrequently, suggesting that issues with compatibility and atypical social structures remain.
- Older elephants showed more frequent affiliative behaviour when a young elephant was present. Lying rest appeared to be socially facilitated, with more lying occurring when another elephant was also lying down.
- Elephants commonly engaged in their own activities during the daytime, independent of keeper routines, and approached other elephants, when given the opportunity to do so
- There have been marked declines in both daytime and night observations of stereotypies among younger elephants.
- Overall, in 2019, stereotypies were frequently seen in ~20% (10/51) of UK zoo elephants.
- A legacy of stereotyping was present among the older elephants.

5.6 INTERACTIONS AMONG EWG WELFARE ASSESSMENT TOOLS

Summary

- Validation of welfare assessment derives in part from internal consistency among different tools, indices and measures.
- There was no correlation between Body Condition Score and either foot health or locomotion scores.
- No correlation was found between foot and locomotion scores in 2019.
- There were no correlations between any of the health tool scores and any of the behaviour tools (EBWAT) scores.
- There were a number of correlations between EBWAT scores, across QBA, daytime behaviour and night-time behaviour tools, providing evidence of internal consistency between the different tools and measures as well as criterion validity for QBA scores.
- Correlations were primarily between items measuring social interactions, as well as between assessments of stereotypical behaviour during the day and at night.

5.6.1 Comparisons between health and behaviour tools

There were no significant correlations among any of the health scores (Body Condition, Foot Health, Locomotion) for elephants sampled in 2019 (correlations and sample sizes shown in Appendix 5.6.1). Poor foot health was unrelated to compromised locomotion, and neither was significantly related to Body Condition Scores. Additionally, there were no correlations with the three health tools and any of the behavioural data collected using the EBWAT in 2019.

5.6.2 Comparisons between behaviour tools

Scores between the three different sections of the behaviour tool (QBA, daytime and night time behaviour) were positively correlated for several social behaviours: two positive affiliative behaviours (approaching others; lying with others at night) were correlated with QBA scores associated with positive welfare (content, relaxed, not uncomfortable, not agitated, not tense, not frustrated) (Appendix 5.6.1).

Stereotypical behaviour scores assessed during the day were correlated with those at night (r_s= 0.796, $p<0.001$, n=49; Figure 5.6.1). Those elephants which scored as having fewer stereotypies at night were the same individuals with fewer stereotypies during the day. There were no other behavioural correlations with low frequencies of stereotypies, suggesting that stereotypies did not affect time available for other activities.

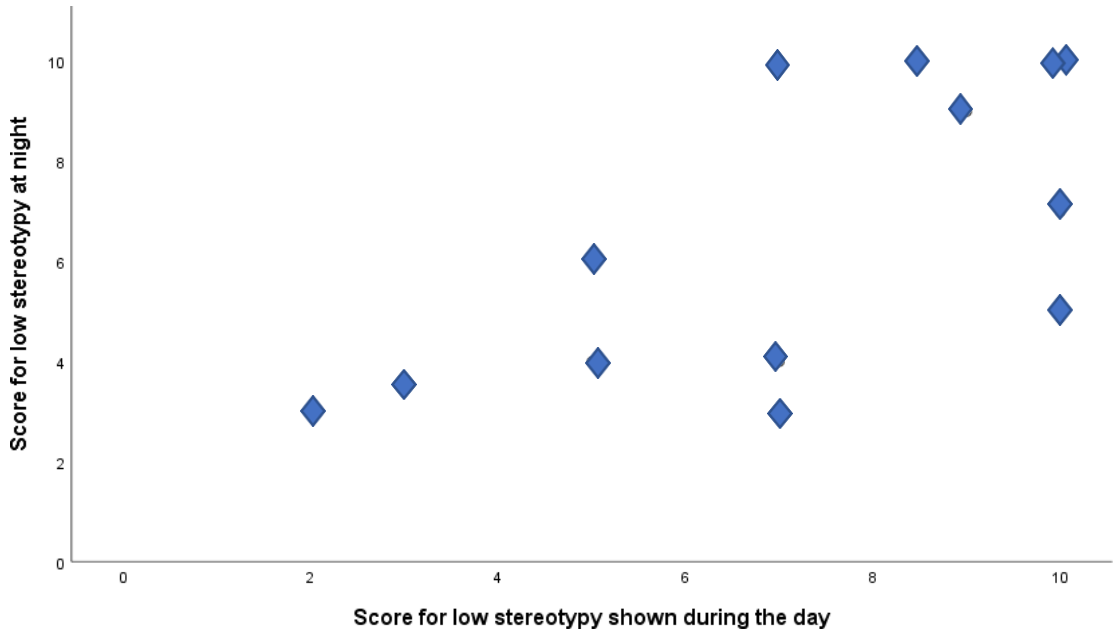


Figure 5.6.1: Scores for 'low frequency' of stereotypical behaviour observed during the day with scores for night observation for 49 UK zoo elephants in 2019.

5.7 Interactions Between Welfare Tools, Enclosure Variables and Group Composition

Summary

- None of the elephants in the smallest enclosures (<5,000m^2; n= 3) had healthy feet and their foot health scores were significantly poorer than elephants in the largest enclosures (>30,000m^2; *n*= 27), which had healthy or only superficial foot concerns.
- Neither locomotion score nor body condition score was associated with total enclosure space.
- Elephants housed in smaller enclosures were reported to perform more frequent stereotypical behaviours during the day.
- Elephants in more closely related groups scored higher than elephants in less related groups on scores for three daytime social affiliative behaviours ('approaching others' and two composite scores, each of which incorporated social behaviours).

5.7.1 Health data and enclosure variables

There was a significant association between foot health scores in 2019 and total amount of enclosure space available (Figure 5.7.1) (p= 0.013, n= 50). There were no elephants housed at zoos with <5,000m^2 space available (n= 3) which had scores of zero (healthy feet). Additionally, no elephants housed at zoos with >30,000m^2 (n= 27) had scores associated with foot health problems (score >5). There was no association between the presence or absence of abnormal gait and total space available (p> 0.05). Nor was there an association between body condition scores and total space available (p> 0.05).

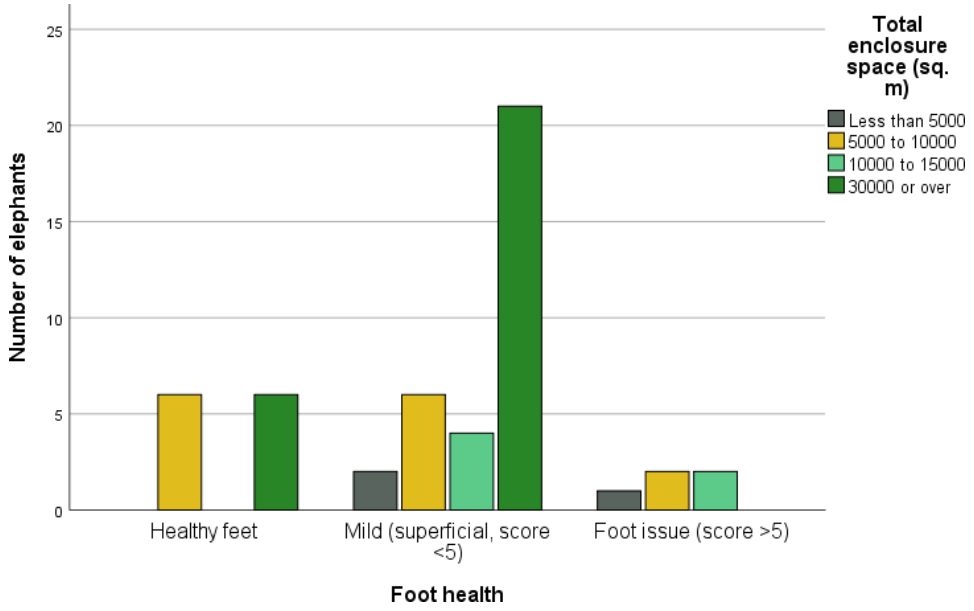


Figure 5.7.1: Foot health scores recorded in 2019 for 50 elephants were worse for the elephants in the smallest enclosures.

5.7.2 Behaviour and enclosure factors

5.7.2.i Stereotypical behaviour

There was a significant association between daytime stereotypical behaviour and total enclosure size ($p < 0.01$), with elephants housed in smaller enclosures performing more frequent stereotypical behaviours (median score 4 "very frequently') during observations than the other three enclosure size categories. However, sample sizes were varied and small across groups.

Similarly, elephants that spent a higher proportion of overnight observations engaged in stereotypical behaviour tended to be those housed in smaller enclosures (Figure 5.7.2); however this association was not significant across all enclosure sizes ($r_s = -0.149$, $p > 0.05$, $n = 48$).

Of the twelve elephants (out of 49 elephants with night-time data) that displayed stereotypical behaviour overnight, five (41%) performed this behaviour for an average of 20% or more of the time observed (Table 5.7.1). The highest percentage of overnight stereotypical behaviours was performed by three females in the smallest enclosures (Table 5.7.1 **bold** shows individuals with >20% of overnight observations in stereotypies), and by two adult males. The two adult males also had reduced space access overnight, relative to their daytime space.

Overall enclosure size didn't necessarily indicate the space available for each elephant, as access to enclosures was a function of how keepers managed group-housed elephants (this was dynamic, and varied), and for some elephants, how they chose to use their enclosures throughout the year. In the absence of details on enclosure use (as opposed to size), we were unable to relate the occurrence of stereotypical behaviour to enclosure size, other than the high night-time occurrence noted for the four elephants in the smallest night time space (see Table 5.7.1).

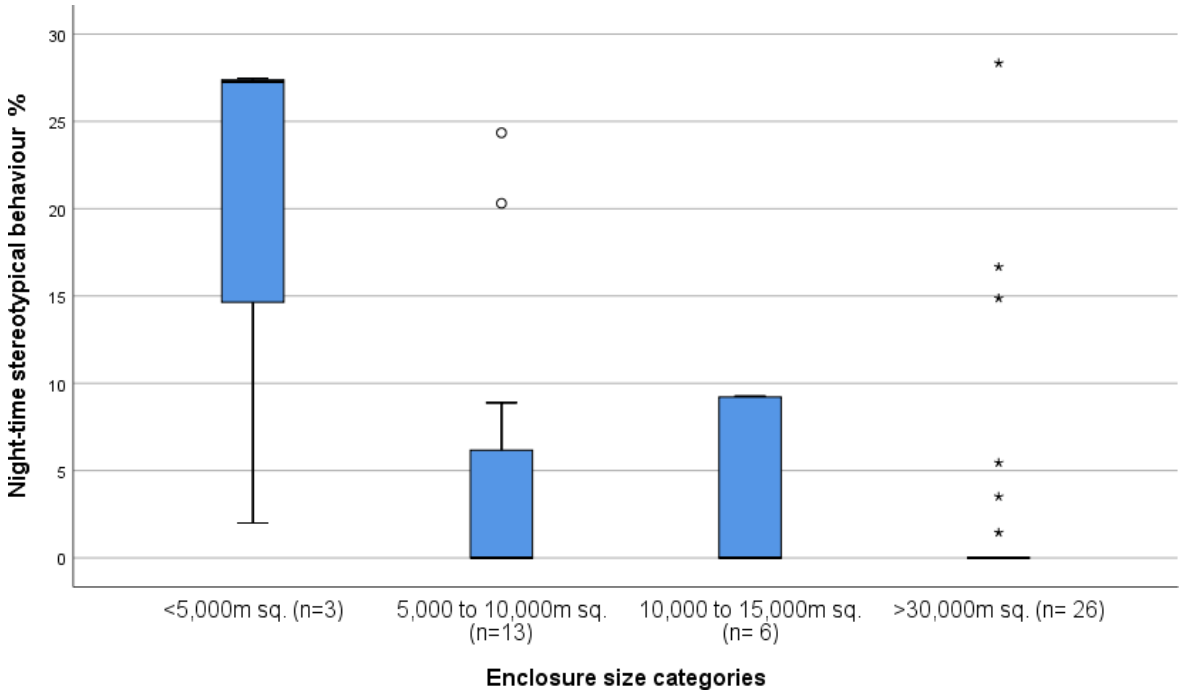


Figure 5.7.2: Enclosure size categories and night-time stereotypical behaviour frequency observed in 2019.

Table 5.7.1: Description of elephant characteristics, enclosure space and access for all elephants that displayed stereotypical behaviour overnight in 2019. Elephants in bold displayed stereotypical behaviour for an average of ≥20% each night they were observed (1 to 4 nights of observations for each elephant).

Individual	Average % of stereo. frequency at night	Night space available (sq. m)
a)	**27.5**	**212**
b)	**27.3**	**212**
c)	6.2	1,864
d)	9.2	10,744
e)	8.9	7,421
f)	**20.3**	**5,600**
g)	9.3	14,325
h)	16.7	Unknown
i)	5.4	Unknown
j)	**24.3**	**440**
k)	14.9	Unknown
l)	**28.3**	**187**
Mean (SD)	**16.5 (±8.8)**	**4,556 (±5,292)**
Elephants that had no observations of stereotypical behaviour at night in 2019		
m)	0	256
n)	0	256
o)	0	160
p)	0	11,925
q)	0	1,924
r)	0	480
s)	0	66
t)	0	11,925
u)	0	1,000
v)	0	480
w)	0	845
x)	0	845
y)	0	11,925
z)	0	1,098
aa)	0	66
bb)	0	845
cc)	0	480
dd)	0	1,000
ee)	0	1,924
ff)	0	845
gg)	0	400
hh)	0	1,000

ii)	0	845
jj)	0	400
kk)	0	1,924
ll)	0	256
mm)	0	845
nn)	0	14,325
oo)	0	139
pp)	0	1,000
qq)	0	480
rr)	0	19,325
ss)	0	19,325
tt)	0	480
uu)	0	480
vv)	0	19,325
ww)	0	66
	Mean (±SD)	**3,485 (±6,067)**

5.7.2.ii Lying behaviour during rest

The proportion of overnight observations that the elephants (*n*= 49) spent in lying rest in 2019, showed a trend towards longer durations of this behaviour where the elephants had access to sand substrate (p= 0.078; Figure 5.7.3).

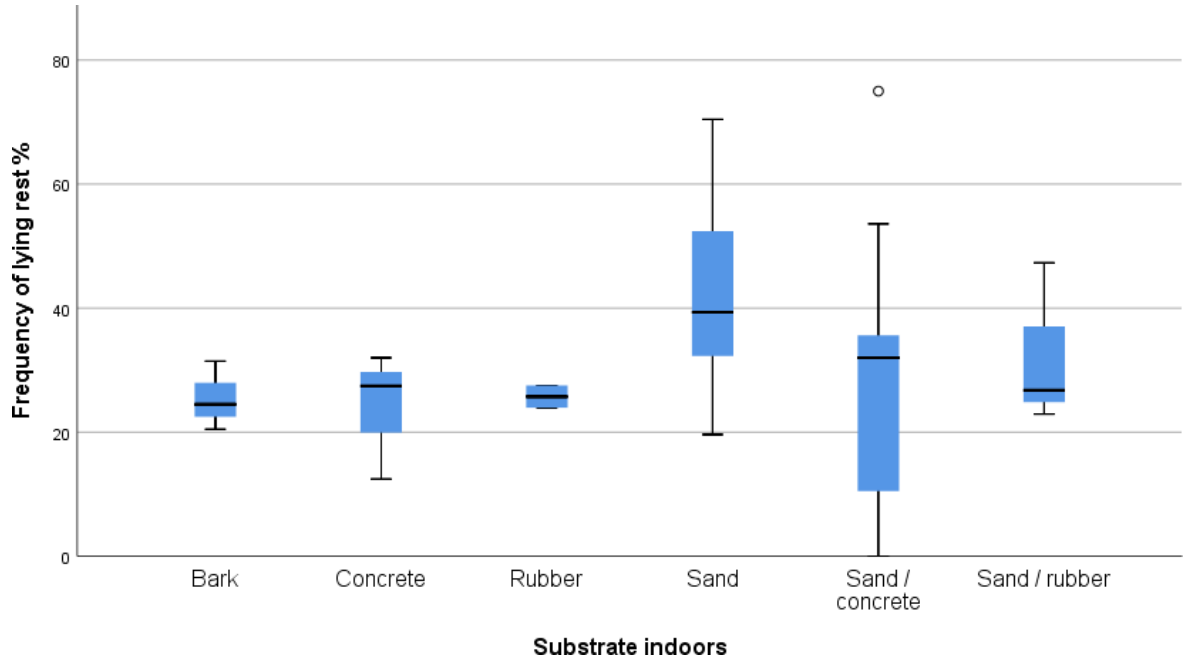


Figure 5.7.3: Frequency of overnight observations where elephants were engaged in lying rest behaviour, by substrate type indoors in 2019 for 49 elephants.

5.7.3 Interactions between behavioural welfare scores and group relatedness

Relatedness was calculated as the coefficient of relatedness (0 to 1 score where 0 is an individual not related to any other elephant) for each individual elephant (see section 5.1.2 above).

Of the ten behavioural scores generated with the EBWAT tool (3 QBA, 5 daytime observations and 2 overnight observations) in 2019, three behaviour

scores were positively correlated with overall elephant relatedness coefficient scores for 2019, calculated regardless of age or sex (Table 5.7.2). These three behavioural scores all incorporated elements of affiliative social interactions. More approaching others, more independence, and more positive engagement with the environment were all seen when the group composition promoted a higher degree of kinship.

Table 5.7.2: Elephant relatedness coefficient scores were correlated with three daytime behaviour scores generated by the EBWAT.

Items	Relationship	Result	Interpretation
Approaching others v relatedness	+ve	r_s= 0.564, p< 0.001, n= 47	Expected (behaviour in the wild, multi-generational family herds)
Low dependence† on routine v relatedness	+ve	r_s= 0.658, p< 0.001, n= 48	Possibly expected (behaviour in the wild, multi-generational family herds)
Engaging positively with the environment‡ v relatedness	+ve	r_s= 0.605, p< 0.001, n= 45	Expected (behaviour in the wild, multi-generational family herds)
Individual behaviour items that make up the two composite EBWAT daytime behaviour scores above: †Low dependence on routine = Feeding, foraging (*Rho*= 0.568, *p*< 0.001) does not wait for scheduled events (*Rho*= 0.449, *p*< 0.01), play with others (Rho= 0.472, p< 0.01).			
‡Engaging positively with the environment = Wallowing (*p*> 0.05), affiliative behaviour (*Rho*= 0.713, *p*< 0.001), interactions with the environment (*Rho*= 0.606, *p*< 0.001)			

6. Discussion

We summarise the results of the EWG's work using the tables set out in the introduction which provided indicators of compromised welfare. These tables illustrate highlights and details of how the keeping of elephants in UK zoos has changed substantially over the ten-year period of the EWG, in response to welfare concerns. We would note that some of these changes were occurring prior to the formation of the EWG, and were initially driven by changes in the Secretary of State's Standards in 2008, as well as further revisions to these guidelines in response to EWG work in 2014 (see Table 4.1). Nor are the studies and instruments detailed in this report the only work on elephant welfare in captivity in the UK (e.g. Lucas & Stanyon, 2017; Williams *et al*., 2018; 2020; Webber, 2017; Webber & Lee, 2020; Finch *et al*., 2020, among others). Furthermore, zoos themselves have already responded to highlighted issues of obesity, poor substrates (in enclosures) and facility design, styles of management (moving to Protected Contact), and enabling greater choice and control on the part of elephants for location, movement and social partners.

Data collected by the EWG over the past 10 years have, where possible, been directly compared against the results reported by Harris *et al*. (2008). In order to further evaluate the EWG data with regard to changes in welfare of elephants in UK zoos over the past 10 years, additional comparative evidence has been drawn from many sources, including studies on the wider European and North American populations. It is important to note that, in many cases, the methods used by the EWG were not directly comparable to those used by Harris *et al*. The EWG has developed a range of tools to evaluate welfare, which were individually scientifically validated, and data were collected over a longer period of time than that covered by the Harris *et al.* report. Moreover, a wider range of behaviours was assessed by the EWG, to encompass both negative and positive welfare states. Where possible, the EWG scores were adapted to enable comparison with Harris *et al*., and current EWG data can serve as the baseline against which potential future improvements might be assessed.

It is also important to consider that the animals themselves have changed over time within the UK population; some animals have died or moved out of the UK, and new animals have been born or moved into the UK. Furthermore, it is essential to recognise that the number of elephants in the UK remains relatively small – this makes it difficult to have a sufficiently large sample size for statistically robust results. Despite these limitations, we have presented a number of statistically significant results, indicating the potential for replication of our findings.

It is essential to recognise that welfare is a complex construct, and no single measure should be used in isolation to assess welfare; rather, a suite of different measures should be employed. The EWG tools were designed to appraise different aspects of physical and mental well-being, and to provide a more holistic evaluation of elephant welfare.

Table 6.1: EWG summary findings related to animal-based welfare indicators highlighted as a cause for concern in 2002-2010. Comparisons were based on the specific UK zoo elephant population of concern, the European zoo population (managed as a single "breeding" population) and the well-studied North American zoo population.

Welfare indicator	Population Context	Findings of welfare concern before EWG work	EWG findings for current UK captive elephants
Survivorship	European zoo population	• Overall population median lifespan from birth = 17 years[1]. Lifespan truncated at <20 years compared to a maximum possible of 75-80 years for wild elephants; shortening resulted from excess calf deaths and adult mortality[1]. • Female African captive born elephants = 16.9 years (vs > 50 for wild African females[1]) • Female Asian captive born elephants = 18.9 years (vs >40 for working Asian elephants[1]) Insufficient data for full survival analysis of males.	• Overall population median lifespan from birth = 40.2 years. For females in captivity for over 20 years, median longevity = 50 years (comparable to wild elephants). Median longevity for captive born elephants remains <20 years due to high early mortality. Captive born: Female African elephants = 14.5 years Female Asian elephants = 20.7 years No captive elephants have yet survived to maximum ages seen in the wild (75-80 years). Insufficient data for full survival analysis of males.
Infant mortality	European zoo population	• Calf first year mortality (including stillbirths) 2-3x > wild[1]. African calves = 21% mortality (vs 11% in wild[1]). Asian calves = 39% mortality (vs 5% in wild from birth to 5 years[2]). Mortality for calves born alive: African elephants = 18% (vs 9% in wild); Asian elephants = 26% (vs 9% in timber camps).[1] Stillbirths: African = 33% (vs. wild = 13.5%) Asian = 42% (vs. timber camp[1]= 13.5%)	• Calf survival in captivity remains low, with first year mortality 3x> wild. African calves = 33% mortality. Asian calves = 14% mortality (0-5 years = 48%) Stillbirths in the EAZA population are now more similar to wild populations at 12% of pregnancies vs. 11.9% wild African females, 12.3% working Asian females)[4]. Cause of death in calves: Maternal neglect or trauma is still associated with 5% of 20 births for captive African elephants and 4.1%

		Main causes of death in calves: dystocia, infanticide, and maternal neglect. Especially for Asian elephants, *Herpes* virus (EEHV)[3] is a major mortality factor. [NB: Infanticide and calf rejection are seldom, if ever, seen in wild populations]	out of 24 births for captive Asian elephants. Primiparous females, lacking experience with calves, have lower rearing success than in the wild (1.45 times the risk)[5] and are still at risk of calf loss in captivity[4]. EEHV significant cause of death for UK Asian calves (those >1 year), causing 12 deaths from 2006 to 2019.
Fecundity and birth rates	European zoo population	• Low fecundity: Obese mothers[3], abnormal reproductive cycling, lack of access to males. Reproductive onset either atypically early (4 years) or late (>28 years)[4]. Reproductive lifespan is terminated by 45 yrs for > 50% of females[4] vs 60+ for wild elephants[5,6]. Birth rates for captive females over the last 20-30 years: <0.09 calves per female per year[1] (vs wild African= 0.18-0.22 [5]; Asian =0.13-0.17[6])	• Low fecundity: Reproductive onset remains too young (particularly in Asian elephants) with mean age at first conception for UK & EU: Captive Asian = 5.5 yrs (vs wild = 11.6 yrs[6]). Captive African = 9.2 years (vs wild = 11.9 years[5]). Early first reproduction is associated with excess calf mortality[1], and possible maternal depletion[7] potentially leading to lower lifetime fertility. Sex ratio at birth (31F:22M born 2006-2019) is very slightly female biased. Age-specific birth rates and reproductive lifespan could not be reliably determined for the EWG subset of breeding females (<30 individuals, 9-year time span).
Sustainability of zoo population	European zoo population	• Zoo population was not self-sustaining due to low fecundity and poor survivorship. Predicted to decline by 10-11% each year if reliant on captive-bred animals kept under historically prevailing conditions. Extinction predicted within 29-37 years[1].	• Models for time to extinction were not derived by EWG as breeding is managed at a European level.

Body condition	UK zoo population	• Overweight[8]. 92% (of 76 UK zoo elephants): mild to moderately 'overweight' or 'very overweight'. Only 6 elephants were considered normal to underweight in body condition. Higher BCS were correlated with gait problems, lameness and poor foot health.	• EWG Body Condition Scores of UK elephants: high end of the 'normal' range or lower end of 'over condition/weight'. Similar for both sexes (median = 7, *n*= 13 males, 37 females), but higher for Asian elephants (median = 8). Direct comparison with Harris *et al*. (2008)[8] not possible due to the use of a novel scoring method validated with body fat scans. EWG Body condition unrelated to foot or gait health. Work to improve diet and reduce obesity began prior to the EWG activities in recognition of Clubb & Mason (2002)[9] report.
	European zoo population	Overweight. Ponderal Index and Body Mass Index were significant greater for zoo born calves[3]. Asian elephants: weight 31-72% > similarly sized wild elephants (max=180% heavier)[3]. Overweight at birth suggested increased calf and maternal mortality with obesity in adults leading to lameness[9].	
Lameness and joint problems	UK zoo population	• High prevalence of lameness. 84% of elephants had a non-normal gait (23% had an obvious limp or were severely lame, 35% were mildly lame and 22% had an imperfect gait).[8]	• Improved gait and locomotion (vs. Harris *et al*.[8]). Most (73.7% of 28 elephants) had no locomotory abnormalities by 2019, vs. 15% in 2006[8]. No difference between Asian and African elephants.
	European zoo population	Arthritis common and major cause of euthanasia.[9]	
Foot health	UK zoo population	• High prevalence of foot problems. 20% of 76 elephants had severe problems with their forefeet and 8.0% with their hind feet. Only 20% had no foot problems[8].	• Mostly no or minor foot issues in 2019; decrease in severe foot problems with severe foot problems accounting for fewer than 10% in 2019 (vs. 80% in 2006[8]). No change in percentage elephants with "no foot issues" at 20% of the population (n=50) in 2019 (same as measured in 2006).
	European zoo population	Noted as the major cause of euthanasia[9].	

	North American zoos	Medical foot problems = 50% (of 189 elephants)[9]	Asian elephants and older elephants had the most foot health issues. Foot health was not correlated with locomotory health.
Stereotypic behaviour	UK zoo population	• High prevalence among most elephants[8] Overall prevalence: Daytime = 55% of all elephants (Asian elephants 2x> African) Night-time = 49% of elephants (20/41) Time spent stereotyping: Asian almost 3x> African 37% of elephants stereotyped for > 5% of the time Elephants <15 yrs Daytime = 20% of elephants (6/29) Night time = 10% of elephants (3/29)	• Prevalence of stereotypic behaviour has decreased, overall (less than a third of elephants), due to low rates among young elephants Overall prevalence: Daytime = 33% of elephants No difference between genera. Night time = 24% of elephants Likelihood of night time stereotyping: Asian > African Females > Males No elephants <10 years showed day time stereotypies; only 1 (out of 20) under 15 years showed night time stereotypies. Older females retain a legacy of stereotyping with 44% of 18 females >30 years showing daytime stereotypies at least once. Time spent stereotyping at night decreased in females and African elephants compared to 2006: Females = 3.5% (vs. 8.8% in 2006[8]) African = 0.7% (vs. 4.4% in 2006[8]) Time spent stereotyping at night did not change greatly in males or Asian elephants compared to 2006[8]: Males = 6.5% (vs. 4.8% in 2006) Asian = 7.1% (vs 6.6% in 2006)
	European zoo population	High prevalence Daytime: 41% (of 21 female elephants) stereotyped; Females on average stereotyped for 9.6% of total time observed. Asian (6.8%) > African (1%) [9]	
Aggression	UK zoo population	• Aggressive interactions rarely recorded (0.1% of daytime).[8] Deaths of keepers due to elephant aggression have not	• Aggression between elephants rarely recorded (<0.1% of interactions [10]). Daytime = 0-2%

		been recorded in UK zoos since 2001 (three in 2000-01)[10].	Night time ='Rarely observed' Older elephants (≥6 years) showed less aggression and more frequent daytime affiliative behaviour when housed with young elephants (≤6yrs old). Protected contact management regimes in the UK have reduced keeper contact with elephants. Incidents of keeper-directed aggression have not been reported. Elephants have more choice over their activities and engagement with keepers under Protected Contact management.
	European zoo population	Elephant to elephant aggression-related deaths: 9.4% - 17.6% of all elephant deaths.[9] 31 incidents of aggression towards humans were recorded in European zoos; 15 during 1976 to 1991; four resulted in the death of the handler.[9]	
	North American zoo population	Elephant aggression to other elephants has caused mortality in African elephants (e.g. San Diego, 2011). 15 handler deaths between 1976 and 1991 representing one of the nation's elephant handlers each year.[11] At least 20 deaths and 140 injuries have occurred between 1987-2019.	
Glucocorticoids	UK zoo population	Unclear welfare implications of findings from faecal cortisol metabolite (FGCM) measurements.[8]	Due to the complexities of interpretation, logistics and cost, EWG did not use this measure as an indicator of compromised welfare.
Cardiovascular problems	European zoo population	• Most common cause of death in non-infants[9].	• Still prevalent cause of death for African elephants (4/7 non-infant deaths). For Asian elephants, musculoskeletal causes were more common (7/10 adult deaths).
Elephant Endotheliotropic Herpes Virus (EEHV)	UK zoo population	• Increasingly implicated as a cause of mortality in young captive elephants. Implicated in stillbirths in Asian elephants. High mortality rate: 19/22 diagnosed calves died.[12]	• EEHV remains the most significant cause of death among captive Asian elephants over 1 year of age and represents 44.4% of Asian elephant mortality, killing 12 juveniles aged 1-3 years old (from 2010 – 2019). Treatment and early detection are advancing, with increased survival of clinically affected calves reported in a growing number of cases.
	European zoo population	Screening suggested an incidence of 9.7%. Implicated in deaths of calves born in zoos[9].	
	North American	Prevalence of 3.3% in North American zoos, prevalence	No cases of tuberculosis were detected in the UK zoo elephant

Tuberculosis	zoo population	unknown for Europe.[8] Recent estimates of up to 6%. [13] Infection can be transmitted between elephants and humans as well as between elephants and other susceptible primate species (e.g. chimpanzees, lemurs[14]).	population between 2006 – 2019. More frequent testing of elephants; monitoring protocols undergoing further development. EAZA requires TB testing when any elephants are moved.

Colour coding in table: *Historic findings (pre-EWG)* UK elephants and European/North American zoos
Current (EWG) findings this report EWG findings in current UK elephants

Table 6.2: EWG summary findings related to resource-based welfare indicators highlighted as a cause for concern 2002-2010. Comparisons were based on the specific UK zoo elephant population of concern, the European zoo population (managed as a single "breeding" population) and the well-studied North American zoo population.

Welfare indicator	Zoo / Husbandry Context	Findings of welfare concern before EWG work	EWG findings for current UK captive elephants
Social groupings and composition	UK zoos	• Atypical social composition of most groups in sex and age structure with more young animals and few mature bulls.[8,9] Lack of kin structuring or relatedness in groups. Mean group size = 2 adult females. Overall mean size = 4.1 including calves (vs. wild groups of 6- 60 females and calves[3,15]). Only 6/16 facilities had one or more relatives present in groups[8]. Only 2/16 facilities housed potential breeding bulls. Most bulls kept in some form of social isolation.	• Working towards multi-generational groups, similar to the wild (found in 2 facilities). Slight increase in mean adult female group size = 2.7 (n = 12). Overall mean group size = 4.3 including calves and males. Age-graded structures (different ages present in a group) in 50% of facilities with multiple females. Average relatedness has increased for some breeding groups but remains relatively low at 0.06, (vs 0.20 for wild African elephants[10]). The number of bulls at facilities with females has doubled (5 /12 facilities); Fewer bulls kept in social isolation; one facility houses an age-graded bull-only group (to reflect bachelor herds in the wild).
Transfers between	European zoos	• High rate of transfers to other zoos (~1/3 of elephants	• Now typical to transfer entire family groups or bull peers

zoos		experienced ≥1 transfer). Transfers usually single young elephant alone (<10 years). Significant increase in transfer rates experienced by elephants over time. Transfers associated with 50% greater risk of death[1,9]	together. No transfers of elephants <4 years of age. Nine transfers of males >4 yrs. Between 2010-2019 there were 26 transfers, three of those elephants died before the end of 2019: One female died on the day of transit; the other two (1M; 1F) died 17 months and 15 months after their move. **Transfers need further monitoring due to associations with longer term impacts on lifespan.**
Early weaning	European zoos	• Zoo-born elephants removed from their mothers and transferred alone to other zoos at ages <4 years, especially if male.[9]	• Early weaning (<4) is discouraged by UK legislation, and zoos are instructed not to transfer animals before this age. This now only occurs naturally, due to a successive birth to the same mother, or due to maternal death.
Time confined indoors	UK zoos	• Confinement within indoor or outdoor locations was common. Summer indoor confinement: Average = 12 hrs (range 0-17 hrs) Winter indoor confinement: Average = 18 hrs (range 15-24 hrs) Some elephants spent 83% of the time indoors[8] Elephant choice of free indoor/outdoor access (24/7): in 2/16 zoos (for variable periods of time)[8]. Choice to move between indoor and outdoor constrained by keeper management.	• More elephant choice of location, with free indoor/outdoor access (24/7) for cow-calf herds at 50% of zoos, and at 42% of 12 zoos for all elephants (both male and female). Full location (indoor / outdoor) choice by elephants in all seasons and overnight is still lacking for half of zoos; winter confinement may be felt necessary to ensure adequate ambient temperatures.
Space available	UK zoos	• Space available to each elephant restricted Average indoor space = 165.9m^2 (range 14.5 to 560 m^2). [8]	• Average indoor and outdoor enclosure sizes have increased between 2010 to 2019 Indoor space: 1.4x increase, to 716m^2

		Average outdoor space winter = 8,713m^2 (range 280 to 22,514m^2) Average outdoor space summer = 11,326m^2 (range 280 to 36,422m^2) in summer.[8] Shifting from larger outdoor enclosure to smaller indoor enclosure associated with high stereotypy levels.[8] Most outdoor enclosures were too small to allow natural walking patterns seen in wild elephants.[8] Larger spaces associated with lower stereotypy levels and better gait scores. Small indoors spaces associated with higher stereotypy levels.[8]	Outdoor space: 1.2x increase to 18,266m^2 Mean total enclosure space = 18,982 m^2. Total enclosure space was associated with better foot health scores. Elephants in the smallest enclosures (*n*= 3) had foot problems. Elephants in the largest enclosures had healthy feet or only superficial foot concerns. Space in some facilities may still be smaller than that sufficient to encourage a full range of natural behaviours. Body condition and compromised locomotion was not found to be associated with total enclosure space for current UK elephants. There was a correlation between the occurrence of stereotypical behaviour and enclosure size in 2019; those elephants with the smallest enclosures were most likely to show stereotypies both during the day and at night. Stereotypies were also related to age and the history of individual elephant~~s~~.
	European zoos	EAZA minimum space requirements were not being met. Lack of evidence-base for minimum space requirements in zoo standards.[9]	
Restraint	European Zoos	• Chaining was a common practice but there was no prevalence data.	• Overnight restraint no longer practiced in UK zoos. Chaining (max 1hr per day) only used for management purposes in free contact zoos (11/53 elephants in 5 facilities).
	North American zoos	48% of zoos regularly chained elephants overnight and 13% occasionally chained elephants[9]	
Handling system	UK zoos	• Most elephants handled in free contact (60.5%). Others in no contact (19.7%) or protected contact (14.5%) with a few in mixed systems (5.3%).[8]	• Most elephants (73%, n = 53) in full protected contact EAZA guidelines stipulate that all EAZA zoos must manage their elephants using protected contact by 2030.
	European zoos	Most zoos used free contact systems (79.7% of zoos). Others use no contact (32.8%) or protected	

		contact (21.9%) [note: multiple systems used in some zoos].[9]	
Substrate	UK zoos	• Indoor enclosure substrate: generally concrete or concrete and tile; two zoos used rubber or rubberised concrete.[8] Outdoor enclosure substrate: variable, included grass, mud, clay, sand, concrete, gravel and hardcore.	• Indoor substrate (2019): Most (76.9%) use soft substrate (sand, rubber or bark chips); Only 7.7% had a concrete substrate Outdoor substrates were not assessed in 2019; these were primarily a mixture of naturally occurring materials. Larger enclosures and more natural substrates were associated with fewer severe foot problems, although causality can only be inferred.
	European zoos	Widespread use of hard unyielding substrates like concrete. Associated with foot and joint problems.[9]	
	North American zoos	91% of zoos used concrete flooring. 52% of these zoos believed there was a link with foot disease.[9]	
Facilities for bulls	UK zoos	• No coherent strategy for housing bulls which is a problem particularly if breeding rates increase.[11] Five facilities with bulls in 2006: 10 males ≥10+ years, Five males <10 years[8] Lack of facilities available for mature bulls. Bulls were housed alone in 3/5 facilities with adult males.	• EWG work on male associations[16] has provided recommendations to encourage better management of male groups, and some males were housed with access to females and young, as well as the option to be alone if they chose to do so. Five facilities (of 12) housed adult bulls (≥10 years) in enclosures with male-female access [with an additional one added in 2019]. An all-male group (bachelor herd) was established at one facility. Costs of housing males over a lifespan needs careful planning, especially for bulls in their annual state of high arousal (*musth*) when they require additional management. All bulls of breeding age have higher and more diverse space requirements than do intergenerational groups of female kin.

Diet	European zoos	• Most Asian elephant diets deficient in various vitamins and minerals 86.8% of diets had excessive fat content.[9] 90% of zoos did not provide grazing opportunities in enclosure.[9]	• Foods provided have moved from highly processed to a greater fibre and lower fat content. All facilities provided browse plus hay or grazing. Energy intake was difficult to determine in group-fed animals, which was the case for all the (more appropriately) socially housed elephants. High sugar fruit/veg was used primarily for training rewards only. Food provision was increasingly spread at varying intervals across the 24-hour period; hay was available in both the day and night-time in 10/11 collections. All collections offered browse, with 4/11 collections offering browse over both the day and night-time. Access to grass was available in 9/11 collections.
Climate	European zoos	Colder, wetter climates may be linked to foot and joint problems Cold impacts time confined indoors.[9]	Acceptable temperature range was mandated, but when given a free choice of location, elephants did not avoid outside environments even when cold. Future welfare studies need to investigate effects of cold, especially on calves.

Colour coding in table: *Historic findings (pre-EWG)* UK elephants and European/North American zoos
Current (EWG) findings this report EWG findings in current UK elephants

Sources for Tables: 1. Clubb *et al*., 2008; 2. Sukumar, 1997; 3. Clubb *et al.,* 2009; 4. Hartley & Stanley, 2016; 5; Lee *et al*., 2016; 6. Da Silva *et al*., 2013; 7. Mumby *et al*., 2015; 8. Harris *et al*., 2008; 9. Clubb & Mason, 2002; 10 William *et al*., 2019; 11. Zoos Forum 2010; 12 Richman *et al.,* 1999; 13. ; 14. Lyashchenko, *et al*., 2006; Murphree *et al*. 2011; 15. Moss *et al.,* 2011; 16; Hartley *et al.,* 2019.

6.1 Welfare indicators showing improvement over time

A. The proportion of obese elephants has declined somewhat, along with an associated major change in foot problems and lameness. These are significant health improvements and reflect marked shifts in the quality of nutrition and the provision of browse (increasing roughage). Moreover, elephants were more frequently fed while in their social groups, which supported social cohesion and social learning, although presenting challenges for monitoring and managing individual intake.
B. Longevity has increased for the older section of the population, representing significant changes to husbandry and management for these "legacy" elephants. The question remains as to how best to support their ageing processes.
C. There has been a sustained move to improved and enlarged facilities, with softer substrates,

less restraint, and greater 24-hour access. These moves have been associated with a shift to protected contact management in more facilities, giving elephants greater choice over their daily activities. These changes should be reflected in more facilities in the future.

D. The expression of stereotypical (abnormal) behaviour has decreased in all but the oldest individuals, and is now seen very rarely in elephants under 10 years old. Ensuring that elephants do not acquire stereotypies either through social learning, or due to physical and emotional stressors, in the future remains challenging.

E. Male elephants are now socially housed and provided with greater opportunities for social learning. This is one of the most significant welfare changes, potentially improving the quality of life for the increasing number of males born in breeding facilities.

6.2 Welfare indicators showing little or no substantial change

A. The space available has increased overall (and slightly per elephant), but this increase is on the order of a few hundreds of square metres. The space available remains too small and too unvaried for elephants to exhibit a full range of natural movements (over uneven substrates, up and down slopes, through diverse vegetation) or behaviours. Being able to engage in a wider range of physical activities over a 24-hr period would also assist with weight management and improve muscle tone.

B. Despite some improvements in Body Condition Scores, BCS still does not take muscle tone into account, and these measures need further refinement and monitoring. Additionally, while some problems with locomotion are captured in the gait assessment, better evaluation of the capacity to move freely, to physically lie down and get up, to swim, and so on, requires further monitoring using tools such as the EBWAT.

C. The longevity of the captive born individuals remains too short as a result of premature death in comparison to non-captive populations. Improved disease management and greater maternal experience is required in order to reduce early deaths.

6.3 For the future, the Elephant Welfare Group and its BIAZA hosts need to consider:

If elephants continue to be kept in UK zoos, the work of the EWG has highlighted a number of issues which need further, ongoing investigation:

- The EWG's tools, developed in collaboration with many stakeholders including zoos, now provide a basis for gathering detailed evidence on the quality of life for captive elephants. We have not in this report focused on quality of life, and this will need future analysis using the EBWAT (and other tools focused particularly on this aspect of welfare).
- Consideration needs to be given to how to sustain continued data collection, analysis and reporting of tools to monitor the welfare of elephants in UK zoos.
- Future monitoring needs to be designed to detect the changes experienced by individual elephants in their welfare, as a function of demographic changes, management regimes, and facility structures.
- Gathering further evidence on whether and how changes to health, husbandry and management impact on welfare and wellbeing is needed – a challenge of evidence.
- Greater detailed understanding of elephants as individuals, including their history of captivity, how they experience their environment, and how their past and current social experiences affect their welfare is required.
- A move to a management regime based on elephant (rather than keeper or facility design) choice for movement, social contact and location needs development, which can be part of the mandated move to protected contact (PC) throughout all facilities.
- Training for PC could also be recognised as both an "interesting" way of passing time and source of some cognitive stimulation, while recognising that it may serve as a trigger for anticipatory behaviour and potentially for future development of stereotypies.
- Space requirements to support and encourage the expression of natural behaviours, to allow for fission-fusion (avoidance as well as affiliation), and to enable elephants to experience positive welfare remain unknown, and there is an urgent need further study.

- A recommendation for future-proofing space in relation to herd size increases should be a requirement for all breeding facilities; this space must be larger than the current mandated requirements.
- Welfare impacts, and the importance of different types, of enrichment are poorly understood and need further study.
- More evidence is needed on how to evaluate social bonds/relationships between elephants, and their impact on welfare.
- Critically, we need to determine if elephants can be provided with a 'good life', taking full consideration of their psychological welfare and a holistic look at their life-time experience, building on tools such as the EBWAT.

6.4 Future planning for elephants in zoos

If it is decided that there will be further breeding of UK zoo elephants, there are a number of issues that require further consideration:

- It is recognised that elephants must be kept in multi-generational groups. Breeding can provide important social and behavioural opportunities, benefits herd stability and encourages affiliative behaviours, which are all important for the welfare of the herd that calves are born into. Breeding also avoids or reduces some female reproductive pathologies.
- With treatment for EEHV and with greater maternal competence, resulting in greater numbers of calves surviving, reproductive rates could become very high, posing potential survival risks to elder siblings deprived of milk too early and to mothers who may lose condition after too many birth events.
- There needs to be considerable planning associated with reproduction and reproductive rates. A recommendation for a 4 to 5-year interbirth interval, similar to natural populations, should be made. Furthermore, breeding facilities should aim for as much space as possible (rather than just meeting minimum requirements), to enable dynamic social group structures over time and to allow for adult male housing which provides options for the male(s) to move away from the herd if he/they desire to do so.
- For facilities which aim to continue breeding, housing must be managed to provide choice for elephants, grazing/browsing opportunities and be large enough to hold herds and their offspring, including bulls, and to facilitate fission-fusion behaviours. This will require a substantial commitment by zoos, of their finances, resources and space.
- Since the UK captive 'population' is managed as part of a European 'population', breeding, social group sizes, and the numbers and ages of males all need to be considered within a broader context, ensuring that (a) transfers between facilities minimise stress and consequent mortality, (b) facilities across the population offer comparable excellent welfare, and (c) future planning is integrated.

APPENDICES

Appendix 3.1: Priorities and recommendations of the Zoos Forum (2010)

6.1 Remit and composition of the Elephant Advisory Group

Indicative issues identified by the Zoos Forum for the Elephant Advisory Group to consider and ensure are addressed:

- development of scientifically based nutritional guidelines
- development of a body mass index chart that takes into consideration species, age and sex
- to facilitate the maintenance of healthy weight to height ratios
- establishment of guidance on exercise requirements
- development of a health programme including screening and preventative measures, clinical
- and pathological investigations
- drafting of standards on elephant keeping for the Secretary of State's consideration for inclusion in the SSSMZP
- a review of causes of lameness to inform best practice on preventative measures
- development of a protocol for welfare assessment and monitoring
- development and promotion of knowledge and expertise in lameness detection and
- locomotion analysis through workshop meetings between elephant keepers, veterinarians and scientists
- development of a strategy for bull management (in liaison with the European Endangered Species Breeding Programme)
- ongoing review of demographics (to monitor progress with breeding and reduction in mortality)
- ongoing review of elephant health and welfare (to monitor progress with improvements)
- ongoing review of relevant scientific developments
- identify research needs and ways to address these
- development of criteria for assessment of progress at the five and ten year reviews
- movement of animals

6.2 Monitoring and review of progress

We recommend that there should be an independent comprehensive review of progress in ten years time (to compare, among other things, indices of health and welfare, survivability and reproduction, with those published by Harris et al (2008) and the other researchers referred to in this Report), with an interim review in five years time. In recommending a review in ten years, we are aware that some effects of improvements in housing and husbandry on health and reproductive performance may not be manifested until the next generation (i.e. over a period that is longer than ten years) and, obviously, the history of individual animals will need to be taken into account in any review.

Such a review will need to be able to make comparisons with the Harris et al (2008) study, whose data should be kept safe and made available to the individual zoos. However, it seems very reasonable to expect evidence of improvements within this time scale and of improvements in concerted cooperation between zoos on these important issues.

6.3 Recommendations for zoos

As noted above, we envisage it to be the role of the Elephant Advisory Group to develop and set out the matters that individual zoos should address. We do not wish to pre-judge this but strongly recommend that the list should cover the following topics:

- zoos must participate constructively with the Elephant Advisory Group either individually or through BIAZA (e.g. infectious disease screening programmes, workshops on locomotion scoring);
- zoos must positively address the means to enable elephants to maximise outdoor access and put measures in place to enrich indoor and outdoor environments (day and night);
- elephants should be weighed regularly (at least quarterly, but the appropriate frequency to be established in the light of individual health needs);
- the body mass index chart (see above) should be applied to facilitate the maintenance of healthy weight to height ratio;
- opportunities to exercise must be ensured in line with Elephant Advisory Group recommendations;
- browse (twigs and branches) must be provided every day;
- forage should be analysed by appropriate laboratories on a regular basis to ensure diets keep within the nutritional guidelines;

- monitoring and recording should be undertaken of health, welfare and other parameters as specified by the Elephant Advisory Group in its efforts to monitor progress in the national herd and to identify best practice; and
- zoos must ensure adequate training for all staff. There is a need for systematic elephant keeper training and sharing of good evidence-based practice across the UK, and this should take advantage of links across the rest of Europe and more globally.

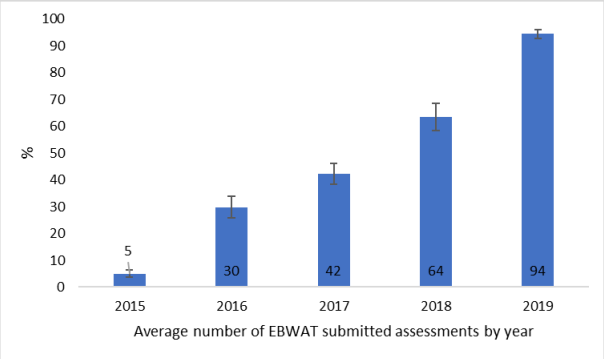
6.4 Recommendations concerning the Secretary of State's Standards of Modern Zoo Practice

The Secretary of State's Standards of Modern Zoo Practice (SSSMZP) set out general standards regarding the husbandry of zoo animals. More specific information is provided for some taxa (e.g. birds of prey, waterfowl) in Appendix 8 of the SSSMZP. Zoo Inspectors are required to take account of these standards in undertaking zoo inspections and making their recommendations to local authorities as to whether to grant a licence under the Zoo Licensing Act 1981 (as amended 2002) or not. At present, no specific standards are included in the SSSMZP regarding elephants. We recommend that a section be included in Appendix 8 with specific standards for elephants. We suggest that the Elephant Advisory Group should draft these for consideration by Defra. Here again, we would not wish to prejudge the content but suggest that points to be covered might include the following:

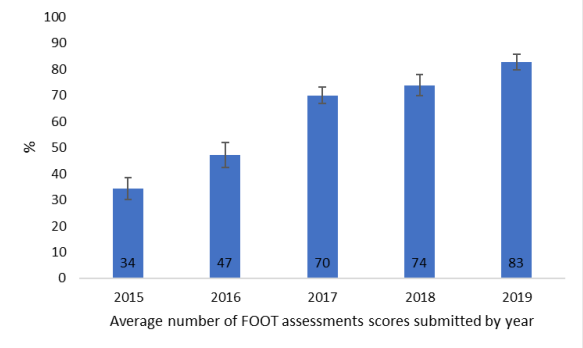
- elephants should be weighed regularly (at least quarterly, but the appropriate frequency to be established in the light of individual health needs);
- elephants must have the opportunity, and steps should be taken to strongly encourage elephants to engage in suitable levels of daily exercise, and records kept regarding this;
- browse must be provided every day;
- forage should be analysed by appropriate laboratories on a regular basis to keep diets within the nutritional guidelines;
- elephant keeping zoos must engage constructively with the Elephant Advisory Group, including monitoring and recording of health, welfare and other parameters as specified by the Elephant Advisory Group in its efforts to monitor progress in the national herd and to identify best practice; and
- elephant keepers should be involved in continuing professional development regarding elephant husbandry.

Appendix 4.1 Engagement with EWG tools over time

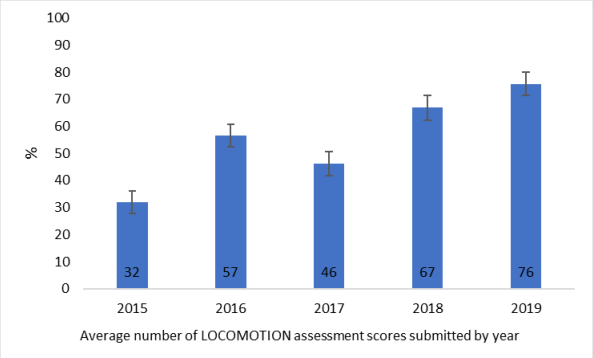
Appendix Figure 4.1. Submission of the four longitudinal welfare assessments increased with time, relative to expected submissions (a) EBWAT (Elephant behaviour and Welfare Assessment Tool), (b) foot health, (c) locomotion scores and (d) BCS (body condition score).



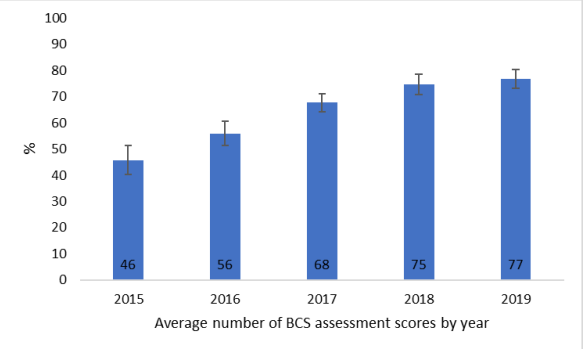
a)



b)



c)

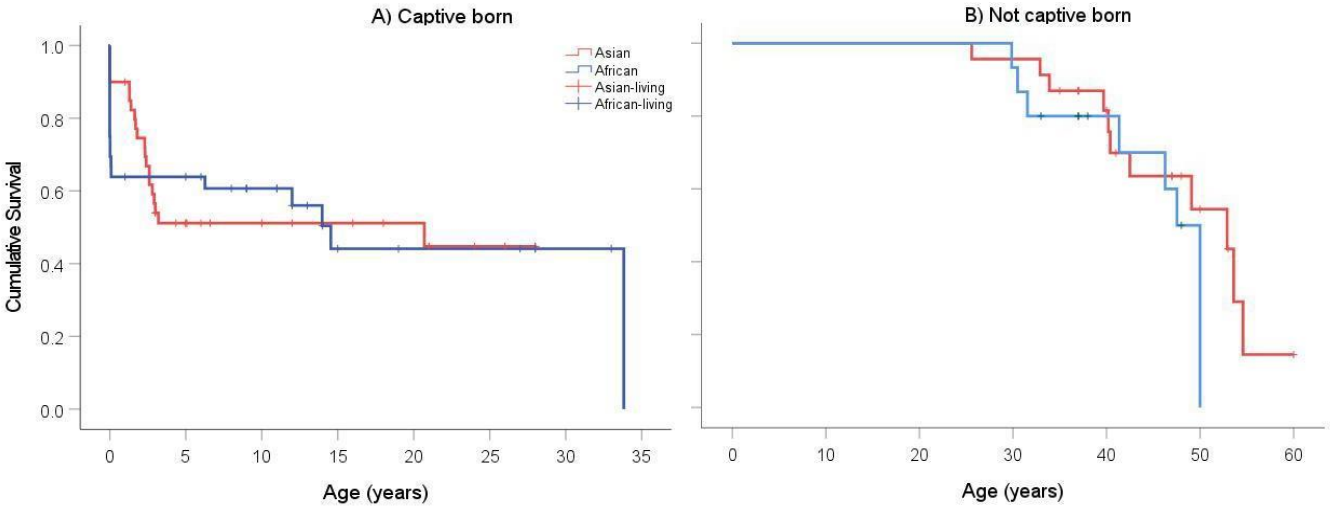


d)

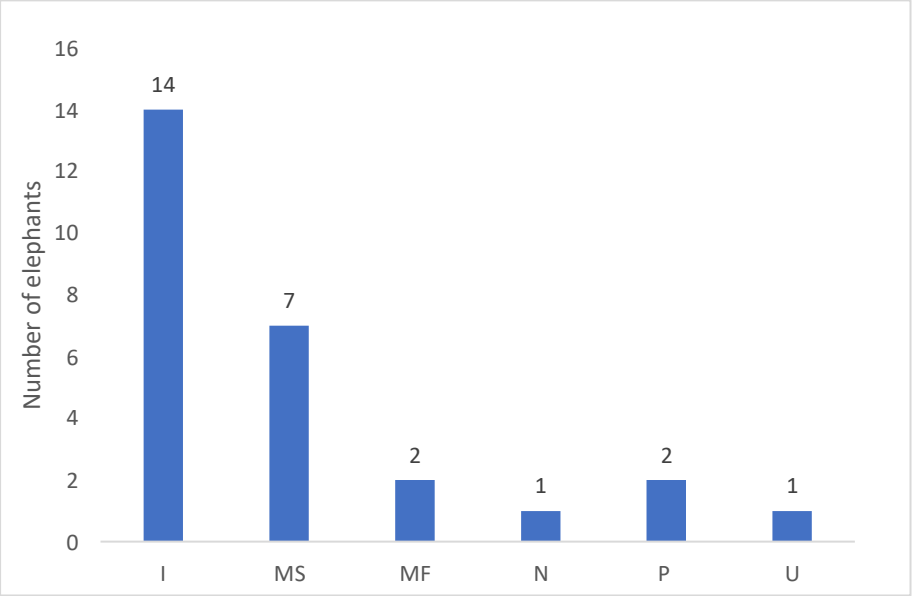
Appendix 5.3A. Survival and data on causes of mortality

Appendix Table 5.3A.1: Average survival times (mean and median with Standard Error and 95% Confidence Intervals) of Asian and African elephants in UK zoos, comparing between those born in captivity in the UK and those born in the wild / of unknown origins (Not captive born). L = lower, U = upper range.

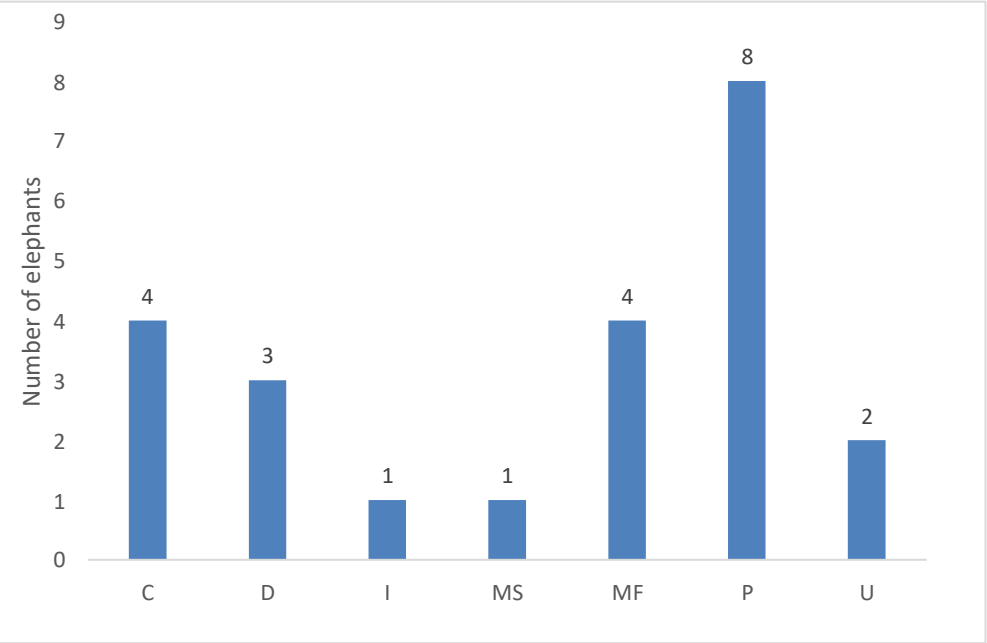
Genus	Origin	N eles (N deaths)	Mean (±SE)	95% Confidence Interval		Median (±SE)	95% Confidence Interval	
				L	U		L	U
Asian	Not captive born	23 (11)	48.2 (± 2.2)	43.9	52.5	52.9 (± 7.4)	38.5	67.3
	Captive born	40 (20)	14.7 (± 2.1)	10.6	18.8	20.7 (±13.9)	0	47.9
	Overall	*63 (31)*	*33.5 (± 3.1*	*27.4*	*39.5*	*40.4 (± 1.9)*	*36.7*	*44.1*
African	Not captive born	15 (10)	44.6 (± 2.1)	40.5	48.7	47.5 (± 0.9)	45.7	49.4
	Captive born	36 (18)	17.4 (± 2.9)	11.7	23.1	14.5 (± 2.2)	10.3	18.8
	Overall	*51 (28)*	*29.5 (± 3.2)*	*23.2*	*35.8*	*33.8 (± 6.7)*	*20.7*	*46.9*
Overall		**114 (59)**	**31.7 (± 2.2)**	**27.3**	**36.0**	**40.2 (±3.9)**	**32.4**	**48.0**



Appendix Figure 5.3A.1: Survival probability by age for (A) UK captive born African (N =36) and Asian (N = 40) elephants from 1987 onwards. (B)Survival probability by age for adult elephants already in the UK zoo population from 2006 onwards (N = 23 Asian, 15 African elephants).



Appendix Figure 5.3A.2: Cause of death of 27 Asian elephants in the UK between 2006 and 2019 (I Infectious, MS Musculoskeletal, MF Multifactorial, N Neoplasia, P Perinatal, U Unknown).

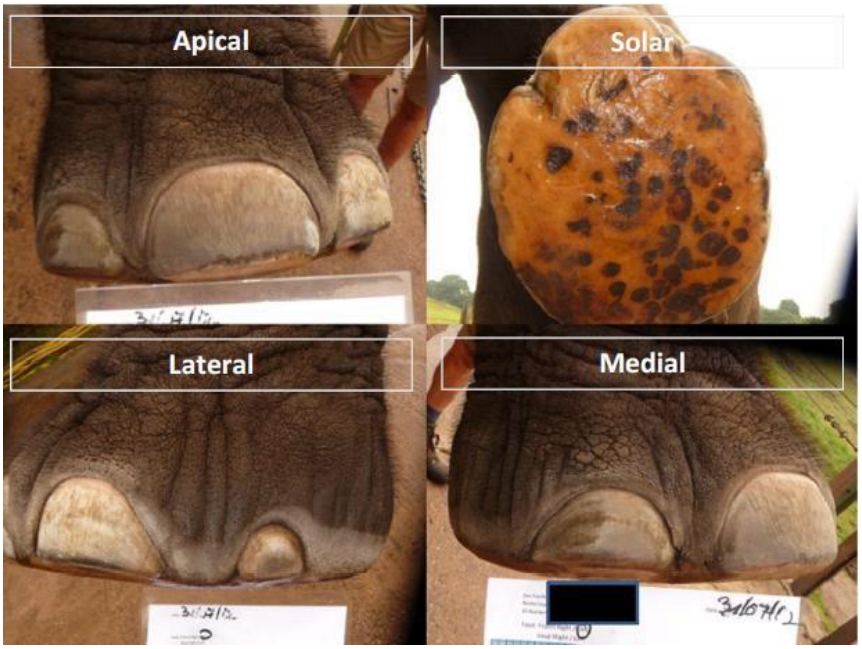


Appendix Figure 5.3A.3: Cause of death of 23 African elephants in the UK between 2006 and 2019 (C circulatory, D Digestive, I Infectious, MS Musculoskeletal, MF Multifactorial, N Neoplasia, P Perinatal, U Unknown

Appendix 5.3B Foot Health and Locomotion

The EWG tools for assessing foot health and locomotion can be found at:

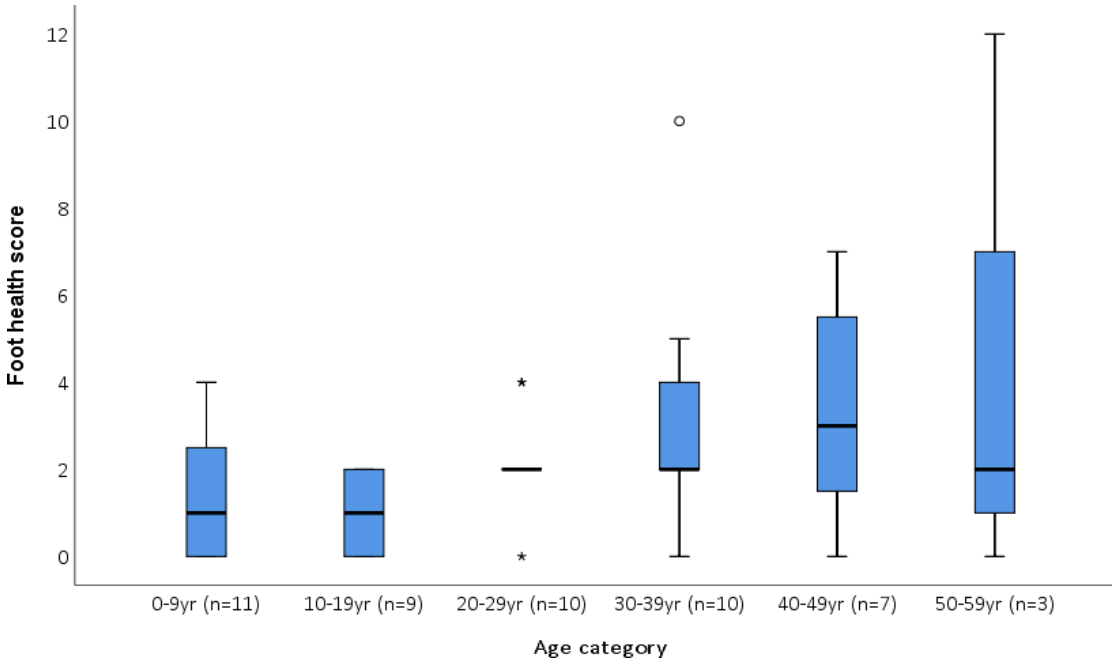
https://biaza.org.uk/elephant-care-management



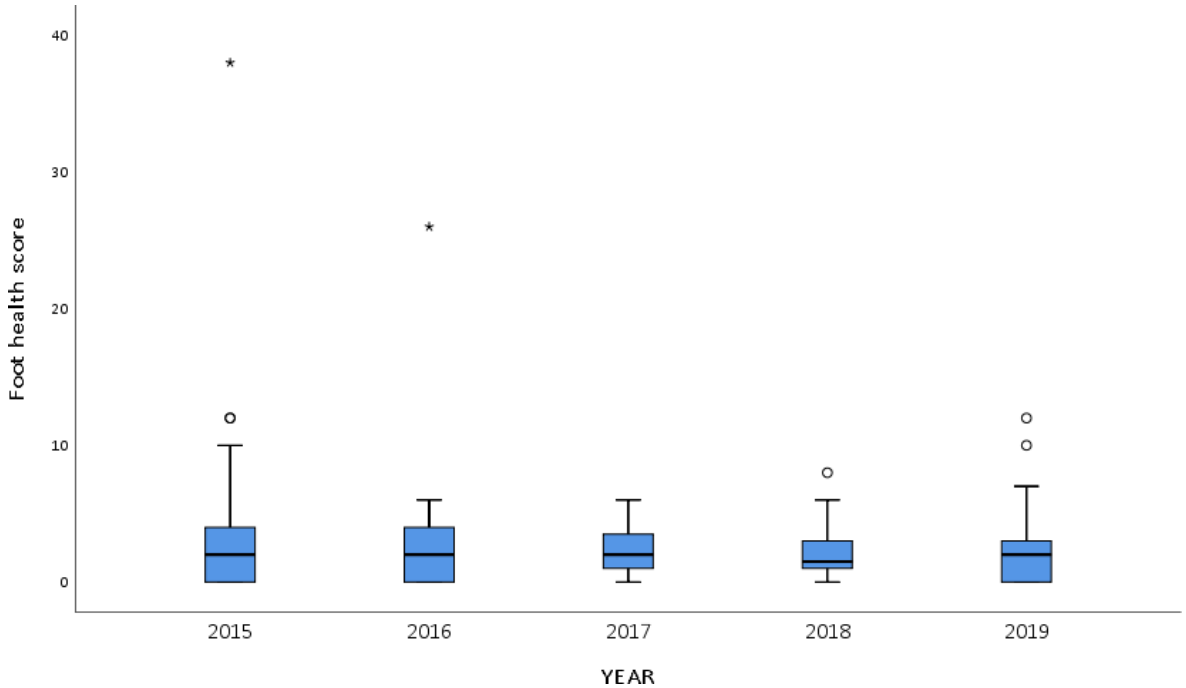
Appendix Figure 5.3B.1: Photographs of each foot were taken from four angles and the photographs were used to generate foot health scores.

Appendix Table 5.3B.1 Demographic details of the elephants represented in the EWG Foot health scoring data. For each year, the total sample size is presented along with the number of male (M) and female (F) for each genus.

	2015 (29)				2016 (30)				2017 (47)				2018 (42)				2019 (50)			
Genus	Asian		African		Asian		African		Asian		African		Asian		African		Asian		African	
Sex	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
N	2	14	2	11	1	14	4	11	2	17	7	21	3	16	7	16	4	21	9	16



Appendix Figure 5.3.2: Elephant foot health scores in 2019 within each age category.



Appendix Figure 5.3B.3: Elephant foot health scores measured by the EWG foot health tool (2015 n= 29, 2016 n= 30, 2017 n= 47, 2018 n= 42, 2019 n= 50).

Appendix 5.3B: description of locomotion / gait scoring procedures

Procedures for scoring gait can be found at:

https://biaza.org.uk/elephant-care-management

Appendix Table 5.3B.2 Demographic details of the elephants represented in the EWG locomotion scoring data. M = Male, F = Female

	2015 (32)				2016 (39)				2017 (31)				2018 (38)				2019 (38)			
Genus	Asian		African		Asian		African		Asian		African		Asian		African		Asian		African	
Sex	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
N	2	18	2	10	3	20	4	12	3	19	4	5	4	22	5	7	4	22	5	7

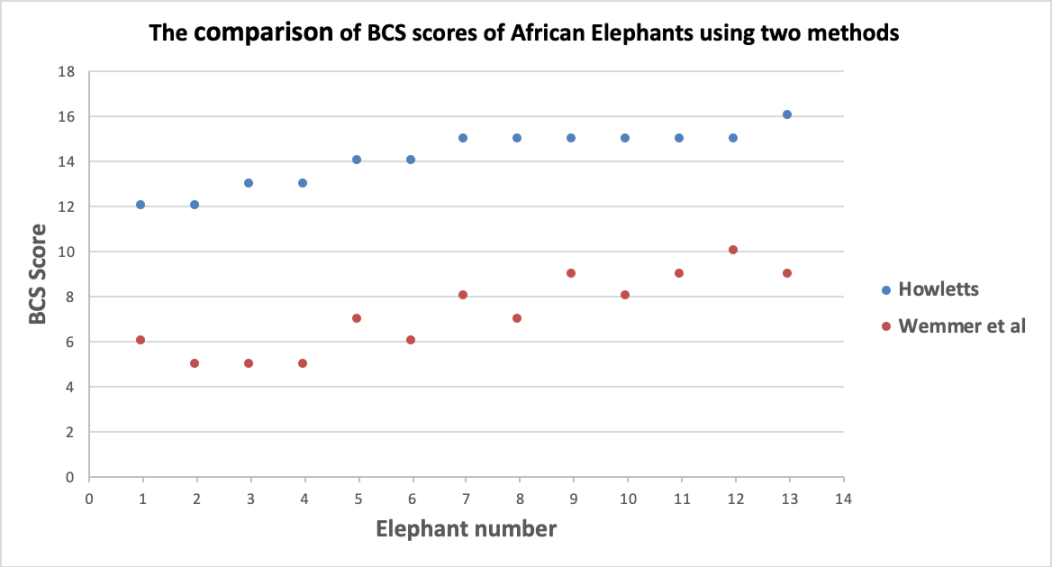
Appendix Table 5.3b.3 Locomotion scores reported to the EWG, indicating the number and percent of elephants that scored zero (no abnormality) or greater than 24 (reluctant to bear weight on at least one leg) in each year.

Year	Total N	Number of elephants with a score = zero	% of elephants with score = zero	Number of elephants with scores > 24 (at least one leg 'reluctant to bear weight')	% of elephants with scores > 24 (at least one leg 'reluctant to bear weight')
2006 (Harris *et al*. 2008)	69	12	17.4	Unavailable	Unavailable
2015	32	20	62.5	2	6.3
2016	39	22	56.4	3	7.7
2017	31	19	61.3	2	6.5
2018	38	26	68.4	1	2.6
2019	38	28	73.7	1	2.6

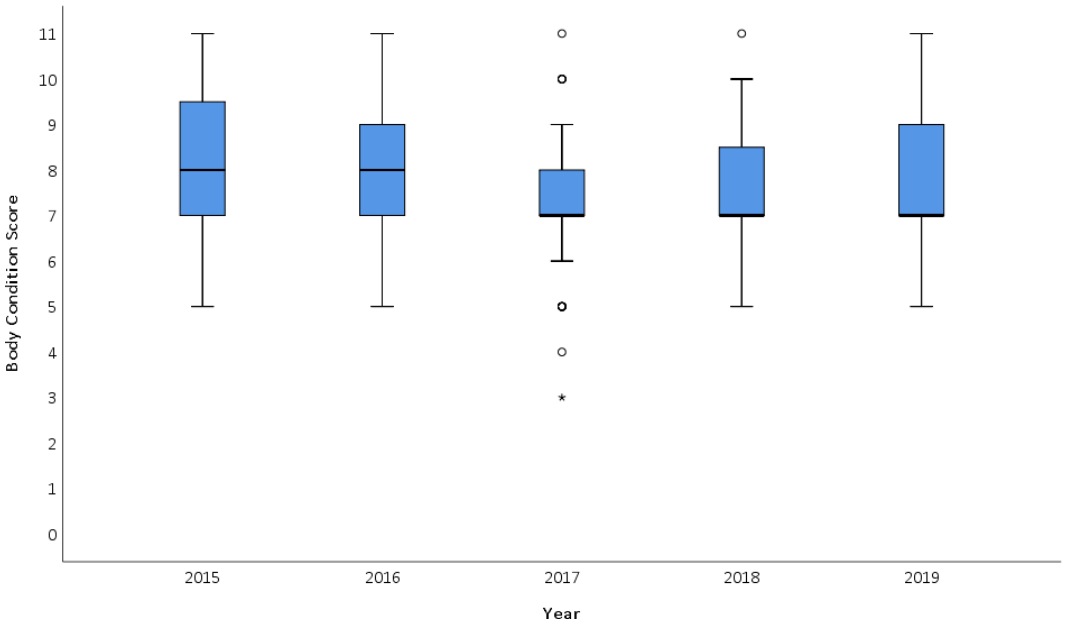
Appendix 5.4: Body condition scoring and nutritional information

Appendix 5.4: Body condition scoring procedures (instructions to keepers) can be found at

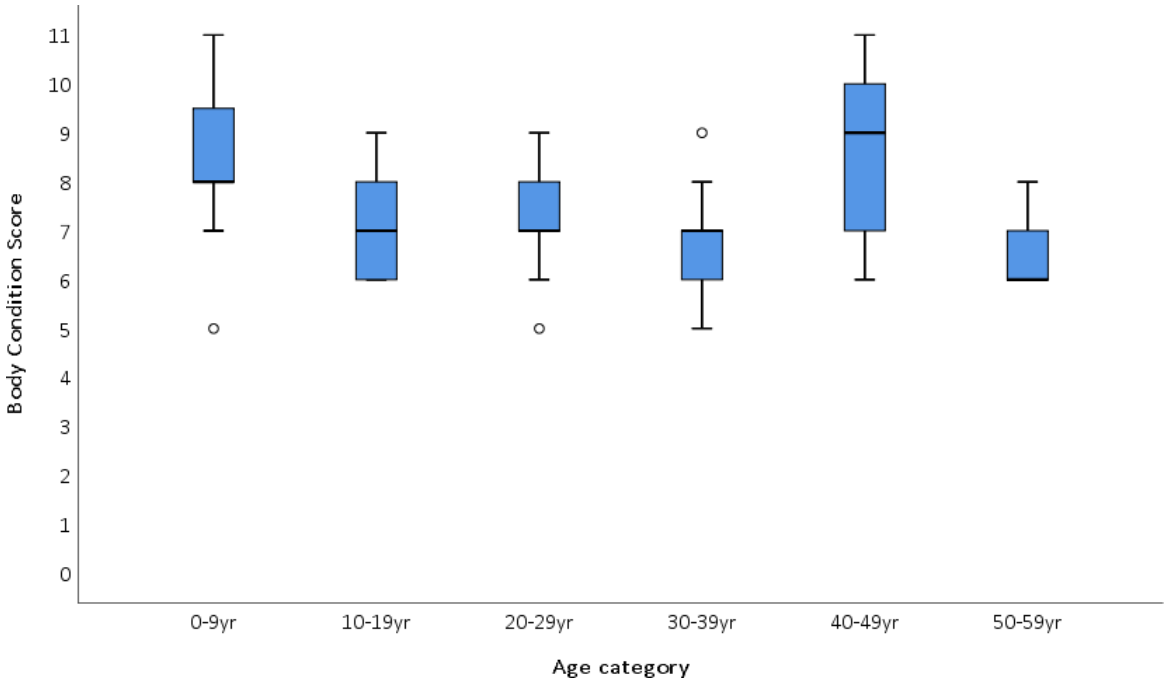
https://biaza.org.uk/elephant-care-management



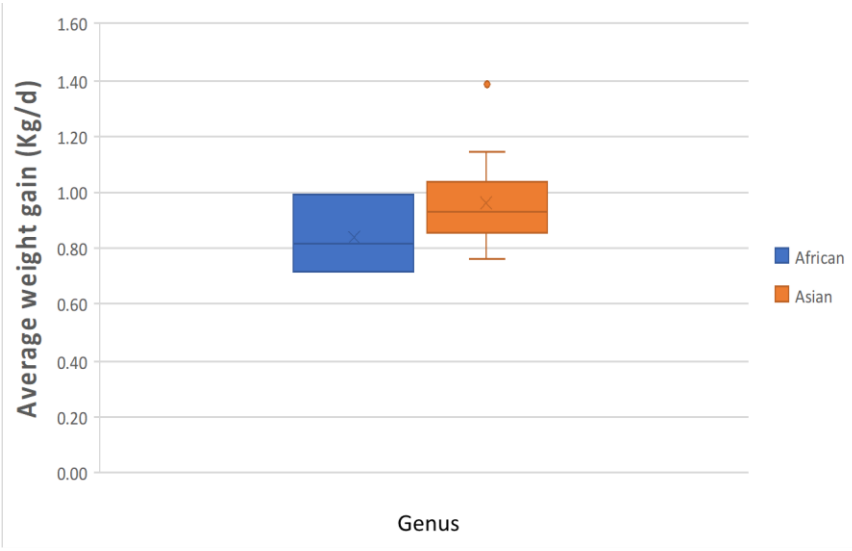
Appendix Figure 5.4.1: Comparison of body condition scores for 13 African elephants using the EWG BCS tool and Howletts tool designed specifically for African elephants.



Appendix Figure 5.4.2: Body condition scores measured with the EWG BCS tool (2015 *n*=36, 2016 *n*=42, 2017 *n*=53, 2018 *n*=51, 2019 *n*=50)



Appendix Figure 5.4.3: Body condition scores across age groups in 2019 (n= 50).



Appendix Figure 5.4.4: Comparison of African (n=3) and Asian (n=17) calf growth rates (kg/d) from birth to 3 years.

Appendix Table 5.4.1: Demographic details of the elephants represented in the EWG body condition scoring data (M = male, F = female).

Year (Total N)	2015 (36)				16 (42)				2017 (53)				2018 (51)				2019 (50)			
Genus	Asian		African		Asian		African		Asian		African		Asian		African		Asian		African	
Sex	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M
N sampled	19	5	9	3	21	5	12	4	21	4	21	7	21	4	17	9	21	4	16	9

Appendix 5.4.2: Details of estimated daily dietary components per Asian or African elephant at nine zoos in the UK.

	Zoo 1	Zoo 2	Zoo 3	Zoo 4	Zoo 6	Zoo 7	Zoo 8	Zoo 9
Elephant cubes (Dodson & Horrell)	2-4 kg	4kg soaked pellets + 100ml linseed oil			2 Kg	3 Kg		
High fibre nuts (HJ Lea Oakes)	1.5 kg	4kg					3.5 Kg	
Low- Pro Elephant Rolls (HJ Lea Oakes)	2 kg	1 Kg	5.4 Kg					
Horse and Pony nuts								2 scoops
Linseed pellets				1 Kg				
Bran + Linseed + vitamin mix							2 Kg	
16 + pellet						1 Kg		
Vitality elephant rolls						5.5 Kg		

Dog biscuit (Pointer)	1.5 - 3 kg (used for training)							
Bran + Linseed oil (+ prebiotics and Biotin)			0.8 Kg + 100 ml					
Grass hay	~1.5 bale (estimate/ elephant) total about 45 Kg	~50 kg hay (estimated)	ad-lib	40 Kg	ad-lib	60 Kg	ad-lib	ad-lib
Straw	4 kg – estimate/elephant							
Grass	0	0	ad-lib	1 Kg				
Browse	35 kg (group feeding – estimate/elephant)	Browse (tree branches) ad lib	ad-lib	ad-lib	Few pieces of browse/ sticks	ad-lib	'half a landy's worth' + Giraffe sticks	ad-lib
Carrots	4 kg	90kg chopped mixed veg/ 12 elephants	13.3 kg à (Cut up for training + enrichment)	10.5 Kg	Selection of fruit and vegetables (apples, carrots, bananas, cabbages, or oranges)		5 Kg	
Apple + banana	4 kg in total					as training rewards	as training rewards	2 buckets of mix fruit/veg
Sweet Potato			2 kg - demonstration, training					
Sugar Beet					2 Kg			

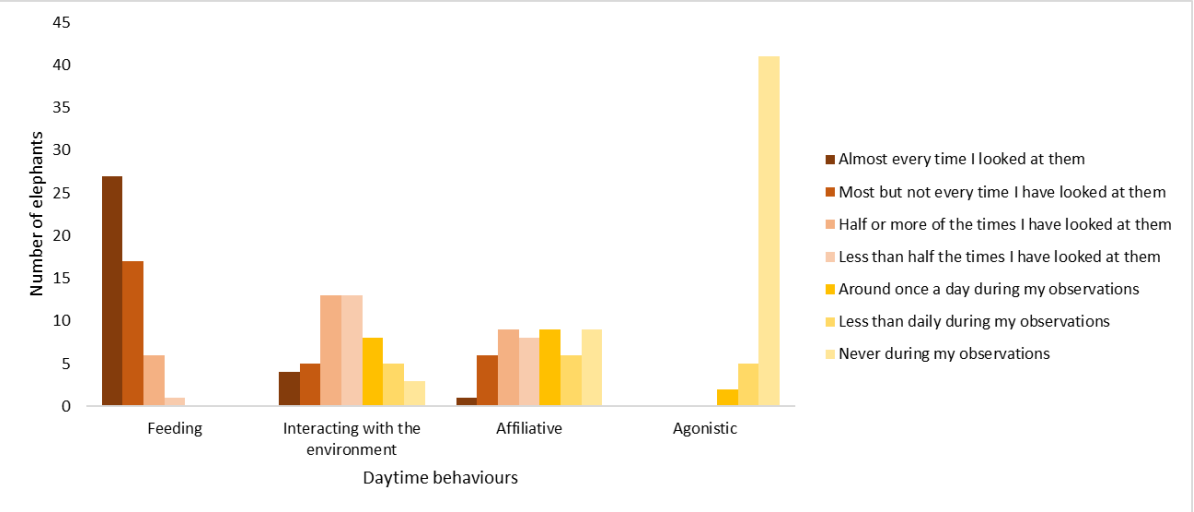
Appendix Table 5.4.3: The major nutrient composition of some non-forage pellets, nuts and rolls fed to elephants in UK zoos.

	Crude Protein (%)	Crude Fibre (%)	Crude oils/fats (%)	Digestible Energy
Elephant cubes (Dodson & Horrell)	11	10	4	
Vitality elephant Rolls	11	13.5	3.25	
16 + pellets	17	17		
High fibre nuts (HJ Lea Oakes)	7.5	21		8.5 MJ/Kg
Low- Pro Elephant Rolls (HJ Lea Oakes)	No Details	No Details	No Details	No Details
Horse and Pony nuts	11	19		
Linseed pellets	20	30	40	36 MJ/Kg
bran + Linseed + vitamin mix	No Details	No Details	No Details	No Details

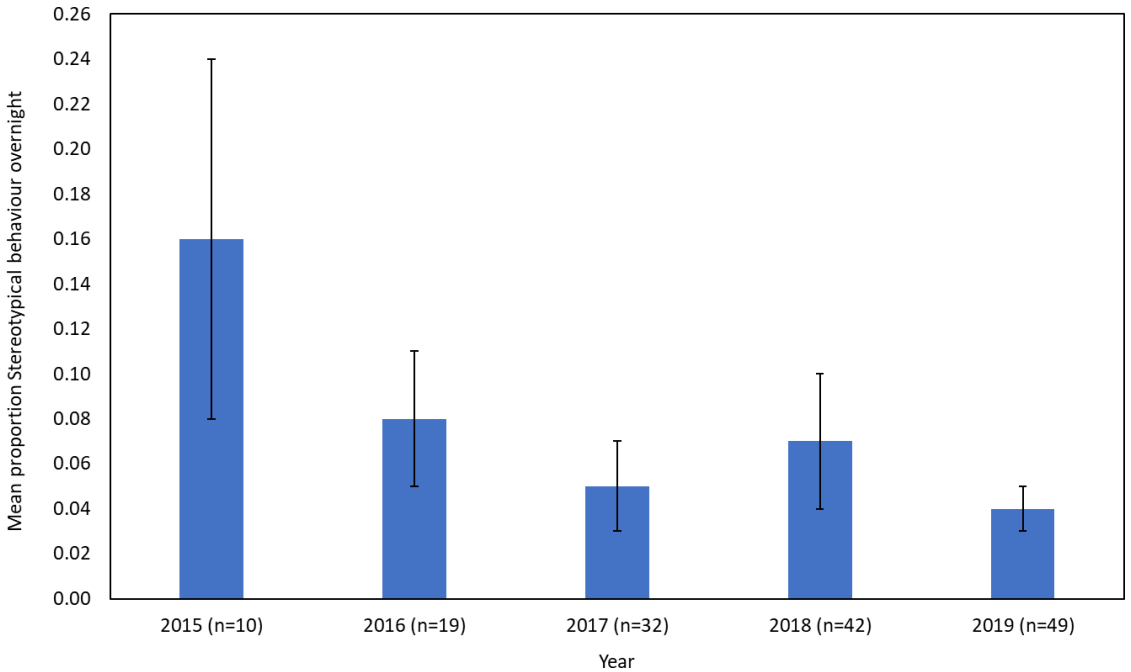
Appendix 5.5 Behaviour and Abnormal Behaviour

5.5.1: EBWAT Scoring sheet: guidance for keepers and others can be found at:

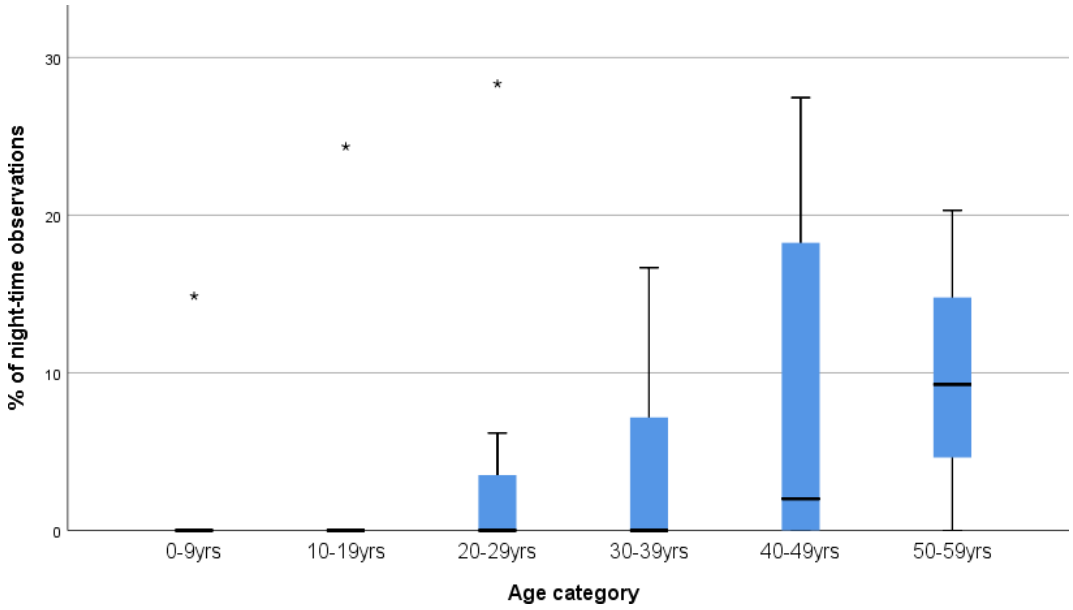
https://biaza.org.uk/elephant-care-management



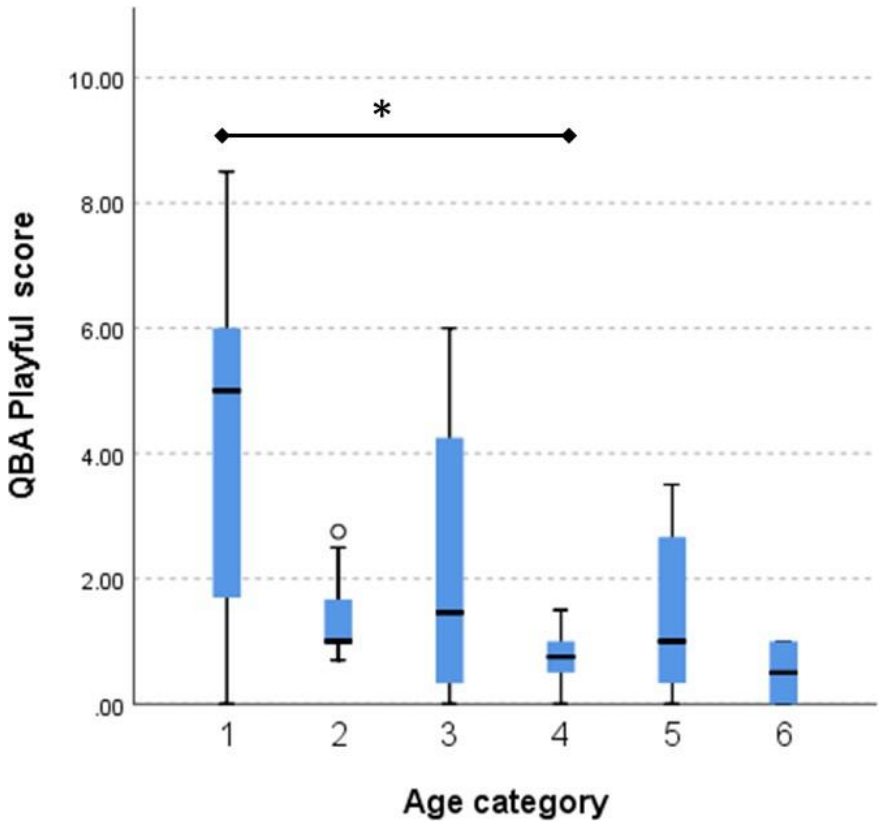
Appendix Figure 5.5.1: Time engaged in various behaviours during the day based on keeper observations of 51 elephants in 2019 (affiliative and agonistic behaviours *n*= 48 as they were not recorded in three lone elephants



Appendix Figure 5.5.2: Mean proportion (±SE) of stereotypical behaviour (vs. other overnight behaviours) from 2015 to 2019.



Appendix Figure 5.5.3: Proportion of time engaged in stereotypical behaviour at night and age categories. (sample size: 0-9 = 14, 10-19 = 8, 20-29=9, 30-39=8, 40-49=7,50-59=3)



Appendix Figure 5.5.4: QBA playful component average scores in 2019, by age category. Age 1 = 0-9yrs, n =14; 2 = 10-19yrs, n =9; 3 = 20-29yrs, n = 10; 4 = 30-39yrs, n = 9; 5 = 40-49yrs, n = 7; 6 = 50-59yrs, n=2.

Appendix 5.5.2: Demographic details of the elephants represented in the EWG daytime behaviour observations data. F = Female, M = Male.

Year (total N)	2015 (11)				2016 (32)				2017 (47)				2018 (46)				2019 (51)			
Genus	Asian		African		Asian		African		Asian		African		Asian		African		Asian		African	
Sex	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M
N	8	1	2	0	19	5	5	3	24	4	15	4	24	6	11	5	21	5	16	9

Appendix 5.5.3: Demographic details of the elephants represented in the EWG night-time behaviour observations data. F = Female, M = Male.

Year (total N)	2015 (10)				2016 (19)				2017 (32)				2018 (42)				2019 (49)			
Genus	Asian		African		Asian		African		Asian		African		Asian		African		Asian		African	
Sex	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M
N	8	1	1	0	13	1	3	1	13	2	14	3	24	5	9	4	23	4	15	7

Appendix 5.6.1: Correlations between the behaviour and health tool overall scores. Significant correlations are in bold. [Note that all p values have been corrected for multiple comparisons using Bonferroni correction. * <0.05, ** <0.01, ***p<0.001]

Welfare measures	Statistic	QBA Wary	QBA Playful	Day Low stereo typy	Day Low agonistic behaviour	Day Approach others	Day Low dependence on routine	Day Engage +ve with the environment	Will lie with others at night	Low stereo typy at night	Foot health	Locomotion score	Body Condition Score
QBA At ease in the environment[1]	*Rho*	**0.540****	-0.106	0.236	0.188	**0.420***	0.371	0.315	**0.480***	0.222	-0.272	-0.156	-0.169
	p	**0.001**				**0.038**			**0.015**				
	n	**51**	51	51	49	**48**	51	50	**43**	49	48	37	48
	L 95% CI	**0.292**	-0.401	-0.014	-0.022	**0.119**	0.082	0.019	**0.226**	-0.018	-0.497	-0.449	-0.434
	U95% CI	**0.719**	0.162	0.439	0.378	**0.668**	0.616	0.574	**0.694**	0.451	0.009	0.148	0.135
QBA Wary	*Rho*		-0.304	-0.202	0.258	0.183	0.064	0.080	0.146	-0.143	0.005	-0.103	-0.112
	p												
	n		51	51	49	48	51	50	43	49	48	37	48
	L 95% CI		-0.541	-0.415	-0.026	-0.124	-0.234	-0.207	-0.213	-0.369	-0.250	-0.353	-0.394
	U95% CI		-0.024	0.042	0.497	0.450	0.327	0.355	0.441	0.074	0.248	0.161	0.160
QBA Playful	*Rho*			0.197	0.017	**0.428***	0.304	**0.464****	0.112	0.161	-0.104	0.057	0.198
	p					**0.031**		**0.009**					
	n			51	49	**48**	51	**50**	43	49	48	37	48
	L 95% CI			-0.063	-0.280	**0.161**	0.036	**0.228**	-0.219	-0.089	-0.336	-0.230	-0.119
	U95% CI			0.449	0.284	**0.647**	0.556	**0.648**	0.388	0.423	0.159	0.315	0.463
DAY Low stereo typy	*Rho*				-0.033	0.274	0.336	0.225	0.254	**0.796*****	-0.340	-0.175	-0.112
	p									**<0.001**			
	n				49	48	51	50	43	**49**	48	37	48
	L 95% CI				-0.212	0.057	0.103	0.000	-0.052	**0.533**	-0.592	-0.556	-0.406
	U95% CI				0.270	0.485	0.535	0.417	0.494	**0.950**	-0.040	0.221	0.160
DAY Low agonistic behaviour	*Rho*					0.163	0.036	0.024	0.361	0.241	-0.076	0.076	-0.317
	p												
	n					48	49	48	43	47	46	35	46
	L 95% CI					-0.079	-0.224	-0.288	0.154	-0.116	-0.346	-0.271	-0.548
	U95% CI					0.394	0.288	0.306	0.570	0.608	0.216	0.289	-0.037
	Rho						**0.694*****	**0.720*****	**0.577****	0.340	-0.174	-0.239	0.173
	p						**<0.001**	**<0.001**	**0.001**				

DAY Approach others	*n*			**48**	**47**	**43**	47	45	35	45
	L 95% CI			**0.521**	**0.555**	**0.327**	0.118	-0.488	-0.520	-0.126
	U95% CI			**0.814**	**0.825**	**0.797**	0.541	0.168	0.086	0.455
DAY Low dependence on routine	*Rho*				**0.752*** **	0.299	0.404	-0.167	-0.445	0.109
	p				**<0.001**					
	n				**50**	43	49	48	37	48
	L 95% CI				**0.622**	-0.038	0.191	-0.474	-0.714	-0.174
	U95% CI				**0.849**	0.570	0.598	0.144	-0.064	0.372
DAY Engage positively with the environment	*Rho*					0.353	0.358	-0.218	-0.052	0.047
	p									
	n					42	48	47	36	47
	L 95% CI					0.034	0.158	-0.511	-0.340	-0.229
	U95% CI					0.623	0.536	0.107	0.250	0.365
Will lie with others at night	*Rho*						0.312	-0.271	-0.213	-0.187
	p									
	n						43	40	31	40
	L 95% CI						-0.029	-0.529	-0.470	-0.481
	U95% CI						0.553	0.020	0.112	0.174
Low stereotypy at night	*Rho*							-0.380	-0.273	-0.251
	p									
	n							46	36	46
	L 95% CI							-0.627	-0.616	-0.497
	U95% CI							-0.088	0.103	0.032
Foot health	*Rho*								0.068	0.241
	p									
	n								38	49
	L 95% CI								-0.324	-0.027
	U95% CI								0.434	0.527
Locomotion score	*Rho*									-0.019
	p									
	n									38
	L 95% CI									-0.327
	U95% CI									0.306

Definition: At ease in the environment = Content, relaxed, not uncomfortable, not agitated, not tense, not frustrated

REFERENCES

Abbondanza, F. N., Power, M. L., Dickson, M. A., Brown, J. & Oftedal, O. T. (2013). Variation in the composition of milk of Asian elephants (*Elephas maximus*) throughout lactation. Zoo Biol, 32, 291-298.

Archie, E.A., Moss, C.J. & Alberts, S.C. (2006). The ties that bind: genetic relatedness predicts the fission and fusion of social groups in wild African elephants. Proc. Roy. Soc. B, 273, 513–522.

Asher, L., Williams, E. & Yon, L. (2015) Developing behavioural indicators, as part of a wider set of indicators, to assess the welfare of elephants in UK zoos. Defra Project WC1081: final report. Available at: http://sciencesearch.defra.gov.uk/Document.aspx?Document=12816_ElephantwelfarereportWC1081.pdf.

Atkinson, R. (2009). Zoos Forum review of zoo elephant welfare: statement of Rob Atkinson.

Bacon, M. (2019). *The impact of social relationships on reproductive success in captive Asian elephants (Elephas maximus) in European zoos* (Unpublished Master's thesis). University of Edinburgh.

Bahar, A., Nur, H. A. K. & Kamarul, H. (2018). Home range and movement patterns of Asian elephant (*Elephas maximus*) in Gua Musang, Kelantan, Malaysia. Malayan Nature Journal, 70, 221-232.

Benirschke, K. & Roocroft, A. (1992). Elephant-inflicted injuries, in: Verhandlungsberichte Des 34. Internationalen Symposiums Uber Die Erkrankungen Der.

Brown, J.L., Paris, S., Prado-Oviedo, N.A., Meehan, C.L., Hogan, J.N., Morfeld, K.A. & Carlstead, K. (2016). Reproductive health assessment of female elephants in North American Zoos and association of husbandry practices with reproductive dysfunction in African elephants (*Loxodonta africana*). PLoS One 11, e0145673.

Chadwick, C. L., Williams, E., Asher, L. & Yon, L. (2017). Incorporating stakeholder perspectives into the assessment and provision of captive elephant welfare. Anim Welfare, 26, 461-472.

CITES (2019). Working documents on live trade: https://cites.org/sites/default/files/eng/cop/18/doc/E-CoP18-044-02c.pdf and https://cites.org/sites/default/files/eng/com/sc/69/inf/E-SC69-Inf-36.pdf

Clubb, R. & Mason, G. (2002). *A review of the welfare of zoo elephants in Europe* (p. 303). West Sussex, UK: RSPCA.

Clubb, R., Rowcliffe, M., Lee, P., Mar, K. U., Moss, C. & Mason, G. J. (2008). Compromised survivorship in zoo elephants. Science, 322, 1649-1649.

Clubb, R., Rowcliffe, M., Lee, P., Mar, K.U., Moss, C. & Mason, G. (2009). Fecundity and population viability in female zoo elephants: problems and possible solutions. Anim Welfare, 18, 237-247.

de Regt, A.C., Nijboer, J., Bleijenberg, M.C.K., n.d. Diet inventory European Asian elephant (*Elephas maximus*).

de Silva, S., Webber, C. E., Weerathunga, U. S., Pushpakumara, T. V., Weerakoon, D. K., & Wittemyer, G. (2013). Demographic variables for wild Asian elephants using longitudinal observations. PloS One, 8, e82788.

de Silva, S. & Wittemyer, G. (2012). A comparison of social organization in Asian elephants and African savannah elephants. Int J Primatol, 33, 1125–1141.

Dimeo-Ediger, N. (2001). Results of a survey of elephant foot condition and care in North America. In: Csuti, B., Sargent, E.L. & Bechert, U.S. (Eds.) *The elephant's foot: Prevention and care of foot conditions in captive Asian and African elephants*. Iowa: Iowa State University Press.

FAWC (2009). *Farm animal welfare in Great Britain: Past, present and future*. Farm Animal Welfare Council.

Finch, K., Sach, F., Fitzpatrick, M., Masters, N., & Rowden, L. J. (2020). Longitudinal Improvements in Zoo-Housed Elephant Welfare: A Case Study at ZSL Whipsnade Zoo. Animals, 10, 2029.

Fowler, M.E., Csuti, B., Sargent, E.L., Bechert, U.S. (2001). An overview of foot conditions in Asian and African elephants. In: Csuti, B., Sargent, E.L. & Bechert, U.S. (Eds.) *The elephant's foot: Prevention and care of foot conditions in captive Asian and African elephants,* pp 3–7. Iowa: Iowa State University Press.

Fraser, D. (1999). Animal ethics and animal welfare science: bridging the two cultures. App Anim Behav Sci, 65, 171-189.

Gore, M., Hutchins, M. & Ray, J. (2006). A review of injuries caused by elephants in captivity: an examination of predominant factors. Int Zoo Yrbk, 40, 51–62.

Gravett, N., Bhagwandin, A., Sutcliffe, R., Landen, K., Chase, M. J., Lyamin, O. I. *et al*. (2017). Inactivity/sleep in two wild free-roaming African elephant matriarchs–Does large body size make elephants the shortest mammalian sleepers? PLoS One, 12, e0171903.

Greco, B.J., Meehan, C.L., Hogan, J.N., Leighty, K.A., Mellen, J., Mason, G.J. & Mench, J.A. (2016). The days and nights of zoo elephants: using epidemiology to better understand stereotypic behavior of African elephants (*Loxodonta africana*) and Asian elephants (*Elephas maximus*) in North American Zoos. PLoS One 11, e0144276.

Griede, T. (2000). *Results of the 1999 elephant survey*, in: EAZA Conference. EAZA Executive Office, Basel, Amsterdam.

Harris, M., Sherwin, C. & Harris, S. (2008). *The welfare, housing and husbandry of elephants in UK zoos*. *Report to DEFRA*.

Hartley, M. (2016). Assessing risk factors for reproductive failure and associated welfare impacts in elephants in European zoos. J Zoo Aquarium Res, 4, 127-138.

Hartley, M., & Stanley, C. (2016). Survey of reproduction and calf rearing in Asian and African elephants in Europe. J Zoo Aquarium Res, 4, 139-146.

Hartley, M., Wood, A., & Yon, L. (2019). Facilitating the social behaviour of bull elephants in zoos. Int Zoo Yrbk, 53, 62-77.

Harvey, N. D., Daly, C., Clark, N., Ransford, E., Wallace, S. & Yon, L. (2018). Social interactions in two groups of zoo-housed adult female Asian elephants (*Elephas maximus*) that differ in relatedness. Animals, 8, 132.

Hill S.P. & Broom, D.M. (2009). Measuring zoo animal welfare: theory and practice. Zoo Biol, 28, 531-544.

Hosey, G., Melfi, D. & Pankhurst, S. (2009). *Zoo animals: behaviour, management, and welfare*. Oxford University Press, Oxford.

Hutchins, M. & Keele, M. (2006). Elephant importation from range countries: ethical and practical considerations for accredited zoos. Zoo Biol, 25, 219–233.

Keeling, L.J., Rushen, J., Duncan, I.J.H., *et al.* (2011). Understanding animal welfare. In: Appleby, M.C., Mench, J.A., Olsson, I.A.S. & Hughes, B.O. (Eds.), *Animal Welfare*. pp. 13–26. New York: CABI Publishing.

Kurt, F. & Kumarasinghe, J.C. (1998). Remarks on body growth and phenotypes in Asian elephant *Elephas maximus*. Acta Theriologica, Supp 5, 135-153.

Lee, P. C. (1987). Allomothering among African elephants. Anim Behav, 35, 278-291.

Lee, P. C. & Moss, C. J. (1999). The social context for learning and behavioural development among wild African elephants. In: Box, H.O. (ed) *Mammalian social learning*, pp. 102-125. Cambridge: Cambridge University Press.

Lee, P.C. & Moss, C.J. (2009). Welfare and well-being of captive elephants: perspectives from wild elephant life histories. In: Kane, L., Forthman, D., Hancocks, D., Waldau, P. (Eds.), *An Elephant In The Room: The Science and Well-Being of Elephants in Captivity*. pp. 22–38. MA:Tufts University Press,

Lee, P.C. & Moss, C.J. (2014). African elephant play, competence and social complexity. Anim Behav Cogn, 1, 144–156.

Lee, P. C., Fishlock, V., Webber, C. E. & Moss, C. J. (2016). The reproductive advantages of a long life: longevity and senescence in wild female African elephants. Behav Ecol Sociobiol, 70, 337-345.

Lehnhardt, J. (1991). Elephant handling: A problem of risk management and resource allocation. In: AAZPA Regional Conference Proceedings, Wheeling, W. Va., American Association of Zoological Parks and Aquariums.

Lucas, C. & Stanyon, B. (2017). Improving the welfare of African elephants *Loxodonta africana* in zoological institutions through enclosure design and husbandry management: an example from Blair Drummond Safari and Adventure Park. Int Zoo Yrbk, 51, 248-257.

Lyashchenko, K.P., Greenwald, R., Esfandiari, J., Olsen, J.H., Ball, R., Dumonceaux, G., Dunker, F. *et al.* (2006). Tuberculosis in elephants: antibody responses to defined antigens of *Mycobacterium tuberculosis*, potential for early diagnosis, and monitoring of treatment. Clin Vacc Immunol, 13, 722-732.

Mason, G.J. & Latham, N.R. (2004). Can't stop, won't stop: is stereotypy a reliable animal welfare indicator? Anim Welfare, 13, 57-69.
Mason, G.J. & Veasey, J.S. (2009). How should the psychological well-being of zoo elephants be objectively investigated? Zoo Biol, 28, 1–19.
Mason, G.J. & Veasey, J.S. (2010). What do population-level welfare indices suggest about the well-being of zoo elephants? Zoo Biol, 29, 256–273.
McComb, K., Moss, C., Sayialel, S. & Baker, L. (2000). Unusually extensive networks of vocal recognition in African elephants. Anim Behav, 59, 1103–1109.
Mellor, D. (2016). Updating animal welfare thinking: moving beyond the "Five Freedoms" towards "A Life Worth Living." Animals, 6, 21.
Mellor, D.J., Hunt, S., & Gusset, M. (Eds.) (2015). *Caring for Wildlife: The World Zoo and Aquarium Animal Welfare Strategy*. WAZA Executive Office, Gland, Switzerland.
Menargues, A., Urios, V., Limiñana, R. & Mauri, M. (2012). Circadian rhythm of salivary cortisol in Asian elephants (*Elephas maximus*): a factor to consider during welfare assessment. J Appl Anim Welfare Sci, 15, 383-390.
Mikota, S.K., Sargent, E.L. & Ranglack, G.S. (1994). *Medical management of the elephant*. Indira Publishing.
Miller, M.A., Hogan, J.N. & Meehan, C.L. (2016). Housing and demographic risk factors impacting foot and musculoskeletal health in African elephants [*Loxodonta africana*] and Asian elephants [*Elephas maximus*] in North American zoos. PLoS One 11, e0155223.
Moberg, G.P. (2000). Biological response to stress: implications for animal welfare. In: Moberg, G.P. & Mench, J.A. (eds.). *The Biology of Animal Stress*, pp 1-22. New York: CABI Publishing.
Morfeld, K.A., Meehan, C.L., Hogan, J.N. & Brown, J.L. (2016). Assessment of body condition in African (*Loxodonta africana*) and Asian (*Elephas maximus*) elephants in North American zoos and management practices associated with high body condition scores. PLoS One, 11, e0155146.
Moss, C. J. (1983). Oestrous behaviour and female choice in the African elephant. Behav, 86, 167-195.
Moss, C. J., Croze, H. & Lee, P. C. (Eds.) (2011). *The Amboseli elephants: a long-term perspective on a long-lived mammal*. Chicago: University of Chicago Press.
Mumby, H. S., Mar, K. U., Hayward, A. D., Htut, W., Htut-Aung, Y. & Lummaa, V. (2015). Elephants born in the high stress season have faster reproductive ageing. Scientific reports, 5, 1-11.
Murphree, R., Warkentin, J. V., Dunn, J. R., Schaffner, W. & Jones, T. F. (2011). Elephant-to-human transmission of tuberculosis. Emerging infectious diseases, 17, 366.
Nandini, S., Keerthipriya, P. & Vidya, T.N.C. (2018). Group size differences may mask underlying similarities in social structure: a comparison of female elephant societies. Behav Ecol, 25, 145-159.
Perera, V., Silva-Flecher, A., Jayawardena, S., Kumudini, N. & Prasad, T. (2018). Rehabilitation of orphaned Asian elephant (*Elephas maximus maximus*) calves in Sri Lanka. J Wildl Rehabil, 38, 2.
Polansky, L., Kilian, W. & Wittemyer, G. (2015). Elucidating the significance of movement decisions by African savannah elephants using state–space models. Proc Roy Soc B, 282, 20143042.
Pushpakumara, P. G. A., Rajapakse, R. C., Perera, B. M. A. O. & Brown, J. L. (2016). Reproductive performance of the largest captive Asian elephant (*Elephas maximus*) population in Sri Lanka. Anim Repro Sci, 174, 93-99.
Ralph, C.R. & Tilbrook, A.J. (2016). The usefulness of measuring glucocorticoids for assessing animal welfare. J Anim Sci, 94, 457-470.
Richman, L. K., Montali, R. J., Garber, R. L., Kennedy, M. A., Lehnhardt, J., Hildebrandt, T. *et al.* (1999). Novel endotheliotropic herpesviruses fatal for Asian and African elephants. Science, 283, 1171-1176.
Sach, F., Fitzpatrick, M., Masters, N. & Field, D. (2019). Financial planning required to keep elephants in zoos in the United Kingdom in accordance with the Secretary of State's Standards of Modern Zoo Practice for the next 30 years. Intl Zoo Yrbk, 53, 78-88.
Sukumar, R. (1992). *The Asian elephant: ecology and management*. Cambridge: Cambridge University Press.
Sukumar, R. (2003). *The Living Elephants: Evolutionary ecology, behaviour and conservation*. Oxford: Oxford University Press.

Sukumar, R., Joshi, N. V. & Krishnamurthy, V. (1988). Growth in the Asian elephant. Proc Anim Sci, 97, 561-571.

Swaisgood, R.R. & Shepherdson, D.J. (2005). Scientific approaches to enrichment and stereotypies in zoo animals: what's been done and where should we go next? Zoo Biol, 24, 499–518.

Takehana, K., Kitani, R., Hatate, K., Onomi, R. & Yamagishi, N. (2020). Anthropometric and blood data on a hand-reared captive Asian elephant (*Elephas maximus*) calf: A retrospective case report. J Vet Med Sci, 19-0666.

Taylor, V.J. & Poole, T.B. (1998). Captive breeding and infant mortality in Asian elephants: A comparison between twenty western zoos and three eastern elephant centres. Zoo Biol, 17, 311–332.

Turkalo, A.K., Wrege, P.H. & Wittemyer, G. (2013). Long-term monitoring of Dzanga Bai forest elephants: forest clearing use patterns. PLoS One, 8, e85154.

Webber, C. E. (2017). *A comparison of behavioural development of elephant calves in captivity and in the wild: Implications for welfare*. PhD thesis, University of Stirling, UK.

Webber, C. E., & Lee, P. C. (2020). Play in elephants: Wellbeing, welfare or distraction? Animals, 10, 305.

West, G., Csuti, B., Sargent, E.L. & Bechert, U.S. (2001). Occurrence and treatment of nail/foot abscesses, nail cracks, and sole abscesses in captive elephants. In: Csuti, B., Sargent, E.L. & Bechert, U.S. (Eds.) *The elephant's foot: Prevention and care of foot conditions in captive Asian and African elephants*, pp. 93-116. Iowa: Iowa State University Press.

Williams, E., Chadwick, C. L., Yon, L. & Asher, L. (2018). A review of current indicators of welfare in captive elephants (*Loxodonta africana* and *Elephas maximus*). Anim Welfare, 27, 235-249.

Williams, E., Carter, A., Hall, C. & Bremner-Harrison, S. (2019). Social interactions in zoo-housed elephants: Factors affecting social relationships. Animals, 9, 747.

Williams, E., Bremner-Harrison, S., Hall, C. & Carter, A. (2020). Understanding temporal social dynamics in zoo animal management: an elephant case study. Animals, 10, 882.

Wood, A. (2017). *Social proximity of bull elephants in UK and Irish zoos*. Unpublished Masters thesis, University of Chester, UK.

Wong, E.P., Yon, L., Walker, S.L., Mena, A.S., Wadey, J., Othman, N., Saaban, S. & Campos-Arceiz, A. (2018). The elephant who finally crossed the road – significant life events reflected in faecal hormone metabolites of a wild Asian elephant. Gajah, 48, 4–11.

Yeates, J.W. & Main, D.C.J. (2008). Assessment of positive welfare: a review. Vet J, 175, 293–300.

Yon, L., Williams, E., Harvey, N. D. & Asher, L. (2019). Development of a behavioural welfare assessment tool for routine use with captive elephants. PLoS One, 14, e0210783.

Zoos Forum (2010). *Elephants in UK Zoos: Zoos Forum review of issues in elephant husbandry in UK zoos in the light of the Report by Harris et al. (2008)*. DEFRA report.