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Research article

Assessing risk factors for reproductive failure and associated welfare impacts in elephants in European zoos

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Abstract
Reproductive failure in elephants is thought to be caused or influenced by a range of factors such as obesity, infectious disease, husbandry, facilities, stress, behaviour, maternal experience, herd size and social grouping. Due to the low reproductive activity of the small zoo elephant population, scientific study into the relative importance of these factors is limited. This study takes an epidemiological approach using risk analysis methodologies to collate information from expert opinion, data set analysis and a targeted questionnaire to identify and assess a range of physical, behavioural and husbandry based risk factors, which may affect reproductive success in elephants housed in European zoos. Much of our knowledge on reproduction in zoo elephant populations originates from North America where there are significant differences from the European zoo elephant population in herd structure, management practices, climate and mean age. By combining multiple sources of evidence, including a large survey of reproduction in the European elephant population and eliciting expert opinion from scientists, zoo managers, veterinarians and keepers working with European zoo elephants in a structured, transparent and scientifically recognised process, it has been possible to identify the most important causes of reproductive failure and assess the influence of a range of potential confounding factors. Important causes of reproductive failure included lack of access to a compatible bull, herd instability and compatibility, lack of allomothering or maternal experience, management practices at parturition and the impact of elephant endotheliotropic herpes virus. This work is to be used in the development of evidence-based elephant management and welfare recommendations and highlights priority areas for further research.

Introduction

Successful reproduction in captive elephants is not necessarily an indication of high welfare standards, but investigating reproductive failure could identify causes of compromised welfare. Dystocia, stillbirth, reproductive pathology and neonatal morbidity and mortality have all been reported in zoo elephants. Many causative and contributing factors such as obesity, infectious disease, husbandry, facilities, stress, behaviour, herd size and social grouping have been proposed, but due to the low reproductive activity of a small population scientific study into the relative importance of these factors is limited.

Reproductive and maternal behaviour in elephants promotes positive welfare by encouraging social interaction, herd cohesion and an increased repertoire of behaviours including mating and maternal behaviours. Identification of the most significant influences on reproduction would enable zoos to mitigate against reproductive failure and associated negative welfare or to improve opportunity for reproduction and promote the positive impacts of reproduction.

There are several studies examining specific factors associated with reproduction such as group size (Rees 2009), acyclicity (Brown et al. 2004; Proctor et al. 2010), infant mortality (Taylor and Poole 1998; Mar et al. 2012) and dystocia (Flugger et al. 2001; Murray et al. 1996)

A number of studies have used statistical analysis of zoo studbook data to assess reproductive failure (Dale 2010) and then compare this to timber camp elephants (Schmidt and Mar 1996: Taylor and Poole 1998; Hayward et al. 2014) and timber camp elephants and wild African elephants (Clubb et al. 2008, 2009). The results were then used to assess welfare of

zoo elephants using infant mortality and fecundity as indicators. These studies found that fecundity and reproductive life-span was lower and still-birth rate, infanticide and acyclicity higher in zoo elephants and proposed obesity and stress as potential causative factors.

Mason and Veasey (2010) built on these studies to use population level indices such as fecundity, acyclity stillbirths and infant mortality to propose links to assessment of welfare and the use of these factors as welfare indices. They concluded that low fecundity, premature reproductive senescence, acyclicity and high stillbirth rates could be caused by stress or other forms of poor welfare. However, they also accepted that management factors such as access to mates and inadequate reproductive experience could equally cause these population level effects.

Harris et al. (2008) surveyed physical and husbandry conditions and gathered physiological and behavioural data relating to 77 elephants in 13 UK zoos. They proposed indicators of elephant welfare and calculated the prevalence of welfare outcomes. They then attempted to identify risk factors related to husbandry and housing using statistical analysis. This study did not assess reproduction, maternal behaviour or bull management and did not identify any welfare risk factors associated with these issues. The authors determined that, due to the very small sample sizes and the nature of the data, the statistical analysis used was not robust.

Clubb and Mason (2002) conducted a comprehensive study of European zoo elephant welfare through a review of published literature, secondary source materials and interviews with experts. A range of statistical data regarding infant mortality and reproductive failures in both male and female elephants was produced and the authors proposed some causative reasons for these findings. Due to limited access to information on elephant management they were unable to link these findings with specific risk factors.

All of these studies combined assessment and analysis of both species of elephant in single studies despite it being recognised that the population demographics and management and training systems differ significantly between species. Additionally, there are significant differences in elephant management between North American and European zoo populations and therefore it cannot be presumed that the results of studies in one population can be directly applied to the other.

This study builds on previous work by utilising peer reviewed and grey literature, expert opinion and studbook data in combination with detailed elephant husbandry and management information and robust statistical correlation analysis. The specific differences between species and populations are addressed. Recommendations for changes to elephant management, which reflect the most significant risk factors identified are made.

This work is a qualitative risk analysis using standardised techniques to assess risk factors which result in negative welfare impact during reproductive activity in elephants housed in European zoos. It provides an evidence-based assessment of those factors, which influence the likelihood of a successful reproductive event, defined by the birth of a life calf that is maternally reared to independence. The analysis indicates which factors have a greater risk of leading to a negative outcome. This allows for management recommendations to be made regarding these factors and therefore to reduce the likelihood of negative reproduction associated events occurring. This can contribute to improving the welfare of elephants in captivity by implementing measures, which could reduce the risks of stillbirth, abortion, neonatal morbidity and mortality, maternal rejection and suboptimal social behaviour that have been associated with reproduction in captive elephants and identified as negative welfare indicators.

Methods

Epidemiology is the study of patterns in defined populations with the aim of understanding the prevalence of hazards and the risk factors associated with their occurrence. Once the factors have been identified, effective strategies can be developed to minimise those risks (Carlstead et al. 2014). Epidemiology is usually associated with the study of disease but is increasingly being applied to animal welfare studies including with elephants (Carlstead et al. 2014).

There are three approaches to collecting data for welfare epidemiological studies; surveying or interviewing people familiar with the subject population, analysis of pre-existing data collected or a different purpose and collecting data directly from the population under investigation. All three approaches were used in this study.

Risk analysis processes provide an objective, repeatable, transparent and documented assessment of the risks posed by a course of action or chain of decisions. Standardised techniques have been developed and are utilised to aid decision-making. It is a tool now routinely used to guide policy making and disease control by governments and international organisations such as the OIE (World Organisation for Animal Health) (Murray et al. 2004).

This technique has rarely been used to aid decision making in managed zoo captive breeding programmes (Hartley and Schmidt 2013) but risk analysis has significant potential to support formulation of evidence based policies for issues where there is an element of uncertainty, confusion or controversy, as this technique is designed to present fully referenced information in a structured and transparent way. It is particularly useful as qualitative rather than quantitative techniques can be used where numerical or statistical data is not available or is of limited value.

Previous studies on reproduction in elephants have been hampered as they have depended on statistical analysis based on very small samples sizes. By using risk analysis this limitation can be managed so that evidence based recommendations to improve welfare can be made.

The OIE Risk Analysis Framework (Murray el 2004) forms the basis of risk analysis systems used for a wide variety of disease outbreak scenarios. This framework was revised for use in this study but retains the fundamental concepts of risk analysis. A representation of this framework is shown in Figure 1.

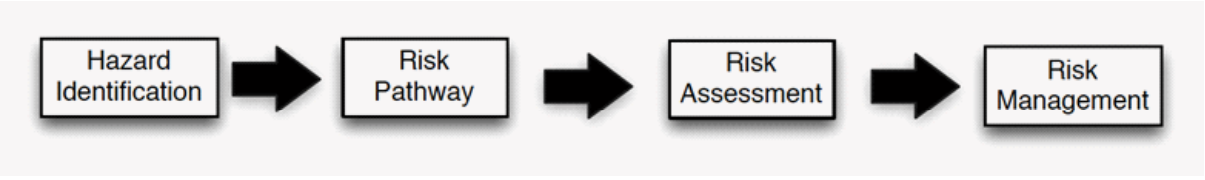

Figure 1. Simplified risk analysis framework used in this study based on the OIE Risk Analysis Framework (Murray et al. 2004).

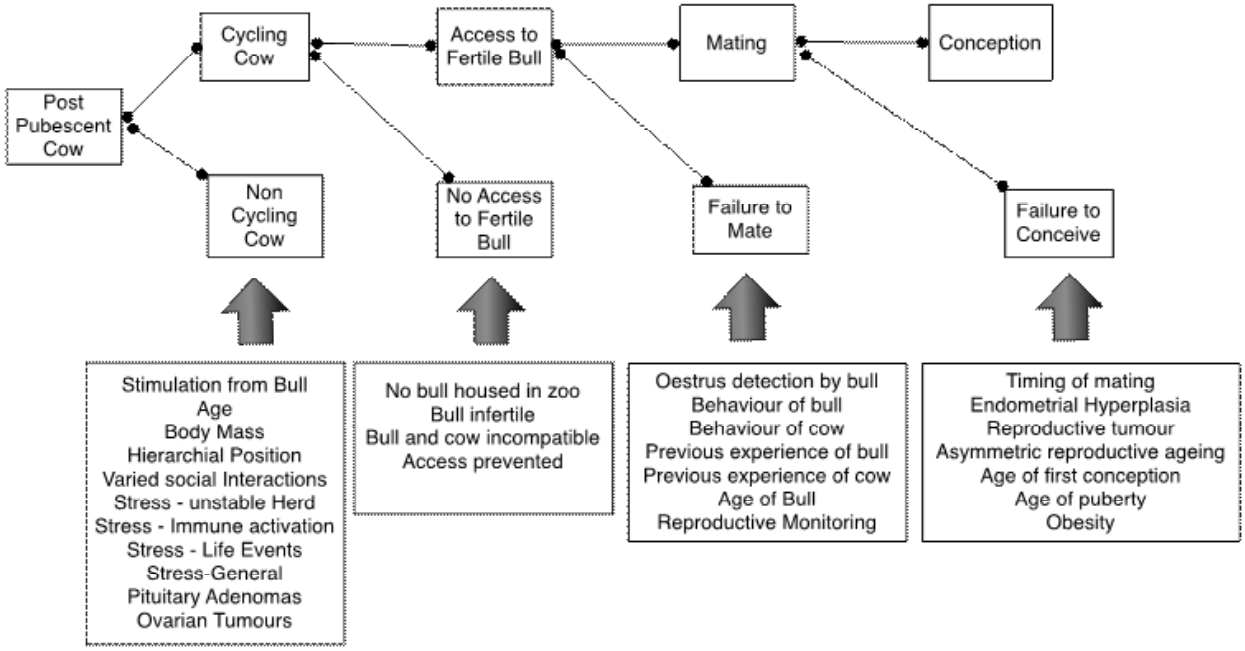

Figure 2. Risk pathway showing risk factors for failure of elephant conception.

Two hazards were defined, failure to conceive and failure to rear a calf to five years of age and so two separate but connected risk pathways were developed. These are shown in Figures 2 and 3. These pathways define the processes experienced by a system (in this case a female elephant) in order for the hazard to occur. Defining these steps allows specific evidence to be assessed independently and simplifies analysis of complex processes. Risk factors, which impact on the progression between the steps in the risk pathway are identified. This was achieved through a comprehensive peer-reviewed and grey literature search and outputs from an expert advice panel. This panel was composed of elephant keepers, zoo curators, managers, directors, scientists and veterinarians with experience of working with elephants. The group was asked to identify facility features, husbandry, health or management issues which they considered to impact on successful reproduction.

The risk assessment itself is an estimation of the probability of each step in the pathway occurring, this can be either quantitative

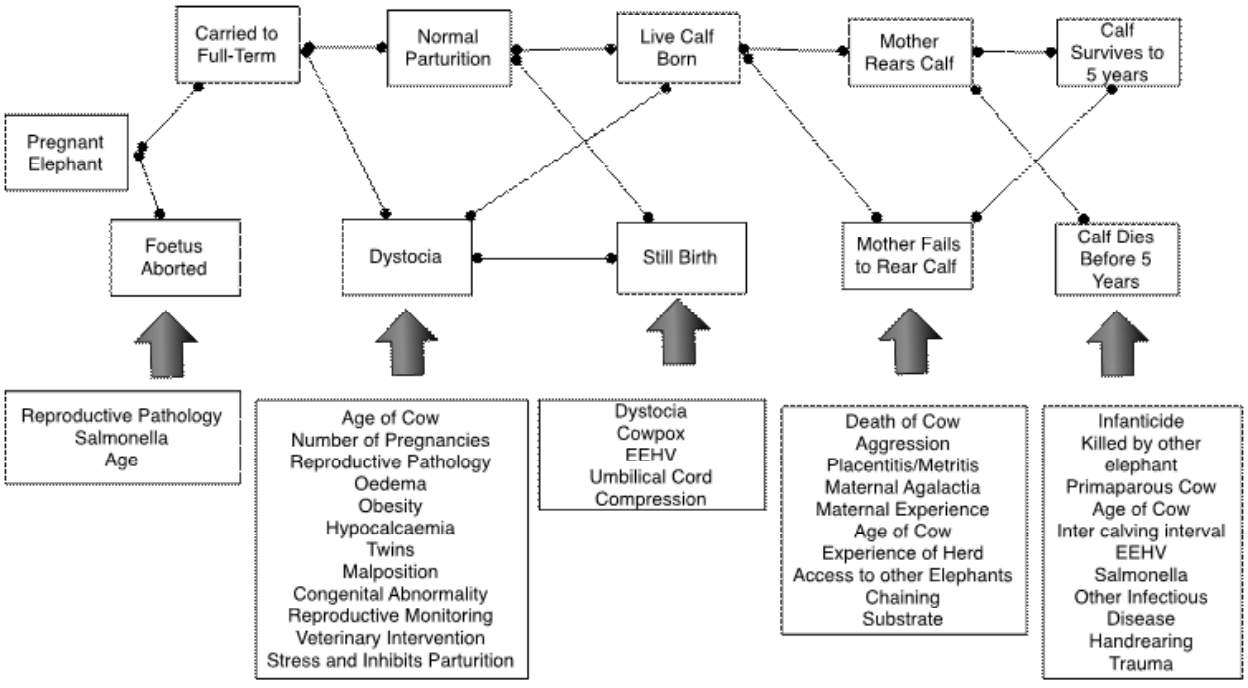

Figure 3. Risk pathway from conception to rearing calf to 5 years showing risk factors.

Table 1. Risk definitions used in risk analysis.

Term	Definition
Negligible	So rare that it does not merit being considered
Very low	Very rare but cannot be excluded
Low	Rare but does occur
Medium	Occurs regularly
High	Occurs very often

where available or qualitative. The probability is estimated following analysis of available evidence.

The European studbooks for Asian elephants (2011 edition) and African elephants (2012 edition), updated with relevant unpublished annual reports, were interrogated to investigate life histories of elephants and calculate reproductive parameters of interest such as age at birth. These studbooks contain demographic information, including births, deaths, parentage and transfers between holdings of elephants held in zoological institutions. The studbooks contained 984 Asian elephants dating back to 1830 and 475 African elephants dating back to 1865. The studbook data was used to assess the social and maternal histories of the current living female elephant population (259 Asian and 150 African) and to determine individuals to be included in two questionnaire surveys.

The first questionnaire was focused on investigating risk factors that affected conception in elephants. Three separate cohorts of elephants were identified of interest for this component of the study: those that had conceived previously but had not conceived in the past five years (the average inter-birth interval in captive Asian elephants has been determined to be five years; Mar et al. 2012); those elephants that had never conceived despite being housed at the same zoo as a proven bull for a period of at least 12 months during adulthood; and those elephants that had never conceived but had never been housed with a proven bull. The distinction between the latter two cohorts of elephants allows for the fact that a cow may be completely fertile and able to conceive but has failed to do so because she has never been mated by a fertile bull.

Information regarding elephants that were reproductively active was not collected as these elephants are not currently being affected by the risk factors under investigation, and so would not contribute to identification of the most important risk factors, which require management actions. The questionnaire for each elephant was detailed and complex, requiring significant time and effort from zoo staff to complete, and therefore a prioritised approach to requesting data was likely to have aided participation.

The second questionnaire was designed to collect information from the point of parturition to rearing the calf to the age of five years. The questionnaire was specific to each birth event recorded in the studbooks (and the 2013 taxon report which supplements the studbook and adds information for the year 2012–2013), therefore multiple questionnaires were completed concerning multiparous cows. This covered the period 1992–2013. Further explanation of the questionnaire and its results are reported in Hartley and Stanley (2016).

The risk assessment was constructed by combining the findings from the two questionnaires, interrogation of the studbook data and the peer reviewed literature for each risk factor and then qualitatively assessing the likelihood that the risk factor would have an impact on successful reproduction using the criteria defined in Table 1. A further assessment of uncertainty was added to identify areas of weak, incomplete or conflicting evidence. In cases where all or the majority of sources of evidence – expert opinion, peer-reviewed and grey literature, studbook analysis and the results of the questionnaire – support a similar risk assessment, there was considered to be low uncertainty. If the survey findings presented were found to be statistically supported the factor was determined to have low uncertainty as a robust association had been found. Where the evidence sources conflicted or the questionnaire results were not found to be statistically significant, uncertainty was considered to be medium or high.

Risk management is the process by which the risk manager uses the results of the risk assessment, balanced with the 'level of acceptable risk' and to determine the risk mitigation measures to be put into place. The levels of acceptable risk and therefore the extent of the mitigation measures will vary depending on resources, ethics, and other confounding factors.

Results

Tables 2–10 present the risk assessment and uncertainty rating for each stage in the risk pathways shown in Figures 2 and 3. The peer-reviewed papers that include evidence relating to the risk factors are referred to using reference numbers from the citations list in this paper. The detailed results of the questionnaire are presented in an associated paper (Hartley 2016); an indication if the results supported the risk assessment is provided. The results are ranked from a high risk to a low risk.

Table 2a. Risk assessment for the impact of identified risk factors on the likelihood of acyclicity in African elephants in European zoos.

Risk factor	Supported by peer reviewed papers	Supported by questionnaire results	Risk assessment	Uncertainty
Older age of cow	5,20,22,47	Trend	High	Low
Less access to daylight	4,58,	Trend	High	High
Higher hierarchial position	20,22,47	No	Medium	Low
Lack of change in social group	21,	Yes	Medium	Medium
Immune activation inflammatory disease	3,6	No	Medium	Medium
Reproductive tract pathology	5,31,34	No	Medium	Medium
Obesity	21,	-	Medium	Medium
General stress	10, 26, 47	-	Medium	High
Lack of stimulation from bull	21,44	Yes	Medium	High

Table 2b. Risk assessment for the impact of identified risk factors on the likelihood of acyclicity in Asian elephants in European zoos.

Risk factor	Supported by peer reviewed papers	Supported by questionnaire results	Risk assessment	Uncertainty
Less access to daylight	4,58	Trend	high	High
Obesity	21	-	Medium	Medium
General stress	10,12,25,56	-	Medium	High
Lack of stimulation from bull	21,44	Yes	Medium	High
Lack of change in social group	12, 17, 25, 56	No	Medium	Medium
Older age of cow	5,20,22,47	Trend	Medium	Medium
Higher hierarchial position	-	No	Low	Low
Immune activation inflammatory disease	-	No	Low	Medium
Reproductive tract pathology	31,34	No	Low	Medium

Table 3a. Risk assessment for the impact of identified risk factors on the likelihood of African elephants in European zoos not having access to a bull.

Risk factor	Supported by peer reviewed papers	Supported by questionnaire results	Risk assessment	Uncertainty
Cows not given access to bulls overnight	40,42	Yes	High	Low
Incompatible behaviour	40	Yes	High	Low
Access only given when in oestrus	40,45,60	Yes	Medium	Low
No bull housed	40,	Yes	Medium	Low

Table 3b. Risk assessment for the impact of identified risk factors on the likelihood of Asian elephants in European zoos not having access to a bull.

Risk factor	Supported by peer reviewed papers	Supported by questionnaire results	Risk assessment	Uncertainty
Cows not given access to bulls overnight	40,42	Yes	High	Low
Access only given when in oestrus	40	Yes	High	Low
Incompatible behaviour	40	Yes	High	Low
No bull housed	40	Yes	Low	Low

Table 4a. Risk assessment for the impact of identified risk factor on the likelihood of African elephants in European zoos failing to mate.

Risk factor	Supported by peer reviewed papers	Supported by questionnaire results	Supported by studbook evidence	Risk assessment	Uncertainty
Lack of choice of bull	44	-	Yes	High	Low
Young age of bull	44,	-	Yes	High	Low
Cow refuses to stand to be mated	24	Yes	-	High	Low
Bull refuses to mate cow	24	Yes	-	Medium	Low
Lack of previous experience of bull	16,24	_	Yes	Medium	Low
Lack of previous experience of cow	24	-	No	Low	Low

Table 4b. Risk assessment for the impact of identified risk factor on the likelihood of Asian elephants in European zoos failing to mate.

Risk factor	Supported by peer reviewed papers	Supported by questionnaire results	Supported by studbook evidence	Risk assessment	Uncertainty
Lack of choice of bull	-	-	Yes	High	Low
Young age of bull	-	-	Yes	Medium	Low
Cow refuses to stand to be mated	24	Yes	-	Medium	Low
Bull refuses to mate cow	24,49,50	Yes	-	Medium	Low
Lack of previous experience of cow	24,51	-	No	Medium	Low
Lack of previous experience of bull	24,49,50	-	No	Low	Low

Table 5a. Risk assessment for the impact of identified risk factors on the likelihood of African elephants in European zoos failing to conceive.

Risk factor	Supported by peer reviewed papers	Supported by questionnaire results	Supported by studbook evidence	Risk assessment	Uncertainty
Unproven bull	32,33	-	Yes	High	Low
Reproductive pathology	31,32,34	No	-	Low	Medium
Age of cow	31	No	No	Low	Low
Young age of puberty	32,34	No	-	Low	Medium

Table 5b. Risk assessment for the impact of identified risk factors on the likelihood of Asian elephants in European zoos failing to conceive.

Risk factor	Supported by peer reviewed papers	Supported by questionnaire results	Supported by studbook evidence	Risk assessment	Uncertainty
Reproductive pathology	2,31,32,34,	No	-	Medium	Medium
Age of cow	31, 60	No	Yes	Medium	Low
Young age of puberty	57	No	-	Medium/low	Medium
Unproven bull	32,33	-	No	Low	Low

Discussion

This risk assessment provides ranked lists of factors that influence each stage of reproduction in captive European elephants. It builds on previous studies by combining multiple data sources in a framework that facilities comparison between the peer-reviewed literature and primary data from the specific target population. This is important as much of the peer-reviewed literature is focused on other populations of elephants such as the North American zoo population, timber camp elephants or wild elephants. There are significant demographic and management differences between these populations and the under-studied European captive elephant population.

For some risk factors both the peer-reviewed literature and questionnaire results are based on a very small number of case reports. These include factors such as twinning, congenital deformities and cases of infectious diseases. These risk factors occurred rarely and so were assessed as being very low to low risk and with a low uncertainty.

Examining the first risk pathway, the assessment suggests that in Asian elephants the age of the cow and reproductive pathology are the primary risk factors for both acyclicity and failure to conceive. These two risk factors are linked as older cows are more likely to develop reproductive pathology. These issues have been well studied (Brown et al. 2004; Freeman et al. 2004, 2010). However, in the North American population, Asian elephants appear likely to continue cycling normally with reproductive tract pathology (Brown et al. 2004b), while in this study only 35% of the cows with reproductive tract pathology were cycling normally, and therefore avoiding the development of the pathology or attempting to treat it could reduce the risk of acyclicity.

In African elephants very different risks were found to be of significance. In this species, there is an association between acyclicity and females being maintained at the same facility with

Table 6a. Risk assessment for the impact of identified risk factors on the likelihood of abortion in African elephants in European zoos.

Risk factor	Supported by peer reviewed papers	Supported by questionnaire results	Risk assessment	Uncertainty
Stress	10	-	Low	High
Age of cow	-	No	Very low	Medium
Primiparous cows	-	No	Very low	Medium
Reproductive pathology	-	No	Very low	Medium
Salmonella	15	Yes (1 case)	Very low	Medium

Table 6b. Risk assessment for the impact of identified risk factors on the likelihood of abortion in Asian elephants in European zoos.

Risk factor	Supported by peer reviewed papers	Supported by questionnaire results	Risk assessment	Uncertainty
Stress	10	-	Low	High
Age of cow	57	No	Low	Medium
Primiparous cows	57	No	Low	Medium
Reproductive pathology	38	No	Low	Medium
Salmonella	-	No	Negligible	Medium

Table 7a. Risk assessment for the impact of identified risk factors on the likelihood of dystocia in African elephants in European zoos.

Risk factor	Supported by peer reviewed papers	Supported by questionnaire results	Risk assessment	Uncertainty
Primiparity	-	Statistically significant	High	Low
Separation of cow from other elephants	40	Trend	High	High
Management system (no contact compared to free contact)		Statistically significant	High	High
Obesity	60	-	Medium	Medium
General stress	8,10,40	-	Medium	High
Stress from chaining cow	8,10,40	No	Low	Medium
Excessively large calves	11,35	No	Low	Medium
Position of calf	-	No	Low	Low
Age of cow at parturition	13	No (statistically proven)	Low	Low
Reproductive pathology	31,32,34	No	Low	Medium
Oedema	-	No	Low	Medium
Hypocalcaemia	-	-	Low	Low
Reproductive monitoring	19,32,34,54	No	Low	Low
Twins	54	No	Very low	Low
Congenital abnormality of calf	23	No	Very low	Low

Table 7b. Risk assessment for the impact of identified risk factors on the likelihood of dystocia in Asian elephants in European zoos.

Risk factor	Supported by peer reviewed papers	Supported by questionnaire results	Risk assessment	Uncertainty
Separation of cow from other elephants	1, 8, 24,19,36,40,	Statistically significant	High	Low
Position of calf	43,61,63	Statistically significant	High	Low
Excessively large calves	10,11,36	Statistically significant	High	Low
Management system (free compared to protected)		Statistically significant	High	High
Stress from chaining cow	8,10,19,36,40	No	Medium	High
Primiparous cow	13	Trend	Medium	Medium
Obesity	60	-	Medium	Medium
General stress	8,10,40	-	Medium	High
Age of cow at parturition	13,19	No	Low	Low
Reproductive pathology	31,32,34	No	Low	Medium
Oedema	-	No	Low	Medium
Hypocalcaemia	61,53,55	-	Low	Low
Reproductive monitoring	19,32,34, 54	No	Low	Low
Twins	54, 57	No	Very low	Low
Congenital abnormality of calf	55	no	Very low	Low

the same herd mates for a long period of time. There are several examples of non-cycling females that resumed cycling either after a transfer or alteration of herd dynamics, though there are also cases of cycling females become acyclic after similar changes (Freeman et al. 2009). There are an increasing number of studies showing that changing herd composition by introducing new animals can have positive effects on social behaviour, whilst stress associated with the move is neither prolonged or severe (Dathe et al. 1992; Schmid et al. 2001; Laws et al. 2007; Fanson et al. 2013). This suggests that in non-reproductive herds a transfer of animals may be a justifiable method to use to attempt to stimulate reproduction.

The amount of exposure to daylight has been reported as positively influencing reproductive cycles (Schulte 2000) and disputed by others (Brown and Lehnhardt 1997). In this study the acyclic animals of both species had at least 50% less access to daylight than cycling animals. This is an important area for further research.

In both species restricted access to a bull was considered a risk factor. In zoos the access of cows to bulls is often restricted for a number of reasons, with some zoos not housing a bull (Mason and Veasey 2010). It is possible that the restrictive management of herds in zoos does not allow conception to occur because during the most fertile period, the cow and bull have been separated.

Table 8a. Risk assessment for the impact of identified risk factor on the likelihood of stillbirth in African elephants in European zoos.

Risk factor	Supported by peer reviewed papers	Supported by questionnaire results	Risk assessment	Uncertainty
Dystocia	-	Statistically significant	High	Low
Primiparity		Trend	Low	Low
Eehv	_	No	Low	Low
Cow pox	_	No	Low	Low

Table 8b. Risk assessment for the impact of identified risk factor on the likelihood of stillbirth in Asian elephants in European zoos.

Risk factor	Supported by peer reviewed papers	Supported by questionnaire results	Risk assessment	Uncertainty
Primiparity	39, 46	Statistically significant	High	Low
Dystocia	39,46	Statistically significant	High	Low
Eehv	30,55,61	Yes	High	High
Cow pox	65	No	Medium	Low

When a cow's reproductive cycle is around 16 weeks, and therefore she only cycles approximately 3–4 times per year, this can have a significant impact on conception rates. In the wild, bulls will stay with family groups when a cow is in oestrus, continually monitoring her status, and indeed receptive females may move away from the herd, maintaining close contact with the male and soliciting him with specific visual and olfactory signs (Poole and Moss 1989). In one study, pregnancy rates were greatly enhanced when cows were left with the bull 24 hours a day (Olsen et al. 1994). Our study has highlighted the importance of elephant social structure and learnt behaviours and how the inevitable restriction of these in captivity can impact on reproductive behaviour.

It is not known to what the extent that the cues and behaviours associated with the detection of oestrus are learnt. Many zoo elephants have not been exposed to cycling cows or adult bulls during their adolescence and therefore some infertility may be due to lack of experience or the lack of an opportunity to learn (Rees 2004). Without bulls in the herd young females grow up not knowing how to behave towards bulls and might remain frightened of them for the rest of their lives (Garai and Kurt 2006).

In the wild, adolescent males (10–20 years of age) are very sociable and associate with older males, providing the opportunity to learn from more experienced individuals (Evans and Harris 2008). This is supported by Rees (2004), who proposed that the development of normal sexual behaviour in juvenile bulls may depend on exposure to reproductively active adults.

It is known that in the wild cows prefer to mate with older bulls more than 35 years old (Ortolani et al. 2005). In the European

Table 9a. Risk assessment for the impact of identified risk factors on the likelihood of poor maternal behaviour in African elephants in European zoos.

Risk factor	Supported by peer reviewed papers	Supported by questionnaire results	Risk assessment	Uncertainty
Primiparous cow	-	Trend	High	Medium
Lack of experience of calves	14,59	No	Medium	Low
Separation from other elephants at birth	8,62	No	Medium	High
Chaining of cow at birth	8,62	No	Medium	High
Maternal aggression	52,	No	Low	Low
Aggression from other herd members	52	No	Low	Low
Placentitis/metritis	-	No	Very low	Low
Maternal agalactia	-	No	Very low	Low

Table 9b. Risk assessment for the impact of identified risk factors on the likelihood of poor maternal behaviour in Asian elephants in European zoos.

Risk factor	Supported by peer reviewed papers	Supported by questionnaire results	Risk assessment	Uncertainty
Primiparous cow	46,60	Statistically significant	High	Low
Lack of experience of calves	59	Significantly significant	High	Low
Separation from other elephants at birth	8,19,46,62	No	High	Medium
Chaining of cow at birth	8,19,46,62	No	High	High
Maternal aggression	46,52,60	No	Low	Low
Aggression from other herd members	46,52,60	No	Low	Low
Placentitis/metritis	-	No	Very low	Low
Maternal agalactia	39	No	Very low	Low

Table 10a. Risk assessment for the impact of identified risk factors on the likelihood of African elephants in European zoos failing to rear a calf to 5 years old.

Risk factor	Supported by peer reviewed papers	Supported by questionnaire results	Supported by studbook evidence	Risk assessment	Uncertainty
Failed handrearing		Yes	Yes	High	Low
Separation from mother <5 years of age	8,9,24	-	Yes	High	Medium
Separation of cow from other elephants at birth	8,62	No	-	Medium	High
Chaining of cow at birth	8,62	Trend	-	Medium	High
Inter-calving interval	-	-	Yes	Medium	High
Primiparous cow		Trend	-	Medium	Low
Lack of maternal experience	14	Trend	-	Medium	Low
Herd stability	5,21,26,62,64	No	-	Low	Medium
Infanticide		No	-	Low	Low
EEHV	30	No	-	Low	Low
Killed by other elephant (not mother)		No	-	Low	Low
Other infectious disease	-	No	-	Low	Low

Table 10b. Risk assessment for the impact of identified risk factors on the likelihood of asian elephants in european zoos failing to rear a calf to 5 years old.

Risk factor	Supported by peer reviewed papers	Supported by questionnaire results	Supported by studbook evidence	Risk assessment	Uncertainty
Failed handrearing	18	Yes	Yes	High	Low
Primiparous cow	39, 46,60	Statistically significant	-	High	Low
Lack of maternal experience	59	Statistically significant	-	High	Low
EEHV	30,55	Yes	yes	High	Low
Herd stability	62,65	Statistically significant	-	High	Medium
Separation from mother <5 years of age	8,9,24,	yes	Yes	High	Medium
Separation of cow from other elephants at birth	8,19,46,62	Trend	-	Medium	Low
Chaining of cow at birth	8,19,46,62	No	-	Medium	Low
Infanticide	46,52,60	No	-	Low	Low
Killed by other elephant (not mother)	46,52,60	No	-	Low	Low
Other infectious disease	39	No	-	Low	Low
Inter-calving interval	39		No	Low	High

population there are relatively few older bulls but a wide age range of cows.

Conception failure can of course be caused by infertility of the bull. This must be differentiated from the bull not having the social or behavioural knowledge to mate the cow successfully. This would require specialist reproduction examinations (Hildebrandt et al. 2000b).

We have used the risk assessment findings and our expert working groups to produce evidence based recommendations for further research and management changes which could improve reproductive success in European zoo elephants.

Examining the second risk pathway, in African elephants little previous work on captive births could be identified and therefore the survey results formed the majority of the evidence. This found the causes of dystocia to be varied, with only separation from other elephants at the time of parturition being considered a high risk factor. In contrast consistent findings were identified in Asian elephants, which were that older, primiparous cows are more likely to suffer from dystocia. In Asian elephants calf birth weight was also consistently found to be significant.

The questionnaire survey generated new information on the impact of calf presentation on the likelihood of dystocia as the literature only describes individual case reports. It is possible that the position of the calf is associated with an increased calf weight as large calves may be less able to change position in the uterus.

In contrast to previous studies, the risk of aggression and infanticide from dams to calves was shown to be low. This may be due to the greater proportion of zoo born cows which are reproductively active and have maternal or allomothering experience, which was found to be very important in reducing poor maternal behaviour and improving calf survival.

In both species, separation from other elephants and, in Asian elephants, chaining at the time of parturition was found to be high risk factors for dystocia. In Asian elephants both these factors were also found to be high risk factor for poor maternal behaviour and calf survival. These assessments were based on statistically significant survey results supported by weak literature evidence. These risk factors require further investigation in order to develop elephant management best practice.

In Asian elephants herd instability was found to be a high risk

Table 11. Summary of the risk factors assessed as highly influencing likelihood of conception in European zoo elephants and proposed mitigating actions.

Step in risk pathway	Species	Risk factors	Potential actions
Acyclicity and failure to conceive	Asian	Age and reproductive tract pathology	Manage cows to breed when younger. Assess and treat reproductive tract pathology, where appropriate in an attempt to start cycling again.
Acyclicity	African	Lack of change in social group	Consider inter-zoo transfers in herds which have not changed in composition and are non-reproductive.
Acyclicity	Both	Restricted access to daylight	Further research needed but increase access to natural daylight. Use special roofing on houses which does not restrict uv.
Access to bull	Asian	Access to bull restricted overnight and to periods when cows considered to be in oestrus.	Design facilities to allow unrestricted access and manage animals so access is unrestricted and the elephants can chose to be together.
Access to bull	African	Incompatible behaviour between cows and bulls, no bull housed and access to bulls restricted.	Ensure all potential reproductive cows are housed with a bull. Manage elephants to encourage affiliative behaviours and provide opportunities for elephants to learn social behaviour from peers.
Failure to mate	Both	Lack of bull choice	Build elephant facilities which can house multiple bulls and allow fission-fusion herd structures.
Failure to mate	Both	Young age of bull	Provide opportunities for young bulls to learn reproductive behaviour by managing multi-bull facilities.
Failure to mate	African	Cow or bull refuses to mate	Manage elephants to encourage affiliative behaviours and provide opportunities for elephants to learn social behaviour from peers.
Failure to conceive	Asian	Unproven bull	Examine bulls to ensure fertile. Manage elephants to encourage affiliative behaviours and provide opportunities for elephants to learn social behaviour from peers.

factor for calf survival. This risk factor is very important as it has consequences for management decisions regarding the movement of incompatible cows out of breeding herds to improve social wellbeing.

Clubb et al. (2008) found a strong association between removal of a calf from their mother before three years of age and a failure to survive. In African elephants this was not supported. However in Asian elephants, the study indicated that the mortality rate of calves removed before they are five years old is double the mortality rate of calves who are removed after they are five years old.

The devastating impact of elephant endotheliotropic herpes virus (EEHV) on captive elephants is demonstrated by this study.

Conclusions

This study aids in the identification of the most significant risk factors to reproduction and, by association, welfare in the European captive zoo elephant population. By providing a structured and transparent assessment of the complex and often conflicting evidence combined with new data from the population, the study allows prioritisation of actions to mitigate these risks. This study begins to address previously recognised differences in the causes of reproductive failure between the European captive elephant population and other populations that have hindered the production of specific and appropriate management recommendations in the past.

The study defines the importance of promoting and supporting the development of broad social experience and expression of natural behaviours in elephant management practices. The challenges of space and resources influence the practicalities of this but further emphasis should be placed on managing multi-maternal line herds and multiple bulls in facilities, which promote fission-fusion behaviours allowing bull choice, elephants to avoid each other during times of conflict or stress and elephants to learn social skills. This in turn will lead to a more natural age structure of the European zoo elephant population.

The findings of this study have been presented to the Elephant Taxon Advisory Group of the European Association of Zoos and Aquaria, which manages and supervises the European zoo elephant population and is using this work as evidence to support current management recommendations, to modify existing husbandry guidelines and as a means of highlighting research priorities. The work is a component of a broad review of elephant welfare in the United Kingdom, which will contribute to revision of the zoo licensing system.

The study has highlighted some key areas for further research which are being investigated in further studies. These include evaluating the importance of learnt social behaviour in bulls, assessing compatibility and herd instability and the impact of daylight on reproductive cycles.

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Table 12. Summary of the risk factors assessed as highly influencing likelihood of rearing a calf to five years old in European zoo elephants and proposed mitigating actions.

Step in risk pathway	Species	Risk factors	Potential actions
Dystocia	Both	Separation of cow from other elephants	Do not separate cows for births
Dystocia	Asian	Stress from chaining cow	Do not chain cows for births
Dystocia	Asian	Older, primiparous cows	Encourage breeding when young
Dystocia	Asian	Excessively large calves	Evidence poor but consider diet management.
Dystocia	Asian	Position of calf	Veterinary monitoring so preparations can be made for a potential dystocia.
Poor maternal behaviour	Both	Lack of experience of calves	Manage elephants to encourage affiliative behaviours and provide opportunities for elephants to learn social behaviour from peers particularly maternal behaviour and allomothering experience.
Poor maternal behaviour	Asian	Separation from other elephants at birth. Chaining of cow at birth	Do not separate or chain elephants for births.
Failure to rear calf to 5 years old	Both	Failed handrearing	Avoid handrearing whenever possible by managing other risk factors.
Failure to rear calf to 5 years old	Asian	Separation of cow from other elephants chaining of cow at birth at birth	Do not separate or chain elephants for births.
Failure to rear calf to 5 years old	Both	Lack of maternal experience	Manage elephants to encourage affiliative behaviours and provide opportunities for elephants to learn social behaviour from peers particularly maternal behaviour and allomothering experience.
Failure to rear calf to 5 years old	Asian	Herd stability	Manage elephants to facilitate herd stability. Consider moving incompatible elephants out of a herd to increase stability.
Failure to rear calf to 5 years old	Asian	Separation from mother <5 years of age	Do not separate calves from mothers – maternal lines are essential for developing normal herd structure. If elephants must transfer the whole maternal line should be moved.
Failure to rear calf to 5 years old	Asian	EEHV	Continued research and treatment protocols should be developed.

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