A brief review of the current use of indicators of welfare identified in the review

Behavioural indicators of welfare

Abnormal repetitive behaviours

Abnormal repetitive behaviours (ARBs) or 'stereotypies' are one of the most frequently described causes for concern in UK zoo elephants (Clubb & Mason, 2002; Harris *et al*., 2008). The definitions of stereotypies vary between researchers but it is generally agreed that they are behaviours which have 'no apparent function' (Mason, 1991). The use of stereotypies as indicators of welfare have been widely reviewed (Broom, 1983; Mason & Latham, 2004; Mason, 2006). It is likely that animals that are known to stereotype have been prevented from expressing their full range of species-typical behaviours at some point in their lives (Mason, 1991; Swaisgood & Shepherdson, 2005). However, Mason and Latham (2004) recognised that stereotypies cannot be used reliably as a sole indicator of welfare. Whilst the type of environment which is believed to elicit or enhance the expression of stereotypies is usually sub-optimal, stereotypies have been associated with good or neutral welfare states almost as frequently as with poor welfare states.

Quantification of the frequency of observed stereotypical behaviour is the most frequently used measure of welfare in captive elephants. Seventeen (57%) of the critically reviewed papers used stereotypical behaviour as an indicator of welfare; in 9 of these papers, a significant change in frequency was noted. Exhibition of stereotypies correlated with 5 other welfare measures: feeding (negative), walking (positive), resting (negative), foot health (positive) and cortisol levels (positive).

Koyama and colleagues (2012) documented a negative relationship between stereotypic pacing and both feeding and resting and a positive relationship between pacing and locomotion. Rees (2009) identified a negative relationship between stereotypies and feeding. Haspeslagh and colleagues (2013) described poorer foot health in elephants that stereotyped than those elephants that did not stereotype, although they concluded that this relationship may not necessarily be causal. Laws and colleagues (2007) documented a decrease in lying rest and an increase in faecal cortisol at the same time as increased stereotypies in a single adult bull elephant post-transport. Meller and colleagues (2007) observed increased stereotypies, increased standing rest, decreased lying rest and decreased exploratory behaviour in captive elephants following introduction of a new floor type. In the studies reviewed, stereotypies changed in frequency when there was a change in the elephants' environments. This was believed to have changed the level of stress they were experiencing in each situation: increased post transport (Laws *et al*., 2007); increased when moved to a small, inside area following being in a paddock for a long period of time (Elzanowski & Sergiel, 2006); decreased when penned rather than chained or shackled (Gruber *et al*., 2000; Schmid, 1995; Friend & Parker, 1999).

Whilst the exhibition of stereotypies may not be indicative of current poor welfare, they remain an issue of welfare concern. Any increase in frequency or intensity of stereotypies may be indicative of a reduction in welfare state. By contrast, a reduction in stereotypies may be indicative of improved welfare, provided that the change in stereotypy expression has resulted from an improvement in environmental conditions (e.g. additional provision of environmental enrichment), rather than simply measures which prevent the behaviour from occurring. It has been suggested that stereotypies may serve as coping mechanisms to aid an animal in dealing with a stressful situation, so physical prevention of these behaviours may lead to reduced welfare (Mason & Latham, 2004).

Sleep/rest behaviour

Research has suggested that sleep behaviour can be used as a reliable assessment of welfare (Abou-Ismail *et al*., 2007; Hanninen, 2007). However, in large herbivores the increased risk of predation may reduce the occurrence of lying rest behaviour in the wild (Lima *et al*., 2005). Although few studies have investigated sleeping behaviour in either wild or captive elephants, researchers have documented changes in sleep behaviour in wild and captive elephants in relation to age (Tobler, 1992), physical environment (Gruber *et al*., 2000) and ambient temperature (Ganswindt & Munscher, 2008; Joshi, 2009). Furthermore, there is evidence to suggest that elephants will express preferences for certain environmental conditions when engaging in lying for rest: they will choose softer flooring (where available) in preference to a hard surface, and will rest more frequently and for a greater duration when conspecifics are near (Williams *et al*., 2015). However, to date, no studies have directly linked duration of lying rest to welfare in captive elephants.

Of the critically reviewed papers 10 (33%) papers investigated sleep/rest behaviour in captive elephants; in three of these papers, a significant change in rest frequency was noted. Rest behaviour was correlated with two other welfare measures: walking (negative) and stereotypies (negative). In the reviewed studies, reduction in frequency of sleep was associated with events which may be perceived to be stressful to elephants, such as travel (Laws *et al*., 2007), death of a conspecific (Koyama *et al*., 2012) and introduction of novel flooring (Meller *et al*., 2007). However in two of these studies, the results were based on a single elephant.

Laws and colleagues (2007) noted that, following 24 hours of transportation and relocation to a novel herd, time spent resting decreased from approximately 30% of a 24 hour period (all of which occurred at night, and 92% of which was recumbent sleep) to 20% or less (sleeping decreased during the night and increased during the daytime, and sleep was only in a standing position – there was no recumbent rest). An increase in stereotypies and faecal cortisol levels were also noted, which may be representative of overall stress levels. Similar changes in types of rest were observed in a lone-housed female elephant after the death of a conspecific and her movement to a novel enclosure overnight. A negative correlation was noted between stereotypies and rest, and locomotion and rest. Immediately after the loss of the conspecific, the female elephant was observed engaging in long periods of standing rest (SR), and no obvious signs of lying rest (LR) (such as imprints in the sand) were noted (Koyama *et al*., 2010). The authors suggested that the stress from the loss of the conspecific and movement to a novel area may have caused the elephant to experience disturbed sleep or she may have simply felt uncomfortable in her new environment. Meller and colleagues (2007) noted similar behavioural relationships when they introduced a herd of six Asian elephants to novel rubber flooring in their enclosure. During the daytime, SR and locomotion increased whilst exploratory behaviour decreased. At night-time, stereotypies and SR increased and LR and exploratory behaviour decreased.

Time spent sleeping is species, and sometimes individual, specific. Reduced sleep may be indicative of poor welfare in some species but long periods of time spent asleep may also be indicative of underlying illness or even boredom. Hnath and Yannessa (2002) noted a reduction in the length of time two female elephants (one African and one Asian) spent resting when they were presented with time-consuming novel enrichment. The authors reported that instead of resting for ’30 minutes at a time’, the elephants were engaging in other activities, such as breaking up logs. They also reported a decrease in undesirable behaviours such as stereotypies, and an increase in enrichment use and overall activity levels.

Although a relatively infrequently recorded aspect of behaviour, rest (in particular LR) may be an important indicator of welfare in captive elephants. Further research should be undertaken to investigate the factors which affect rest in captive elephants and to investigate the relationship between rest and other, more traditional, welfare indicators.

Feeding

It has been stated that feeding opportunities are of great positive significance to captive animals (Koyama *et al*., 2012). Inappropriate diets and lack of opportunity to perform natural behaviours were listed among the reasons cited by Clubb and Mason (2002) for poor welfare among European zoo elephants. Veasey (2006) suggested that captive elephants should be provided with the opportunity to spend the majority of their day engaging in feeding activities, during which time they should be manipulating and working for their food.

In the wild elephants, spend between 60 and 90% of their day feeding or foraging (Mckay 1973; Wyatt & Eltringham, 1974). The diet of wild African and Asian elephants is predominantly grasses, twigs, bark and other low quality vegetation. Due to the low nutritional quality of their food, and the anatomy and physiology of their digestive system, they need to spend a large proportion of their day feeding in order to fulfil their nutritional needs (Clubb & Mason, 2002). Researchers have reported that elephants in captivity spend as little as 25% of their day feeding or engaging in feeding activities; this is considerably less than their wild counterparts (Rees, 2009; Gruber *et al*., 2000). Rees (2009) attributed the reduced duration of time captive elephants spent feeding to the higher quality of the food provided, the reduced time spent foraging, and the lack of food availability later in the day.

Of the 20 critically reviewed papers, ten (33%) documented changes in feeding behaviour in captive elephants. In three (10%) of these papers, a significant change in feeding frequency was observed. Feeding behaviour correlated significantly with both walking (negative) and expression of stereotypies (negative).

Gruber and colleagues (2000) noted a significant increase in feeding behaviour when elephants were penned rather than chained for restraint; however, this may be due to the physical opportunity that penned elephants had to spend an increased period of time grazing. Similarly, Stoinski and colleagues (2000) identified an increase in feeding activity and a decrease in inactive periods when elephants were presented with browse, which provided the elephants with the opportunity to express a range of natural feeding and forging behaviours. Historically, the use of feeding enrichment for captive elephants has been infrequent (Stoinski *et al*., 2000); when feeding enrichment was used, keepers scattered pre-prepared food or hid ‘treats’ such as peanuts for the elephants to seek out. More recently however there has been a move towards providing more naturalistic feeding enrichment, such as browse.

Clubb and Mason (2002) suggested that lack of stimulation from engaging in foraging activities is one of the main underlying causes of development of stereotypic behaviour. Researchers have also suggested that increased food availability is associated with reduced exhibition of stereotypies (Friend & Parker, 1999), and when frequency of foraging was similar to that of elephants in the wild, relatively little stereotypic behaviour was seen (Koyama *et al*., 2012). It is reasonable to consider that the opportunity to engage in increased periods of natural activity and species-typical behaviours are indicative of good welfare in captive elephants.

Social interactions

African and Asian elephants display very strong affiliative behaviours. In the wild, elephants have three broad social unit levels (family groups, bond groups and clans). The most basic of these, family groups, are composed of one or more related females and their offspring (Moss

& Poole, 1983; Sukumar, 1994). Young male elephants stay with their maternal family group until they are early to mid-teenagers (Lee & Moss, 1999). Both Clubb and Mason (2002) and Harris and colleagues (2008) suggested that elephants in Europe and the UK respectively were being housed in inappropriate social groups, and highlighted this as a serious welfare concern. Guidelines from North American and European zoo associations provide standards for minimum numbers of animals to be kept at a facility. The Association of Zoos and Aquariums (AZA) guidelines state that male elephants must be kept in minimum groups of two individuals (although adult males may be housed alone as long as they are not prevented from interacting with others) and females in groups of at least three individuals (AZA, 2012). The British and Irish Association of Zoos and Aquariums (BIAZA) and the European Association of Zoos and Aquaria (EAZA) state that elephants must be kept in minimum groups of four compatible females, with consideration given to moving females where long term compatibility issues arise (Walter, 2010; Leeuwen, 2004). Guidelines for keeping bull elephants are not so clear; neither minimum group sizes nor group compositions are recommended in the BIAZA elephant management guidelines, beyond the suggestion that it is unacceptable to maintain bulls in physical and social isolation apart from for breeding purposes. It is recognised within the guidelines that more research is needed (Walter, 2010).

Six (20%) critically reviewed papers documented frequency of social interactions amongst captive elephants. Changes in social interactions were not correlated with any other potential welfare measures, however none of the papers which detailed social interactions were focusing solely on social interactions so it is possible that the sampling methods resulted in an underestimation of the frequency of these rarer behaviours which prevented an association with other potential welfare measures. Five papers separated positive social interactions from negative (aggressive) interactions. Frequency of interactions were only expressed as a proportion of activity in four of the six reviewed papers; positive social interactions accounted for less than 10% of behaviour and negative social interactions accounted for less than 1% of behaviour. Where interactions were split into positive and negative behaviours the frequency of negative social behaviour was always lower than positive interactions.

Chadwick and colleagues (submitted) conducted teleconferences with elephant keepers and elephant researchers to identify indicators of welfare which may not be present in the published literature. Social interactions were reported as being an important measure of welfare, specifically: affiliative interactions, play, physical proximity to another elephant and behavioural synchrony within the group. Whilst some minor negative social interactions were deemed to be acceptable, it was suggested that ‘excessive or hyper-aggression’ may be indicative of poor welfare on either an individual or group level (Chadwick *et al*., submitted). Schmid (1995) noted that levels of aggression in his study groups did not differ when the elephants were shackled compared to when they were housed in pens. However he did report that some elephants in his study were separated due to incompatibility, which may affect this finding. Cohesive social behaviour, defined as positive contact between two individuals which lasted for greater than 3 seconds, was more frequent among elephants in paddocks than amongst those kept shackled. Schmid (1995) also went on to note that the number of social partners for each study elephant was greater in the paddocks than when they were chained (when each individual was limited to just the two neighbouring conspecifics) and that and 71% of elephants had a ‘primary’ social partner that was not their chain neighbour when shackled. Schmid (1995) suggested following his study that it is the opportunity for choice of social partner and the opportunity to contact all group members, which was of most importance to each individual. Additionally, Stoinski and colleagues (2001) noted that even though physical touching instances between individuals accounted for less than 5% of

observations, elephants were within one elephant body length of another elephant in up to 50% of observations; which suggests that elephants require more than just tactile contact.

Elephants are highly social, and reports in the peer-reviewed literature and by stakeholders suggest that social interactions are an essential part of the behavioural repertoire of an elephant. Excess aggression within a captive group may be indicative of an underlying welfare problem for either a particular individual or for the entire group. While social interactions involving direct touch may account for only a small part of the overall activity budget when data is gathered using scan sampling methods, the opportunity to interact socially with other individuals (through tactile, visual or acoustic means) is very important for good welfare. Behavioural synchrony within the group may be reflective of the strength of social bonds, and may therefore form an important measure of positive welfare.

Interaction with the environment

Five (17%) critically reviewed papers documented a change in frequency of interactions with the environment, three obtained significant changes in this measure over the course of the study. Interaction with the environment was not, however, significantly correlated with any other measure. Associations were identified between increased environmental interaction, reduced stereotypies and increased social interactions in one paper.

Interaction with the environment, in particular object manipulation, was described by Schmid and colleagues (2001) as a possible displacement activity, which could be a sign of stress in elephants. In their study, they observed behavioural and physiological reactions of elephants when one group of three female Asian elephants was introduced to a group of five Asian elephants (one male, four female). Three of the elephants (two of the three introduced elephants and one of the original group of five) showed an increase in object manipulation six months after the introduction, which is suggestive of a long term behavioural change. However, other long term behavioural changes included reduced stereotypies for all but one individual (one of the three introduced elephants), and increased social interaction. There was no change in urinary cortisol levels. Taken together these measures suggest that the increased object manipulation seen was indicative of good welfare.

Definitions of terms which represented ‘interaction with the environment’ were not always included in the reviewed literature, yet it is apparent that they were used differently in different studies. Schmid and colleagues (2001) described manipulation/exploration as ‘all forms of manipulating objects or substrate with trunk, foot, head or other parts of the body’. Whilde and Marples (2011) specifically described ‘manipulation of non-food objects’; however, this means behaviours such as sniffing the environment would be excluded from their definition. Whilde and Marples (2011) acknowledged the possibility of observer error when categorising object manipulation and feeding. Hnath and Yannessa (2002) described ‘yard investigation’ in their ethogram as “walking, contact with barriers and yard furniture”, but they referred to one of their elephants as ‘wandering around the yard’ in the text of their manuscript, which may be suggestive of a less engaged behaviour.

In order for interaction with the environment to be used as an indicator of welfare, there must be a clear definition which is used across all future studies. Wandering aimlessly is likely to be a sign of an environment which is not providing appropriate enrichment or stimulation, and if the elephant is engaging in environmental interaction as a displacement activity, this could also be a welfare concern. However, if the increase in environmental interaction is associated with other positive welfare indictors (for example, reduced periods of inactivity or reduced stereotypies), then increased levels of interaction with the environment may be a sign of the elephant becoming more engaged and active within their environment.

Walking

Provision of food in devices designed to provide cognitive enrichment may occupy time and provide mental stimulation for elephants, but they do not necessitate the walking (Posta *et al*., 2013) that is required in the wild when elephants are foraging and feeding. Distance elephants travel in the wild has been attributed to availability and distribution of resources (Leighty *et al*., 2009), yet to date little is known about how far elephants 'should' walk in order to optimise welfare. Researchers have suggested that obesity is one of the major causes of premature death in European zoo elephants (Clubb *et al*., 2008). Furthermore, obesity and restricted movement are major causes of poor foot health, arthritis and degenerative joint disease in captive elephants (Hittmair & Vielgrader, 2000; Csuti *et al*., 2001). Thus, it would appear that the physical activity of walking is essential for good health, and thus good welfare.

Changes in activity levels, specifically frequency of walking behaviour, was described by 10 (33%) of the peer reviewed papers; half of these papers reported significant changes. Frequency of walking correlated with rest (negative), feeding (negative) and stereotypic pacing (positive).

Whilde and Marples (2011) observed a group of four female Asian elephants prior to and following the birth of an elephant in the group. A significant increase in frequency of walking was recorded in two of the elephants – which the authors attributed to an increased interest and incentive to move about the enclosure caused by the presence of the calf. Similarly, in a study which assessed walking rates in a group of African elephants, Leighty and colleagues (2009) noted that females housed in larger enclosures and in complex social groups (consisting of multiple adult females and their calves) walked more than those housed in smaller enclosures or single parent and offspring groups. During the study, elephants were actively encouraged to move around the enclosures through the use of well distributed resources. In addition, they rotated the social groups between different enclosures to mimic provision of novel scents; it was felt this would encourage naturalistic exploratory behaviours as seen in the wild. In both these instances, it can be assumed that walking is a positive outcome from the stimulation provided by young animals within the group.

However the frequency of walking behaviour appears to be context dependent. Meller and colleagues (2007) documented an increase in walking behaviour in a group of Asian elephants following introduction of novel flooring. At the same time as this behavioural change, an increase in stereotypic pacing was observed. It is therefore possible that the increased walking seen was actually just an increase in expression of stereotypic pacing behaviour; it may be difficult in short term observations to distinguish between 'normal' walking behaviour and stereotypic pacing. Some elephants engage in more 'normal' walking behaviour than others within the same environment (E. Williams, personal observation), so documentation of walking activity may not always be indicative of current welfare state.

Comfort (self-maintenance) behaviours

Frequency of comfort or self-maintenance behaviours were often reported in those studies which determined general activity budgets in captive elephants. Twelve papers in the peer reviewed literature documented a change in frequency of this behaviour, four of them significantly. Despite this behaviour being widely reported, in the studies analysed, comfort behaviours were not correlated with any other measures of welfare. In two of the reviewed papers, the researchers investigated the change in behaviour when elephants were chained versus when they were penned. In both reports, self-maintenance behaviours were significantly more likely to occur when elephants were housed in pens or paddocks than

when they were chained or shackled. However, in both instances the authors suggest this finding is likely due to the restraint imposed in chains or shackles and the physical lack of opportunity to access appropriate facilities.

Elephants are known to use 'tools' to assist in skin care (Kurt & Garai, 2007), and dust bathing in particular is reported to have various benefits to elephants in terms of physical (e.g. through temperature regulation and protection from sun and parasites) and mental health (e.g. opportunity for social interaction and potential for behavioural synchrony) (Rees, 2009). Despite their frequent descriptions in the literature self-maintenance behaviours accounted for less than 5% of total activity in the reviewed papers, and so was frequently grouped into an 'other' category. So while it remains clear that elephants should have the opportunity and the appropriate provisions to perform self-maintenance behaviours such as scratching and grooming, the infrequency of their occurrence renders this behaviour impractical as a welfare indicator.

Other

Less frequently used indicators of welfare included inactivity, play behaviour and vocalisations. None of these measures correlated with the more commonly used indicators of welfare. A change in frequency of play behaviour was reported in two of the peer reviewed papers (6%); in one of these studies, a significant change was reported. Levels of inactivity, and vocalisations, were reported to change significantly in one paper each (3%).

Physiological indicators of welfare

Assessment of levels of stress hormones - corticosteroids

Eight (27%) of the critically reviewed papers assessed levels of cortisol, five of which found a significant change. Cortisol is a glucocorticoid hormone produced by the adrenal glands in response to activation of the hypothalamic-pituitary-adrenal axis, which often happens in times of stress (Mostl & Palme, 2002). Measurement of glucocorticoids (cortisol or its metabolites) was carried out through various mediums; saliva (three papers), faeces (three papers), serum (three papers) and urine (two papers). Glucocorticoids were noted to correlate with stereotypies (positive) and personality traits (as identified using a keeper assessment of personality).

Increases in levels of cortisol have been reported in potentially 'stressful' situations, for example, following the introduction of a new female elephant into a pre-existing herd (Dathe, 1992), zoo opening (Menargues *et al*., 2008), travelling, exposure to loud noises and on days with human interaction (Millspaugh *et al*., 2007). Furthermore increases in levels of cortisol have been associated with other potential welfare indicators: increased stereotypies and reduced lying rest (Laws *et al*., 2007).

Levels of cortisol must be interpreted with caution as an indicator of welfare. It is widely understood that coping mechanisms differ between individuals and it is not yet clear if there is an 'optimum' coping strategy (Fanson *et al*., 2013). During a study investigating adrenocortical activity following translocation in eight Asian elephants, Fanson and colleagues (2013) observed an increase in faecal glucocorticoid metabolites (FGM) but a decrease in urinary glucocorticoid metabolites (UGM) and no change in serum cortisol. Individuals varied in their adrenocortical response to relocation but the authors did observe a positive relationship between baseline FGM levels and duration of increase in FGM post transport.

Grand and colleagues (2012) identified a positive relationship between cortisol levels and the 'fearful' personality score, and a negative relationship between cortisol levels and 'effective',

'sociable' and 'aggressive' scores, where 'effective' was defined as 'gets its own way by controlling other elephants'. Fanson and colleagues (2013) noted that baseline levels of serum cortisol and UGM were lower in Asian elephants who were faster at learning new things. Post relocation they also recorded more prolonged increases in FGM in curious as opposed to timid elephants and in reclusive as opposed to social elephants. More research is needed on the use of keeper assessments of personality in the improvement of zoo elephant welfare. Whilst not necessarily a measure of welfare, personality assessments could provide the information needed to tailor management strategies to individual elephants, which could ultimately help to improve their welfare in captivity (Grand *et al*., 2012).

Physiological responses to stressors are complex and can vary between individuals and contexts, however, when interpreted with caution and where possible used alongside behavioural measures, non-invasive techniques for monitoring GC are a useful tool in welfare assessment (Palme, 2012).

Physical indicators of welfare

The two most well recognised physical measures of welfare in elephants are body condition score and foot health. Four (13%) of the papers critically reviewed assessed physical health of an elephant; three using body condition scoring and one assessing foot health.

Ramanthan and Mallapur (2008) used a keeper questionnaire to gather data on the physical condition of captive working Asian elephants in India. They asked keepers to rate the physical condition (using pre-defined ranks) of each individual in their care based on a selection of indices. The indices included body condition score, skin condition, eye sight, presence or absence of wounds and abscesses, and presence and severity of foot fissures and toe nail cracks. Godogama and colleagues (1998) and Wemmer and colleagues (2006) both developed systems which allowed for visual assessment of the physical condition of Asian elephants. In both papers researchers looked at six predominant areas of the elephant; temporal depression of the head, the scapula (shoulder blade), thoracic region, flank area, lumbar vertebrae and the pelvic bone. Wemmer and colleagues (2006) trialled the proposed scoring method using multiple observers to ensure reliability of the method. Pictures and descriptions were provided to ensure accuracy of the ratings. Elephants were given a score of between 0 and 2 for each body area, and these scores were then added to give a numerical index which related to the physical health of the observed individual (Wemmer *et al*., 2006). At the time this review was conducted no papers were identified which assessed physical body condition in African elephants; however, Morfeld and colleagues (2014) have more recently identified and validated a 5 point body condition index for female African elephants. Using 33 captive female African elephants, they determined that there was a strong positive correlation between measures of subcutaneous fat thickness (assessed using ultrasound scans) and scores of five regions of the body.

Assessment of physical welfare using a body condition scoring protocol has the advantage of being relatively easy to learn and quick to conduct (Wemmer *et al*., 2006). Particularly in the captive setting body condition scoring can be easily incorporated into routine health checks. Obesity in zoo elephants has been cited as a significant problem, and has been linked to poor foot health, arthritis and reduced reproductive output (Clubb *et al*., 2008; Clubb *et al*., 2009). It is therefore vitally important to assess and track body condition in captive elephants over time, to facilitate rapid identification of any changes that may present or be indicative of a health concern. In addition, assessment of physical health, especially foot health, is being increasingly incorporated into preventative care management approaches for elephants in British and Irish zoos (Walter, 2010).

References

Abou-Ismail UA, Burman OHP, Nicol CJ and Mendl M 2007 Can sleep behaviour be used as an indicator of stress in group-housed rats (Rattus norvegicus)? *Animal Welfare* 16: 185 – 188

AZA 2012 AZA standards for Elephant Management and Care.

Broom DM 1983 Stereotypies as Animal Welfare Indicators, in Smidt, D. (ed.) *Indicators relevant to farm animal welfare: A seminar in the CEC Programme of coordination of research on animal welfare, organized by Dr. D. Smidt, and held in Mariensee, 9-10 November 1982*. Netherlands: Springer

Chadwick CL, Williams E, Asher L and Yon L Submitted Stakeholders' opinions on assessing the welfare of elephants (Loxodonta africana and Elephas maximus) housed in UK zoos. *Submitted*.

Clubb R and Mason G 2002 *A review of the welfare of zoo elephants in Europe*. Horsham, UK: RSPCA

Clubb R, Rowcliffe M, Lee P, Mar KU, Moss C and Mason GJ 2008 Compromised Survivorship in Zoo Elephants. *Science* 322(5908): 1649–1649.

Clubb R, Rowcliffe M, Lee P, Mar KU, Moss C and Mason GJ 2009 Fecundity and population viability in female zoo elephants: problems and possible solutions. *Animal Welfare* 18: 237 – 247.

Csuti B, Sargent EL and Bechert US (eds) 2001 *The Elephant's Foot: Prevention and Care of Foot Conditions in Captive Asian and African Elephants*. Iowa State Press

Dathe HH, Kuckelkorn B and Minnemann D 1992 Salivary cortisol assessment for stress detection in the Asian elephant (Elephas maximus): A pilot study. *Zoo Biology* 11(4): 285–289.

Elzanowski A and Sergiel A 2006 Stereotypic Behavior of a Female Asiatic Elephant (Elephas maximus) in a Zoo. *Journal of applied animal welfare science* 9(3): 223 – 232.

Fanson KV, Lynch M, Vogelnest L, Miller G and Keeley T 2013 Response to long-distance relocation in Asian elephants (Elephas maximus): monitoring adrenocortical activity via serum, urine, and feces. *European Journal of Wildlife Research* 59(5): 655 - 664.

Friend TH and Parker ML 1999 The effect of penning versus picketing on stereotypic behavior of circus elephants, *Applied Animal Behaviour Science* 64(3): 213–225.

Ganswindt A and Munscher S 2008 Take a nap: sleeping behaviour of free-ranging male African elephants (Loxodonta Africana) during the day. In: Morris S and Vosloo A (eds) *Proceedings of the 4th CPB Meeting in Africa, Molecules to migration: The pressures of life.* Italy: Morris

Godogama WK, Wemmer C and Ratnasooriya WD 1998 The body condition of Sri Lankan domesticaded elephants (Elephas maximus maximus). *Ceylon Journal of Science (Biological Sciences)* 26: 1 – 6.

Grand AP, Kuhar CW, Leighty KA, Bettinger TL and Laudenslager ML 2012 Using personality ratings and cortisol to characterize individual differences in African Elephants (Loxodonta africana). *Applied Animal Behaviour Science* 142(1-2): 69–75.

Gruber TM, Friend TH, Gardner JM, Packard JM., Beaver B and Bushong D 2000 Variation in stereotypic behavior related to restraint in circus elephants. *Zoo Biology* 19(3): 209–221.

Hanninen L 2007 *Sleep and rest in calves: relationship to welfare, housing and hormonal activity*. PhD Thesis thesis. University of Helsinki.

Harris M, Sherwin C and Harris S 2008 *The welfare, housing and husbandry of elephants in UK zoos. Defra WC05007*. Bristol: Defra

Haspeslagh M, Stevens J, De Groot E, Dewulf J, Kalmar I and Moons C 2013 A survey of foot problems, stereotypic behaviour and floor type in Asian elephants (Elephas maximus) in European zoos. *Animal Welfare* 22(4): 437–443.

Hittmair KM and Vielgrader HD 2000 Radiographic diagnosis of lameness in African elephants (Loxodonta africana). *Veterinary Radiology Ultrasound* 41(6): 511–515.

Hnath PT and Yannessa MN 2002 Effects of facility modifications on elephant activity levels. *Animal Keepers Forum* 29(10): 421 – 427.

Joshi R 2009 Asian Elephant's (Elephas maximus) Behaviour in the Rajaji National Park, North-West India: Eight Years with Asian Elephant. *Nature and Science* 7(1): 49 – 77.

Koyama N, Ueno Y, Eguchi Y, Uetake K and Tanaka T 2012 Effects of daily management changes on behavioral patterns of a solitary female African elephant (Loxodonta africana) in a zoo. *Animal Science Journal* 83(7): 562–570.

Kurt F and Garaï ME 2007 *The Asian elephant in captivity: a field study*. Delhi: Foundation Books

Laws N, Ganswindt A, Heistermann M, Harris M, Harris S and Sherwin C 2007 A Case Study: Fecal Corticosteroid and Behavior as Indicators of Welfare During Relocation of an Asian Elephant. *Journal of Applied Animal Welfare Science* 10(4): 349–358.

Lee PC and Moss CJ 1999 The social context for learning and behavioral development among wild African elephants, in Box HO and Gibson KR (eds) *Mammalian Social Learning: Comparative and Ecological Perspectives (Symposia of the Zoological Society of London)*. Cambridge: Cambridge University Press

Leeuwen 2004 EAZA news – Elephant special, *EAZA newsletter*, 47

Leighty KA, Soltis J, Wesolek CM, Savage A, Mellen J and Lehnhardt J 2009 GPS determination of walking rates in captive African elephants (Loxodonta africana). *Zoo Biology* 28(1): 16–28.

Lima SL, Rattenborg NC, Lesku JA and Amlaner CJ 2005 Sleeping under the risk of predation. *Animal Behaviour* 70(4): 723–736.

Mason GJ 1991 Stereotypies: a critical review. *Animal Behaviour* 41(6): 1015–1037.

Mason GJ and Latham NR 2004 Can't stop, won't stop: is stereotypy a reliable animal welfare indicator? *Animal Welfare* 13: S57 – 69.

Mason GJ 2006 Stereotypic behaviour in captive animals: fundamentals and implications for welfare and beyond. In: Mason G and Rushen J (eds) *Stereotypic animal behaviour fundamentals and applications to welfare*. 2nd edn. Wallingford: CAB International.

McKay GM 1973 Behavior and ecology of the Asiatic elephant in southeastern Ceylon. *Smithsonian Contributions to Zoology* (125): 1–113.

Meller CL, Croney C and Shepherdson D 2007 Effects of rubberized flooring on Asian elephant behavior in captivity. *Zoo Biology* 26(1): 51–61.

Menargues A, Urios V and Mauri M 2008 Welfare assessment of captive Asian elephants (Elephas maximus) and Indian rhinoceros (Rhinoceros unicornis) using salivary cortisol measurement. *Animal Welfare* 17: 305 – 312.

Millspaugh JJ, Burke T, Van Dyk G, Slotow R, Washburn BE and Woods RJ 2007 Stress Response of Working African Elephants to Transportation and Safari Adventures. *Journal of Wildlife Management* 71(4): 1257–1260.

Morfeld KA, Lehnhardt J, Alligood C, Bolling J and Brown JL 2014 Development of a Body Condition Scoring Index for Female African Elephants Validated by Ultrasound Measurements of Subcutaneous Fat. *PLoS ONE* 9(4): e93802.

Moss CJ and Poole J 1983 Relationships and social structure in African elephants. In: Hinde RA (ed) *Primate Social Relationships: An Integrated Approach*. Oxford: Blackwell Science

Möstl E and Palme R 2002 Hormones as indicators of stress. *Domestic Animal Endocrinology* 23(1-2): 67–74

Palme R 2012 Monitoring stress hormone metabolites as a useful, non-invasive tool for welfare assessment in farm animals. *Animal Welfare* 21(3): 331–337

Posta B, Huber R and Moore III DE 2013 The Effects of Housing on Zoo Elephant Behavior: A Quantitative Case Study of Diurnal and Seasonal Variation. *International Journal of Comparative Psychology* 26(1): 37 – 52.

Rees PA 2009 Activity budgets and the relationship between feeding and stereotypic behaviors in Asian elephants (Elephas maximus) in a Zoo. *Zoo Biology* 28(2): 79–97.

Schmid J 1995 Keeping circus elephants temporarily in paddocks – the effects on their behaviour. *Animal Welfare* 4: 87 – 101.

Schmid J, Heistermann M, Ganslober U and Hodges JK 2001 Introduction of foreign female Asian elephants (Elephas maximus) into an existing group: behavioural reactions and changes inn cortisol levels. *Animal Welfare* 10: 357 – 372.

Stoinski TS, Daniel E and Maple TL 2000 A preliminary study of the behavioral effects of feeding enrichment on African elephants. *Zoo Biology* 19(6): 485–493.

Sukumar R 1994 *Elephant days and nights: ten years with the Indian elephant*. New York: Oxford University Press

Swaisgood RR and Shepherdson DJ 2005 Scientific approaches to enrichment and stereotypies in zoo animals: what's been done and where should we go next? *Zoo Biology* 24(6): 499–518.

Tobler I 1992 Behavioral sleep in the Asian elephant in captivity. *Sleep* 15: 1 – 12.

Veasey J 2006 Concepts in the care and welfare of captive elephants. *International Zoo Yearbook* 40(1): 63–79.

Walter O 2010 Management guidelines for the welfare of zoo animals: elephants. 3rd edition. UK: BIAZA

Wemmer C, Krishnamurthy V, Shrestha S, Hayek LA, Thant M. and Nanjappa KA 2006 Assessment of body condition in Asian elephants (Elephas maximus) *Zoo Biology* 25(3) 187–200

Whilde J and Marples N 2011 Effect of a birth on the behavior of a family group of Asian elephants (Elephas maximus) at Dublin Zoo. *Zoo Biology* 31(4): 442–452.

Williams E, Bremner-Harrison S, Harvey N, Evison E and Yon L 2015 An investigation into resting behaviour in Asian elephants in UK zoos. *Journal of Zoo Biology* 34: 406 - 417

Wyatt JR and Eltringham SK 1974 The daily activity of the elephant in the Rwenzori National Park, Uganda. *African Journal of Ecology* 12(4): 273–289

Table 2. Behavioural indicators of welfare identified in the peer reviewed literature which have been used in assessment of captive elephant welfare

Type of indicator	Indicator category	Example of indicators used	Mean (range, SD) of the number of elephants studied	Correlation with other measures	Authors which used the indicator*	Significant change	Percent change
Behavioural	Abnormal behaviour	Stereotypies, foot lifting, faeces manipulation, trunk swinging	16 (1 – 140, 32)	Feeding Walking Resting Foot health Cortisol	Koyama et al (2012) Laws et al (2007) Gruber et al (2000) Vanitha et al (2011) Elzanowski & Sergiel (2006) Friend (1999) Hnath & Yannessa (2002) Schmid (1995) Schmid et al (2001) Wells & Irwin (2008) Wilson et al (2004) Rees (2004) Friend & Parker (1999) Meller et al (2007) Stoinski *et al* (2000) Whilde & Marples (2011) Rees (2009)	9 papers	17 papers
	Sleep/rest	Standing rest, lying rest	7 (1 – 17, 6)	Walking Stereotypies	Koyama et al (2012) Laws et al (2007) Gruber et al (2000) Friend (1999) Hnath & Yannessa (2002) Schmid et al (2001) Posta et al (2013) Friend & Parker (1999) Meller et al (2007)	3 papers	3 papers

				Whilde & Marples (2011)		
Feeding	Eating, drinking, ingestion	6 (1 – 17, 5)	Walking Stereotypies	Koyama et al (2012) Gruber et al (2000) Friend (1999) Hnath & Yannessa (2002) Schmid et al (2001) Posta et al (2013) Stoinski et al (2000) Whilde & Marples (2011) Rees (2009) Wells & Irwin (2008)	3 papers	10 papers
Environmental interaction	Enrichment use, investigative/ exploratory behaviour	4 (2 – 7, 2)		Posta et al (2013) Meller et al (2007) Stoinski et al (2000) Whilde & Marples (2011) Hnath & Yannessa (2002) Schmid et al (2001)	3 papers	6 papers
Comfort (self-maintenance)	Dust bathing, mud wallowing, general grooming	9 (1 – 29, 8)		Koyama et al (2012) Gruber et al (2000) Friend (1999) Hnath & Yannessa (2002) Schmid (1995) Schmid et al (2001) Wells & Irwin (2008)	4 papers	12 papers

				Friend & Parker (1999) Stoinski et al (2000) Whilde & Marples (2011) Rees (2009) Posta et al (2013)		
Activity	Walking/locomotion	6 (1 – 14, 4)	Rest Feeding Stereotypies	Posta et al (2013) Koyama et al (2010) Gruber et al (2000) Schmid et al (2001) Wells & Irwin (2008) Stoinski et al (2000) Meller et al (2007) Rees (2009) Whilde & Marples (2011) Leighty et al (2009)	5 papers	10 papers
Inactive		3		Stoinski et al (2000)	1 paper	1 paper
Social interactions	Positive interactions (affiliation), negative interactions (agression)	10 (2 - 29, 9)		Gruber et al (2000) Schmid (1995) Schmid et al (2001) Wells & Irwin (2008) Posta et al (2013) Stoinski et al (2000)	3 papers	5 papers
Other	Vocalisations	4 (4 – 4, 0)		Wells & Irwin (2008) Soltis (2010)	1 papers	1 papers
	Play	17 (4 – 29, 13)		Whilde & Marples (2011) Schmid (1995)	1 papers	2 papers

Physical	Assessment of body condition/health (except feet)	Body condition score, assessment of mucous membranes, skin condition, eyesight, oedemas, wounds, abscesses	114 (82 – 140, 24)		Ramanthan & Mallapur (2008) Godogama et al (1998) Wemmer et al (2006)	NA	NA
	Assessment of foot health	Toenail cracks, presence of foot fissures, abscesses	87	Stereotypies	Haspeslagh et al (2013)	NA	NA
Physiological	Glucocorticoid and glucocorticoid metabolites analysis	Salivary cortisol, serum cortisol, faecal glucometabolites, urinary glucometabolites	5 (1 – 8, 2)	Other measures of cortisol Personality Stereotypies	Dathe et al (1992) Fanson et al (2013) Grand et al (2012) Laws et al (2007) Menargues et al (2008) Millspaugh et al (2007) Schmid et al (2001) Wilson et al (2004)	8 papers	10 papers

Table 3. Summary of the 30 articles reviewed

Authors	Species	Sample size	No. of institutions	Validity	Reliability	Time period	Method of assessing welfare	Study design	Welfare measures
Dathe et al (1992)	EM	2 (0.2)	1	Criterion	Intra and inter assay coefficients of variation	15 - 18 days	Comparison with normal cortisol concentration range	Observational, repeated measures, qualitative	Salivary cortisol[%]
Elzanowski & Sergiel (2006)	EM	1 (0.1)	1	Criterion	None reported	35 days in 1 year	Monitoring behavioural changes following changes to the environment	Experimental, repeated measures, quantitative	Stereotypies[S]
Fanson et al (2013)	EM	8 (1.7)	3	Criterion	None reported	1 year	Compared observed results with expected results, monitored change in cortisol over time	Observational, repeated measures, quantitative and qualitative assessment of personality	Faecal gluco metabolites (FGM)[SC] UGM[SC] Serum Cortisol[SC] Keeper Assessment of Personality[C]
Friend (1999)	EM/LA	14 EM (0.14), 3 LA (0.3)	1	Criterion	None reported	October 1995 (4 x 8hrs) and April 1996 (3 x 24hrs)	Monitoring behavioural changes prior to scheduled events		Stereotypies[%] Resting[%] Eating/drinking[%] Dust bathing[%]
	EM/LA	14 EM (0.14), 3	1	Criterion		April 1996 and April	Monitoring behavioural	Experimental, repeated	Stereotypies[S] Standing

Authors	Species	Sample size	No. of institutions	Validity	Reliability	Time period	Method of assessing welfare	Study design	Welfare measures
Friend & Parker (1999)		LA (0.3)			None reported	1998 (3 x 24hrs during each period)	changes following changes to the environment	measures, quantitative	Lying Eating Drinking Dust bathing
Godogama et al (1998)	EMM	140 (72.68)	13 districts		None reported	N/A		Qualitative - BCS, independent	Body condition score
Grand et al (2012)	LA	5 (0.5)	1	Construct	Inter-rater	One month	Correlations predicted between types of cortisol measures and between cortisol and personality characteristics	Observational, repeated measures, qualitative	Keeper assessment of personality[SC] Salivary cortisol[SC] Serum cortisol[SC]
Gruber et al (2000)	EM/LA	EM 11 (1.10) LA 3 (0.3)	1	Criterion	Intra rater and inter-rater	2 months per treatment group	Monitoring behavioural changes between treatment groups	Experimental, repeated measures, quantitative	Stereotypies[S] Aggression Comfort[S] Ingestion[S] Locomotion[S] Resting Social[S]
Haspeslagh et al (2013)	EM	87 (16.71)	32	Construct	None reported	N/A	correlation predicted between behavioural		Stereotypies[C] Foot health[C]

Authors	Species	Sample size	No. of institutions	Validity	Reliability	Time period	Method of assessing welfare	Study design	Welfare measures
							and physical measures of welfare		
Hnath & Yannessa (2002)	EM/LA	2 (0.2)	1	Criterion	None reported	3 days per week for 2 weeks, then 4 month break (following environmental change) then 3 days per week for 2 weeks	Monitoring behavioural changes following changes to the environment	Observational, repeated measures, quantitative	Keeper/elephant interaction[%] Feeding[%] Enrichment use[%] Yard investigation[%] Dust bathing[%] Resting[%] Stereotypies[%]
Koyama et al (2012)	LA	1 (0.1)	1	Construct and Criterion	None reported	1 year	Monitoring change in behaviour over time, following presumed stressful event	Prospective, observational, repeated measures, quantitative	Feeding[C%] Comfort[%] Locomotion[C%] Resting[C%] Stereotypies[C%]
Laws et al (2007)	EM	1 (1.0)	2	Construct and Criterion	Intra and inter- assay coefficients of variation	20 days (10 days prior to event and	Monitoring change in behaviour and cortisol following	Prospective, observational, repeated measures, quantitative	Stereotypies[%] Sleep[%] FGM[S]

Authors	Species	Sample size	No. of institutions	Validity	Reliability	Time period	Method of assessing welfare	Study design	Welfare measures
						10 days post event)	presumed stressful event		
Leighty et al (2009)	LA	7 (0.7)	1	Criterion	None reported	1 year	Monitoring behavioural changes in different scenarios	Experimental, repeated measures, quantitative	Locomotion[S]
Lewis et al (2010)	EM/LA	EM 137 (26.111), LA 151 (21.130)	78		None reported	N/A			Presence of foot pathologies
Meller et al (2007)	EM	6 (2.4)	1	Criterion	Inter-observer	3 days per observation period (3 periods)	Compared with choices and then monitored overall behavioural change following environmental manipulation	Experimental, repeated measures, quantitative	Locomotion[S] Standing rest[S] Lying rest[S] Foot-lifting Exploratory[S] Stereotypies[S]
Menargues et al (2008)	EM	6 (0.6)	1	Criterion	None reported	4 months	Comparison with normal cortisol	Observational, repeated measures, quantitative	Salivary cortisol[S]

Authors	Species	Sample size	No. of institutions	Validity	Reliability	Time period	Method of assessing welfare	Study design	Welfare measures
							concentration range		
Millspaugh et al (2007)	LA	5	1	Criterion	standard assay validation	1 year	Monitoring change over time, comparison with wild	Prospective, Observational, repeated measures, quantitative	FGM[S]
Posta et al (2013)	LA	2 (1.1)	1	Criterion	Inter-observer	2 years	Comparison with wild	Experimental, repeated measures, quantitative	Feed[%] Nurse[%] Stand[%] Lie[%] Walk[%] Enrichment Use[%] Self-directed[%] Investigation[%] Affiliation[%] Aggression[%]
Ramanthan & Mallapur (2008)	EM	82 (33.49)	10		None reported – measures taken to increase reliability	N/A		Qualitative - BCS, independent	Mucous membrane Body condition score Skin condition Foot fissures Toenail cracks Edema Eyesight Wounds Abscess

Authors	Species	Sample size	No. of institutions	Validity	Reliability	Time period	Method of assessing welfare	Study design	Welfare measures
Rees (2004)	EM	8 (2.6)	1	Criterion	None reported – measures taken to increase reliability	35 days	Monitoring how stereotypies change over time	Observational, repeated measures, quantitative	Stereotypies[S]
Rees (2009)	EM	8 (2.6)	1	construct and Criterion	None reported – measures taken to increase reliability	35 days	Monitoring how activity budgets change over time	Repeated measures, observational, quantitative	Dust bathing[S] Feeding[C] Locomotion Standing Stereotypies[SC]
Schmid (1995)	EM/LA	EM 19 (0.19), LA 10 (0.10)	4	Criterion	None reported	4 to 11 days	comparison of species typical behaviours between keeping systems	Experimental, repeated measures, quantitative	Social – attractive Social – cohesive[S] Social – repulsive Comfort[S] Object play[S] Stereotypies[S]
Schmid et al (2001)	EM	7 (0.7)	1	construct and Criterion	intra and inter assay coefficients	7 months	Correlation between behavioural and physiological indicators of welfare, looking at changes following	Experimental, repeated measures, quantitative	Stereotypies Social Comfort Feeding Locomotion Resting Manipulation/exploration Glucocorticoids

Authors	Species	Sample size	No. of institutions	Validity	Reliability	Time period	Method of assessing welfare	Study design	Welfare measures
							presumably stressful event		
Soltis (2010)	LA	4 (4.0)	1	Criterion	None reported	14.5 months	Documenting elephant rumbles in different social situations	Observational, repeated measures	Vocalisation[S]
Stoinski et al (2000)	LA	3 (0.3)	1	Criterion	Inter-rater	1 month	Monitoring change over time	Experimental, repeated measures, quantitative	Feed[S] Drink[S] Object exam Faeces manipulation Locomotion Social Sterotypies Mud wallowing Self-directed Inactive[S] Contact[S]
Vanitha et al. (2011)	EM	140	80	Criterion	None reported	2 years		Retrospective, observational, independent measures, objective questionnaire	Stereotpyies[S]
Wells and Irwin (2008)	EM	4 (0.4)	1	Criterion	Test re-test	Initial study over 21 days, study	Environmental manipulation	Experimental, repeated	Stand Move Socialise Aggression

Authors	Species	Sample size	No. of institutions	Validity	Reliability	Time period	Method of assessing welfare	Study design	Welfare measures
						repeated 4 months later for 3 days		measures, quantitative	Dust bathe Object interaction Eat Drink Vocalise Abnormal behav[S]
Wemmer et al. (2006)	EM	119 (58.61)	7		None reported – measures taken to increase reliability	Single point		Qualitative - BCS, independent	Body Condition Scoring
Whilde and Marples (2011)	EM	4 (0.4)	1	Criterion	None reported – measures taken to increase reliability	10 days prior to event, 2 months post event	Monitoring behavioural changes following an event	Experimental, repeated measures, quantitative	Walk[S] Feed Stand[S] Stereotypy Trunk swing Maintenance Manipulation of non-food items[S] Play Lie Associations[S]
Wilson et al. (2004)	LA	3 (0.3)	1	construct and Criterion	Inter-rater	10 weeks during 2001	Comparison of behavioural changes at two points in time	Repeated measures, observational, quantitative	Blood cortisol[%C] Stereotypies[%C]

Authors	Species	Sample size	No. of institutions	Validity	Reliability	Time period	Method of assessing welfare	Study design	Welfare measures
							(1992, 1994, 2001)		

[S] Measure identified as being statistically significant in the study, [C] Measure correlated with another welfare measure in the study, [%] Percentage change in the study