

Chapter 11

How should the psychological welfare of zoo elephants be investigated?

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The welfare of elephants is an enormous challenge for zoos in terms of animal husbandry, financial cost and public perception. This chapter's aim is not to discuss whether elephants should be held in captivity: resolving this issue would involve sound data on the costs and benefits of keeping them in zoos, and reconciling the diverse ethical beliefs of different people. Instead, we review how animal welfare is assessed scientifically; discuss what is known about these various techniques for elephants; survey the evidence concerning population-level welfare of elephants in zoos; summarize the possible causes of reduced welfare amongst captive elephants; review the (disturbingly sparse) information that has been collated to test some of these ideas; and discuss what future work is needed to objectively evaluate the psychological welfare of zoo elephants.

What do we mean by welfare and how can we measure it?

Animal welfare relates to an animal's affective state: what it feels. Good welfare thus means experiencing positive emotional states and negligible suffering, while poor welfare entails severe or prolonged states of mental suffering (e.g., Dawkins 1990; Mason & Mendl 1993). To augment this definition, we should clarify what welfare is *not*. First, health and welfare are distinguishable. Although health can obviously affect welfare (and welfare can affect health, as we review below), health typically refers to physical, not psychological, well-being. Thus, if a disease causes pain, or reduces an animal's ability to behave normally, it may well reduce welfare; however, an ailment that does not influence behavior or stimulate pain receptors (e.g., a tumor that the animal cannot feel) does *not* necessarily affect welfare, at least at that time. Second, welfare is not about simple genetic fitness, i.e. the extent to which an individual increases the frequency of its genes in subsequent generations. While poor welfare can decrease reproductive output, this is not always the case. It would be incorrect, for example, to assume that highly selected livestock that are managed intensively have acceptable welfare simply because they are reproducing. Third, good welfare is not about mimicking all aspects of natural life. Performing some natural activities may be important for an animal's welfare, but others may be harmlessly eliminated when human provisioning and protection render them obsolete (e.g., Veasey, Waran & Young 1996a). Furthermore, life in the wild can, as Hobbes put it, be "nasty, brutish and short"; the behavioral repertoire, health status and lifespan of free-living animals thus do not automatically yield high welfare benchmarks (see also Veasey et al. 1996a; Veasey, Waran & Young 1996b). Finally, death *per se* must be differentiated from welfare. The manner in which an animal

dies, and the factors precipitating its death, are relevant to welfare—since the processes involved may have caused suffering. However, because death involves the cessation of brain activity (which eliminates the possibility of suffering), and because death can be humane (the aim of "euthanasia" by definition), loss of life *per se* need not imply poor welfare.

If welfare is about how an animal feels, then in the absence of a common language, how do we investigate it? The subjective experiences, thoughts and feelings of an individual animal are inaccessible (the so-called "Other Minds" problem), and so to assess them we need indirect indicators of psychological well-being. When evaluating welfare in other humans, we use learned verbal or sign language, as well as innate "body language" (smiling, crying, grimacing, etc.), whose affective correlates we understand from our own experiences and behavior. In general, these indices serve us well—but they can be challenging and potentially unreliable in some cases: for example, for premature and neonatal infants, the profoundly physically disabled, and people with disorders like psychopathy. In such instances, physiological indices may be used, such as changes in heart rate, skin conductivity, or endocrine and immune responses validated as correlates of distress. Similar challenges—perhaps even greater ones—are faced when evaluating welfare in other species. We have to interpret alien signals (ear-flapping, growling, etc.); we may well need indices of physiological functioning; and we must interpret all our findings without anthropomorphism, bias or circular reasoning. Overall, we have to recognize that we can never be certain about the conscious experiences of other beings, although assuming that they do exist is a precautionary principle used by most. As a

result, what are commonly referred to as “welfare measures” are, in fact, welfare *indicators* from which we can only make inferences.

But what exactly are these indices and where do they come from? Most have their historical origins in two well-established fields of science: clinical research into humans with physical or mental problems, and experimental animal-based physiology and neuroscience research. The relevant human clinical research involves work on suffering people: individuals going through stressful events like divorce, bereavement, war or exams; experiencing emotional disorders such as anxiety and depression; or experiencing physical harm that causes pain or nausea. These individuals’ verbal reports of their subjective experiences can be compared with changes in their biological functioning (e.g., hormonal profiles), to glean potential indices of mental state. The second type of research to generate welfare indices has been fundamental work in which research animals (typically rats, mice and primates) are exposed deliberately to events believed to cause fear, sickness or pain. Some relevant work also experimentally mitigates suffering via analgesic drugs, anxiolytics or anti-depressive agents. Behavioral and physiological changes seen in these animals are, again, potential indices of the emotional state assumed to be caused or redressed by those stimuli. Reassuringly, indices from both these broad fields tend to indicate similar responses for use in welfare assessment. Next we review what these indices are and how they might be used to gauge the welfare of elephants in captivity.

How to assess elephant welfare?

Below we review several stress and welfare texts (e.g., Archer 1979; Dawkins 1980, 1990; Mason & Mendl 1993; Broom & Johnson 1997; Toates 1997; see also Clubb & Mason 2002, p. 7) to extract some key welfare indices. Note that in welfare research on other animals (e.g., agricultural species), such indices are most often used to assess aspects of husbandry such as enclosure size, stocking density and so on; findings are typically then used to generate general, population-wide recommendations (which might not be implemented until long after the research animals yielding the relevant data are dead). In zoos, however, such an approach may be both difficult (an issue we return to later), and even inappropriate: the individuals under study are typically the very objects of concern, not merely exemplars of their species. Happily, welfare indices can be used to investigate individual differences within a population, thus identifying influential aspects of the environment, genotype or past experience that render individuals either particularly vulnerable or impervious to certain welfare challenges; and furthermore, by applying these indices to known individuals, work can also be carried out with the specific aim of improving the immediate welfare of these particular individuals on a case-by-case basis.

Below, we summarize indices that are particularly sensitive to psychological welfare, i.e. to stress, frustration and anxiety, or fear. For brevity, we sidestep indices of problems caused by physical disease or injury (and note too that the list below is not exhaustive). In each section we summarize what species-specific knowledge we have of these indices for use with zoo elephants. We cover first behavioral and psychological changes, then physiological changes, and, finally, the consequences of physiological changes for reproduction and physical health.

Behavioral and psychological changes

Behavioral changes and the processes in the brain that drive them (e.g., assessment, decision-making and learning) are at the heart of animal welfare assessment because they are so intimately connected with pleasure, pain and other feelings. Indeed, the very reason that animal welfare causes concern, while plant welfare does not, is because animals move, forage and perform a range of other activities in which emotions have seemingly evolved to play a key controlling role.

Preference and avoidance

Stimuli or resources that decrease welfare are typically avoided, via both learned and unlearned behavioral responses; stimuli or experiences that increase welfare are typically sought out, again via unlearned responses (like approach), and learned ones such as moving to specific locations associated with the presence of reward (“conditioned place preference”) or performing an arbitrary task to gain it (e.g., rats learning to lever-press). The more important a resource is to fitness and welfare, the more effort animals are likely to allocate to gaining it: thus animals typically work harder (travel farther, overcome greater obstacles, lever-press longer, etc.) for food and water than they do for non-essential resources, and they do so more after deprivation than when satiated. Such behavioral responses are inextricably tied up with the emotional value of different stimuli and experiences: some argue that the function of emotions is to control motivation (the goal-directed, effortful aspects of behavior) and promote learning (e.g., Cabanac & Rolls as reviewed by Dawkins 1990).

Preference tests have therefore been used to reveal what animals would choose in order to secure better welfare. For example, chickens will choose larger cages with a substrate, compared to smaller cages with a wire floor (Dawkins 1980), while naturally semi-aquatic American mink will push door-weights as heavy as those they will push to gain food, in order to reach water in which they can perform natural swimming and head-dipping activities (Mason, Cooper & Clarebrough 2001). Negative stimuli can be assessed too, such as animals' avoidance of noxious gasses, or aspects of being transported by truck (e.g., physical vibration: Cooper, Mason & Raj 1998; Jones, Wathes & Webster 2003; MacCaluim, Abeyesinghe, White & Wathes 2003). Nor are techniques like these restricted to assessing attributes of the environment; lame poultry will choose food dosed with analgesics over unadulterated food, thus showing that they are sensitive to the analgesic effect and seek it out, and therefore must have been experiencing pain (e.g., Danbury, Weeks, Chambers, Waterman-Pearson et al. 2000). Overall, identifying whether stimuli or experiences induce learning, and assessing the efforts animals put in to reach or avoid them, can therefore be very useful for identifying and ranking factors that increase or decrease welfare.

Issues to be aware of when using such data include the fact that animals may need a period of time to experience and learn about the positive or negative effects of the stimuli on offer. In addition, preference data may need interpretation: threatening stimuli can elicit an approach response due to animals' need to gain information about potential danger (e.g., "predator inspection" by prey species); and, furthermore, when animals interact with a rewarding resource, the stimuli elicited by it (its sounds, odors, etc.) and experience gained by interacting with it, may enhance or even create a motivation for it—

without such effects, "out of sight" could well have been "out of mind." Thus, preference for enrichments typically indicates the benefits of adding them to an enclosure, and the welfare implications of then removing them; but it does not necessarily indicate suffering in animals that have never experienced such enrichments at all (Warburton & Mason 2003).

Measures of preference and avoidance are likely to be as relevant and useful for elephants as they are for other animals. For example, studies of wild elephant ranging behavior has been used to quantify their avoidance of areas of human disturbance, seen even when these humans are merely groups of harmless (albeit obstructive) tourists on safari (Slotow 2002; Blom, van Zalinge, Mbea, Heitkonig et al. 2004). Satellite tracking has also demonstrated that African elephants avoid walking uphill (Wall, Douglas-Hamilton & Vollrath 2006). In zoos, studies of preference have been little used as yet (Mellor, Cronley & Shepherdson 2007 give one preliminary example). However, preference data could potentially be very useful. For example, an experiment in which elephants could choose between two identical overnight pens, one in which they would be chained, one in which they would not be, could be used to tackle the question "Do zoo elephants dislike being shackled at night?" Preference experiments could also be designed to address the question "Do elephants find some keeper contact rewarding?" and many other topical welfare issues.

Other behavioral measures related to preference, avoidance and other motivations

Animals' tendencies to avoid threatening stimuli can be used in a quite different way in welfare assessment. For one, avoidance responses (e.g., "startle") can be of value for assessing an animal's state, not just for quantifying the aversiveness of particular

stimuli—with increased tendencies to avoid a known, standardized threatening stimulus reflecting underlying anxiety. We review this in more detail in the following section. In addition, high levels of frustrated motivation, such as a thwarted desire to approach or avoid stimuli, or thwarted motivations to engage in other activities, can also cause other changes in behavior that are useful in welfare assessment. These comprise “intention movements,” where animals attempt to reach a relevant resource despite repeated failure; “redirected activities,” where animals use inappropriate stimuli as outlets for their motivation (e.g., mating with an inanimate object); and “displacement activities,” where a conflict between two strong but incompatible motivations causes an animal to perform irrelevant activities like brief grooming movements. These responses can thus help reveal an animal’s state. Furthermore, if repeated and sustained, these responses can give rise to stereotypic behaviors—abnormal behaviors that we review in more detail below.

Free-living elephants seem to show many examples of intention and displacement activities. In the Elephant Voices “Signals” database for African elephants (see <http://www.elephantvoices.org>), these include trunk twisting or foot swinging, often seen when elephants are unsure of what action to take; and displacement grooming, often seen when elephants have the competing motivations to both fight and flee. “Shuffling back and forth” (as well as “swinging one leg”) have also been described anecdotally for African females caught between wanting to defend their calves and being frightened of a threat (Masson & McCarthy 1994, citing work by Moss). Such indices seem not, however, to have been used in studies of captive elephant welfare, with the possible exception of stereotypic swaying (see below).

“Startle” and other responses to ambiguous, potentially threatening stimuli

Many tests of anxiety, especially those conducted on rodents to research anxiety disorders and their treatment, involve exposing an animal to a stimulus that is inherently mildly aversive, and observing its reaction. Such stimuli include open, brightly lit areas or novel objects/foods, which rodents typically avoid, especially at first. Importantly, such avoidance responses are strongest in individuals exposed to prior treatments that increase their anxiety levels (e.g., social isolation). Another innate avoidance response used to test for anxiety is a “startle” response that can be induced by a sudden sound or touch; again, animals previously exposed to stressful experiences such as isolation or predator cues show more exaggerated startle responses than those without comparable exposure.

These anxiety indices are standard in biomedical research (see e.g., Crawley 2000), have recently come to be used in rodent welfare research and have also just started to be used on other animals, for example agricultural hoofstock. In contrast, their use to address zoo animal welfare questions has been negligible, with no known application to elephants as yet. However, it is notable that in the Elephant Voices Signals database, signs of apprehension include the “fearful body-jolt,” a sudden jerk of the body away from a frightening sound or movement, suggesting that startle magnitude could be a useful index of elephant anxiety. Caveats in the use of all these avoidance-related measures include that they are more sensitive to some welfare problems (e.g., anxiety, fear) than to others (e.g., hunger, pain).

Signs of increased vigilance such as head-up scanning postures, or eye widening, may be used as welfare indicators. For example, “eye widening,” as manifest in eye-white exposure, has been well validated as a fear/distress index for cattle (e.g., Sandem

2002). Opening the eyes wide to show the whites has similarly been reported in wild African elephants that are alarmed, frightened or engaged in intense social interactions and excited play (Poole 1996, cited in the Elephant Voices Signals database). This suggests that, with the caution that one should control for high general arousal, “eye white” could be useful in elephant welfare assessment—both to identify negative stimuli and, via the use of standardized “probe” stimuli, to assess underlying levels of anxiety.

Signals to conspecifics

Social animals, and mothers and infants, often signal to each other about events of emotional significance, particularly to warn of danger, and also seemingly to convey relaxation and social contentment (e.g., the purring of cats). The use of such responses in welfare assessment needs to be validated for each species on a case-by-case basis. Good examples in welfare or stress research include vocal pain responses in piglets (Weary, Braithwaite & Fraser 1998) and chromodacryorrhoea, a red tear-like secretion thought to contain pheromones, in laboratory rats (Mason, Hampton, Wilson & Würbel 2004). Caveats in the use of signals include: the dangers of anthropomorphic responses to signals that look like our own (e.g., liquid running from the eyes); that humans are insensitive to many animal signals, such as odors, or sounds made at frequencies that our ears cannot detect; and that signals typically indicate specific problems, not *all* problems (thus an absence of vocalizations indicating predator threat, for example, does not mean an animal has no welfare problems).

Those working directly with wild elephants report many signals to conspecifics that seem emotionally significant, including a diverse range of trunk and ear postures (the Elephant Voices database once again includes many examples). The flow of liquid

(“temporin”) from the temporal glands has also anecdotally been linked with excitement and high arousal, including stressful situations; Slotow (2002) even suggests that it flows when wild elephants are disturbed by humans, though not all report this and most interpret it as a social signal (e.g., Weibull & Eriksson 1998) especially as it is most marked during musth (Sukumar 2003). Postural and other conspicuous signals are no doubt used in an informal, everyday way by experienced and perceptive elephant keepers, and indeed by the mahouts of working Asian elephants. However, their potential usefulness in and formalized application to welfare assessment seems not to have been developed. Note that it is likely that not all social signals of warning, fear or distress in elephants can be detected readily by humans, especially those involving infrasound (anecdotally, African elephants have displayed signs of fear when conspecifics many kilometers away have been alarmed, possibly by detecting their infrasonic vocalizations: Masson & McCarthy 1994).

Negative cognitive bias

Humans in a negative mood state or with depression (see below) show pronounced alterations in how they perceive and classify events; in particular, neutral or mildly negative events are reported as being more negative or threatening than they are by humans in a positive mood state. Recent research has shown that similar “cognitive biases” seemingly occur in animals. Rats were trained that if they heard a sound at a certain pitch, food would be delivered if they pressed a lever, but if they heard a sound of another pitch, the lever would not deliver food, and instead would emit a blast of aversive “white noise” (Harding, Paul & Mendl 2004). These trained rats were housed in two ways—in large cages full of rewarding enrichments, or in standard cages made stressful

by regular disruption. The two groups were then exposed to the two sounds again—as well as a range of control sounds of intermediate pitch. The rats housed in “enriched” versus “stressful” environments differed in their response to these ambiguous sounds. “Enriched” rats treated intermediate sounds as though likely to predict a lever-delivered treat, while stressed rats, in contrast, were more “pessimistic,” acting as though there were a low chance of reward.

Such methods of quantifying “negative cognitive bias” are still in the process of being refined and fully validated, and thus have not yet been used on zoo animals. However, in the future they could be ideal for doing so, especially for species like elephants whose learning abilities should make training in the relevant tasks quite easy.

Abnormalities in behavior and brain function I: apathy and depression-like changes

As well as negative cognitive bias, humans with depression reduce their performance of activities that require motivation or usually cause pleasure, e.g., personal care, work, exercise, social interaction and sexual activity. Similarly, low levels of activity and reduced libido are often observed in rodents subject to repeated stressors, and indeed such stressful treatments are often used to “model” depression in biomedical research. Low levels of activity, poor self-grooming, low libido and a lack of interest in maternal care are often observed in captive animals. Sometimes labeled “apathy,” these changes are disturbing—but, typically, it is hard to classify them with confidence as depression-like. Validation would include looking for negative cognitive bias (see above) or for alterations in certain endocrine systems (see “the HPA axis,” below); and using antidepressants to see if these reverse the observed effects.

Such cautions firmly in mind, there have been striking—if anecdotal—accounts of elephants becoming intensely quiet and inactive, especially after social separation (Masson & McCarthy 1994). Similarly, ill elephants have been said to move their trunks, switch their tails and flap their ears far less than healthy animals (Chatkupt & Sollod 1999, citing Schmidt 1986). Indeed, one survey of Thai working elephants (Chatkupt & Sollod 1999) used the degree of body movement to assess welfare. Elephants that moved “intermittently” were found to have poorer body condition than those that moved “frequently”; animals described as dull or quiet were also more likely to have poorer body condition. While such categorization was rather subjective, and confounding variables abounded in this study (for example, poor body condition and little movement both occurred more in shady conditions), attempts to use such behavioral indices could prove useful in future studies.

Abnormalities in behavior and brain function II: stereotypies and other repetitive behaviors

Abnormal repetitive behavior, such as stereotypic pacing, is common in zoo animals (e.g., Mason, Clubb, Latham & Vickery 2007), and has long been used in welfare assessment. The rationale for this is two-fold: it often originates from behavioral signs of high, frustrated motivation (see above); and it is typically caused by environments that induce other signs of poor welfare (e.g., other indices reviewed here; see also Mason & Latham 2004; Mason 2007a; Mason et al. 2007). Indeed, stereotypic behaviors have been formally defined as “repetitive behaviors induced by frustration, repeated attempts to cope and/or central nervous system (brain) dysfunction” (Mason 2007a). As with all welfare indices, they are not perfect. Some repetitive behaviors seem innocuous with

respect to welfare (e.g., a toddler sucking a pacifier or a cat kneading on a lap); and, often, we simply do not know the biological cause of repetitive behavior in zoo animals. A second caveat is that some stereotypic behaviors may indicate past welfare problems more than present, for instance if they reflect abnormal brain development during infancy (Mason 2007b; Mason & Latham 2004; Mason et al. 2007). A third caveat is that, whether groups or individuals with little stereotypic behavior have better welfare than those displaying high levels depends on what they are doing instead: if those with low rates of stereotypic behavior are instead “apathetic” (see above), hiding or comparatively immobile due to pain (e.g., Mellor, Croney & Shepherdson 2007), their welfare may actually be poorer than that of animals with overt abnormal behavior.

Common examples of abnormal repetitive behavior in zoo elephants include swaying/weaving, head-nodding and sometimes pacing (see Clubb & Mason 2002). Because at least some forms are increased by treatments like tethering (e.g., Friend 1999; Kurt & Garaï 2001) or stressful experiences like the onset of parturition (Szdzyu, Dehnard, Strauss, Eulenberger et al. 2006), it seems reasonable to class them as true stereotypic behaviors. In one recent survey of 29 individuals in five zoos, side-to-side swaying/weaving was the most common form. Performance of weaving/swaying increased with age, and females performed these behaviors more than males (Quaid, Harris, Harris & Sherwin 2006). Stereotypic behavior typically does not seem time-consuming in zoo elephants (e.g., Clubb & Mason 2002; Harris, Harris & Sherwin 2006). However, it is prevalent: although reported at low rates, it is found in a large proportion of the population (40 percent; Clubb & Mason 2002). Zoo elephants are less prone to stereotypic behavior than are circus elephants (Clubb & Mason 2002). However, they are

certainly more prone than wild elephants: although transient swaying has been observed here (see above), such behaviors, when they do occur, occur far less frequently than in captivity.

Physiological responses and their consequences

Behavioral and cognitive responses to threats or stressors are supported (e.g., fuelled) by appropriate changes in underlying physiology. Many of these necessary, adaptive changes in organ function, cellular responsiveness and metabolic rates underlie the common stress responses with which we are all familiar: racing hearts, dilated pupils and so on. Such changes are very useful as welfare indices, although like some of the behavioral responses previously discussed, they can suffer from poor specificity because they may be elicited by all situations of activation or excitement, including positive ones. If activation is prolonged or excessive, some of these physiological responses change and either habituate or sensitize; adaptive side effects can occur, such as hypertrophy of the organs involved; and harmful side effects can also occur, such as poor growth rates or compromised abilities to resist disease (changes that we review in a later section).

Adrenaline and “sympathetic nervous system” responses

The release of adrenaline (epinephrine) and noradrenaline into the bloodstream is part of the sympathetic response—a suite of neural and hormonal changes that help animals optimize the performance of behaviors that need energy, such as fleeing or fighting. Sympathetic activation causes the effects most of us will know from personal experience: increased heart and respiration rates, pupil dilation, urination and defecation, and a measurable increase in skin conductance caused by sweating. All of these are

common effects of acute stress or fear; and in humans with chronic anxiety, such responses may be elevated for long periods of time. In animal studies, especially in rodent-based research, defecation rates are often used as indices of acute anxiety, while heart rate is often measured in studies of fear, either via implanted devices or strap-on external heart-rate monitors. Furthermore, adrenaline and noradrenaline can be detected in saliva and urine; these non-invasive ways of detecting events in the plasma minimize risks that the sampling method itself will elevate the hormones being measured. The main caveat when using such indices in welfare assessment is that they are also sensitive to pleasurable behavioral activation, such as playing or copulation.

In terms of using the sympathetic responses of elephants in welfare assessment, adrenaline and noradrenaline levels can be assayed from urine (Dehnhard 2007), and adrenaline can also be extracted and assayed from elephant saliva (Exner & Zanella 1999). To date these hormones seem to have been investigated in zoo animals only, so there are no data from free-living animals to provide a reference. Skin conductance measures are only valid for species with glandular skin, so are unlikely to yield useful data for elephants. Measures like urination and defecation rates, pupil diameter and heart rate, in contrast, have great potential value for elephant welfare assessment, yet seem not to have been used.

The hypothalamic-pituitary adrenal axis I: corticosteroid levels

For physiologists, the hypothalamic-pituitary adrenal (HPA) axis is the classic stress system of the body. It involves glucocorticoids being secreted by the adrenal gland, in response to the release of adrenocorticotrophic hormone (ACTH) by the brain's pituitary gland. Glucocorticoids are hormones that facilitate the mobilization of energy

reserves to prepare the animal for a response such as fight or flight. They are secreted during an animal's normal activity periods (thus showing a circadian pattern in many species), but are also elevated by exposure to aversive stimuli. They thus complement sympathetic responses, but typically are activated for longer after a threat and have more diverse secondary effects on other physiological processes throughout the body.

Assessment of HPA activity in animal welfare work involves measuring ACTH and corticosteroids in the plasma, or corticosteroids that diffuse into the urine or saliva (as with adrenaline, peaks track peaks in the plasma, while being easier to collect without causing sampling stress), and corticosteroid metabolites evident in the feces. Techniques have also been developed recently to assay corticosteroids laid down in the follicle during hair/fur growth (e.g., Davenport, Tiefenbacher, Lutz, Novak et al. 2006). Like sympathetic responses, HPA responses sometimes have to be treated with caution because acute elevations in glucocorticoids can occur during excitement or simple exertion rather than in situations where welfare is compromised.

In elephants, cortisol is the key corticosteroid produced by the adrenal gland. Baseline levels, or rapid, brief elevations of cortisol output, may be detected in both elephant saliva (Dathe, Kuckelkorn & Minnemann 1992; Exner & Zanella 1999) and urine (Brown, Wemmer & Lehnhardt 1995). Baseline levels and longer, more sustained changes in output, may also be detected via metabolites in the feces (Wasser, Hunt, Brown, Cooper et al. 2000; Foley, Papageorge & Wasser 2001; Ganswindt, Palme, Heistermann, Borrigan et al. 2003; Hunt & Wasser 2003 for Africans; Millspaugh 2003; and, e.g., Laws, Ganswindt, Harris, Harris et al. 2007 for Asians). These metabolites peak in the feces approximately 30 hours after a stressful event. Validation of these fecal assay

techniques in wild elephants includes their increase with natural stressors like being a subordinate herd member, or being exposed to severe dry seasons (Wasser et al. 2000; Foley, Papageorge & Wasser 2001); they also co-varied with submissive behavior in one study of zoo elephants (Burks, Mellen, Miller, Lehnhardt et al. 2004). Intriguingly, 13 zoos recently surveyed across the UK were found to differ significantly in the mean levels of such metabolites in their elephants' feces (Harris et al. 2006). There may now be enough published data to compare zoo and wild outputs, at least for African elephants—although this task should only be done by someone knowledgeable about assay techniques and how they may affect results (Touma & Palme 2005). Some specific findings from zoo studies are outlined in a later section.

A final assay technique with untapped but enormous potential is to quantify cortisol trapped in hair. If cortisol extraction techniques were validated for elephant hair, we could use the long hairs from their tails to assess the impact of events throughout the previous year, which would be extremely useful for the retrospective investigation of past experiences. Assaying hair steroids to infer the time line of significant past events has thus long been used in human drug-testing, thanks to the serial deposition of such compounds along the hair shaft (see Davenport et al. 2006). Furthermore, research in a quite different field has shown that certain isotopes deposited in free-ranging elephants' tail hairs reliably reflect their movements and diets over the previous 12 months (Cerling, Wittemyer, Rasmussen, Vollrath et al. 2006).

The hypothalamic-pituitary adrenal axis II: changes in HPA functioning

In cases of chronic stress, HPA outputs and responsiveness can be chronically elevated; this can even result in the hypertrophy of the adrenal gland cortex (e.g., Terio,

Marker & Munson 2004 on cheetahs). The HPA system can also respond with changes in circadian patterning (the loss of the normal night-time trough is a feature of some humans with depression) or even decrease in adrenal activity, largely due to habituation of the adrenal gland to ACTH. Thus, while chronic elevation is a likely sign of severe welfare problems, unchanged or even reduced activity may also occur, making interpretation complex and in need of validation by other measures—particularly ACTH levels, signs that any chronic changes in HPA function have caused lasting harm (see below) or independent welfare indices (e.g., those reviewed elsewhere in this chapter). Long-term studies of HPA output or changes in circadian patterning seem not to have been conducted on zoo elephants; and although elephant adrenals have been well-studied (Kramer, Teixeira & Hattingh 1991) and are typically removed during necropsies (*cf.* AZA standard protocols), there also seems to have been no use of elephant adrenal size/structure *post mortem* to assess the merits or demerits of particular husbandry systems.

Negative effects of prolonged physiological stress

If stress is chronic, health and fecundity may be affected. Consequences of chronic physiological stress include immuno-suppression, poor wound healing, reduced fertility, reduction in protein synthesis (e.g., body-mass loss), elevated blood pressure, gastric ulceration, thickening of the arteries and premature death. These result partly from the direct effects of over-activation of the endocrine systems involved (e.g., on reproductive physiology and inflammatory pathways), and partly from less effective immune responses to pathogens.

Increased morbidity and decreased lifespan

In humans, stress is well documented to cause increased susceptibility to both opportunistic infections (e.g., oral and gastric ulcers, fungal infections, skin boils and *Herpes* sores) as well as to infectious diseases caught from conspecifics (e.g., colds and influenza). The same effects can be seen in a range of other species (*cf.* Mikota, Chapter 6). Recovery rates, including the repair of damaged tissues, also decline. Isolating social rodents can impair wound healing, for example (Detillion, Craft, Glasper, Prendergast et al. 2004). Although they can sometimes be complex to interpret (for example, do increased disease rates indicate compromised defenses against parasites, or merely chance exposure to more pathogens?), these potential consequences of chronic stress can be useful in assessing animal welfare, not least because they may *cause* as well as reflect poor welfare. Because stress increases both infectious and non-infectious disease, chronic stress also decreases lifespan in species as diverse as rats, humans and rhesus monkeys (reviewed by Clubb, Lee, Mar, Moss et al. *subm.*), the typical pattern seemingly being that stress shortens mature adult lifespan (e.g., Kiecolt-Glaser, McGuire, Robles & Glaser 2002; Cavigelli, Yee & McClintock 2005). As ever, there are constraints on the usefulness of lifespan to infer welfare, not least that it can be affected by a host of other variables, some of which, like access to *ad lib.* food, may even be positive for psychological welfare. However, despite this caveat, premature adult death could, if used carefully, be a particularly useful welfare indicator for zoo animals because they are frequently allowed to reach maximal longevity (even if there is terminal veterinary intervention).

So, what relevant work has been done in elephants? Foley and co-workers (2001) found a correlation between conspicuous signs of gastro-intestinal parasitism and corticosteroid levels in wild African elephants. This would be consistent with a link between stress and increased vulnerability to parasitism (although it could equally indicate an increase in stress as a result of a parasitic infestation). In zoo elephants, considerable welfare concern has been raised by their apparently high rates of skin infections and lameness. Much of this may be due to enclosure substrates that do not optimize skin and foot condition, but the possible role of stress-related immunosuppression has been little discussed in the zoo community (*cf.* Clubb & Mason 2002) and certainly not investigated, neither in terms of underlying biological mechanisms nor via correlations with other welfare indices. However, in one recent survey of 16 zoo elephants, lameness scores co-varied with fecal corticosteroid metabolite outputs, with the lamest animals showing the greatest endocrine signs of stress (Rajapaksha, Harris, Sherwin & Harris 2006). This could be consistent with stress playing a role in the underlying causes of some foot problems (although it could equally reflect that pain and disability cause stress to these animals).

Welfare concern—as well as much controversy—has also been raised by apparently short lifespans in zoo elephants (*cf.* Clubb & Mason 2002). For example, survivorship curves in Kurt (1995) for female Asian elephants show median lifespans of c. 33 years for Burmese working animals, c. 20 for free-living animals and just c. 10 years for captive-born zoo animals. Sukumar (2003) also claims that Asians have curtailed lifespans in zoos, while Lee and Moss (Chapter 2) discuss similar effects in African elephants (see also Clubb, Lee, Mar, Moss et al. *subm.*).

Reduced reproductive success

A well-documented effect of chronic stress in humans, research rodents and a host of other species is reduced fertility (see e.g., von Borell, Dobson & Prunier 2007 for an excellent overview of agricultural ungulates). In adult females, this can be manifest as impaired cycling/reduced estrous periods; premature reproductive senescence; reduced conception rates; increased pre-term foetal losses; prolonged parturitions; smaller birth weights; asymmetrical infant development; increased offspring stress responsiveness; poor maternal care (or infanticide); and/or increased infant mortality. Many of these effects stem directly from HPA axis over-activation, but additional causal factors include stress-induced prolactin elevation (Sobrinho 2003), and—more speculatively—luteolytic stress-activated protein kinases (as activated by mitogens: Yadav, Natrajan & Medhamurthy 2001). Oxytocin is also a crucial reproductive and maternal hormone, especially during parturition and in the early stages of maternal care, that can be affected by stress (see e.g., Leng, Mansfield, Bicknell, Brown et al. 1987; Pederson & Boccia 2002; Detillion et al. 2004).

Of course, reduced fecundity, as with many of our previous welfare indices, is not a perfect index always indicating stress. For example, Hermes, Hildebrandt and Goritz (2004) suggest that the mere lack of breeding when young accelerates reproductive senescence—although in zoos, such data are correlational only, so might indicate that females that failed to breed when young had sub-clinical problems only manifest overtly later in life. Furthermore, other brakes on reproduction that are independent of stress include: restricted access to males; limited mate choice; the role of nutrition (and excess weight) in many aspects of reproductive success; and dam parity and past experience

(including with the infants of other females). However, these caveats acknowledged, chronic stress remains a sensible hypothesis to test when there is evidence of reproductive problems, be they low conception rates or high rates of infant death.

Zoo elephants do seem to have prevalent and diverse reproductive problems: apparent low libido; poor fertility in both sexes; premature reproductive senescence in females; and, in some instances, high rates of stillbirth and infant mortality rates (Kurt 1995; Taylor & Poole 1998; Clubb & Mason 2002; Brown et al. 2004). For instance, Kurt (1995) reports infant mortality rates in zoo Asians as being five to six times higher than in Burmese working animals, although more recent analyses suggest the more moderate (but still unacceptable) figure of three times (Clubb, Lee, Mar, Moss et al. *subm.*). However, despite the work reviewed above on the non-invasive assessment of HPA activity, and also some preliminary work on African elephants to develop assays for stress-activated proteins (Bechert & Southern 2002), only one laboratory, Janine Brown's, has investigated possible links between stress and reproductive success in zoo elephants. Brown's work has focused on acyclicity only; it has revealed no significant links between this and HPA output (although the highest cortisol levels did seem to occur in non-cyclers), but in Africans, acyclicity was linked with elevated prolactin levels that stemmed from super-normal prolactinaemia in about one-third of the non-cycling population (Brown, Walker & Moeller 2004; Brown, Olson, Keele & Freeman 2004; Freeman, Weiss and Brown 2004). In contrast, the endocrine and behavioral correlates of reduced libido, pre- or post-natal infant mortality, reproductive senescence and the common problem of ovarian cysts, still remain unknown for zoo elephants. Furthermore, nor has any work focused on immediate maternal stress at the time of parturition, such as

the effects of the management (e.g., tethering, isolation) on the dam's levels of oxytocin at this time.

To conclude: an overview of potential welfare indices for zoo elephants

A number of behavioral, physiological and health-related variables are used in scientific animal welfare assessment. The most rigorous scientific welfare research to date has typically been done on farm and laboratory animals. The best of this research uses multiple approaches, because no one single measure is perfect; it also controls for known potential confounds. Work on zoo animals, including elephants, lags very far behind. However, so far, population-level data analyses have revealed poor reproduction and reduced lifespans in both species of zoo elephants compared with protected *in situ* reference animals. Smaller scale studies have also recorded stereotypic behavior, and successfully assayed corticosteroid output in non-invasive ways, again for both species; additionally, one or two studies have also investigated the catecholamine output of zoo elephants, again non-invasively. However, no studies have formally compared these measures with those from protected *in situ* animals as a benchmark; furthermore, other potential welfare indices (e.g., those behavioral responses that field workers are expert in) have so far largely been overlooked.

Does this general lack of scientific data matter? After all, for many, this type of scientific, investigatory approach to captive elephant welfare issues will seem painfully pedantic and unnecessarily labor-intensive (“Isn’t it *obvious* that small concrete enclosures are bad?”). We would argue that the use of scientific welfare indices has three major advantages over just assuming that we know what elephants need for good welfare.

First, when contrasting opinions exist about the potential causes of and solutions to welfare problems (*cf.* e.g., hypotheses about whether human contact substitutes for interactions with conspecifics, or whether environmental enrichments remove the need for large enclosure sizes), such data may eventually reveal objectively which viewpoint is correct. Second, where there are assumptions about what animals need for good welfare, based on human perspectives (e.g., “they have little to do, therefore boredom must be a source of misery”), such data can test them by reflecting the animals’ own perspectives. Third, where welfare needs are costly to meet, or in practical terms mutually exclusive (*cf.* e.g., having large social groups versus lots of space per animal), such data can help rank which are most important to provide. In the next section, we review what the few studies to date suggest about some potential causes of zoo elephants’ welfare problems.

Where do elephant welfare problems come from?

The “five freedoms” with special reference to elephants

The “Five Freedoms” (e.g., Anonymous 1992) are tenets for ensuring good welfare, developed to facilitate the provision of adequate standards. These are as follows:

- (1) freedom from injury and disease;
- (2) freedom from hunger, thirst and malnutrition;
- (3) freedom from fear; (4) freedom from thermal or physical distress; and
- (5) freedom to express most “normal” behaviors. Although developed for

agricultural systems, they are now incorporated into the UK zoo licensing legislation (Department of the Environment Transport and the Regions 2000). For elephants in zoos, it is the first and last items in this list that are arguably met least well—and the last that

has caused most controversy. This is because captive conditions differ enormously from the wild (Clubb & Mason 2002; Kane, Forthman & Hancocks 2005; Veasey 2006; Lee & Moss, Chapter 2; Poole & Granli, Chapter 1; Williams, Chapter 3)—and yet we also know from other species that not all natural behaviors are essential for animal welfare (see e.g., Veasey, Waran & Young 1996a). Thus, a catalogue of great contrasts between wild and captive time budgets does not *necessarily* represent a list of proven causes of stress, frustration or “boredom”; instead, it represents a list of hypotheses that should be tested. Below we look at the evidence for the impact of three key behavioral differences between wild and captive life for elephants’ psychological health and welfare.

What effects do curtailed freedoms to perform natural behaviors have on elephants?

The differences between natural and captive life are extensive and diverse, ranging from the cognitive (Poole & Granli, Chapter 1) through to dietary and thermoregulatory challenges, the effects of which may be physical as well as psychological. However, frustration and lack of stimulation potentially caused by the curtailment of movement in zoos and unnatural social structures, have probably attracted most public criticism.

“Weaning” age: is early removal from the dam a problem?

Zoos almost ubiquitously remove calves from their mothers as infants or juveniles—a great contrast with how young elephants (especially females) live in the wild. Does this have implications for welfare? For wild African elephants in Kenya, the loss of their mother before the age of nine has lasting negative effects on female

survivorship (Moss & Lee in press). However, it is near impossible to investigate whether similar effects occur in zoos because very few females are left with their mothers beyond this age. In “orphanages” in range countries, poorly socially integrated Asian calves apparently show more stereotypic behavior (Garaï 2001)—but this is not a test of weaning age *per se*; nor can this sad finding tell us which of these two correlated phenomena is cause, and which effect (but see Sheldrick, Chapter 16). Finally, across zoos and circuses, early-weaned Asian females reportedly had significantly lower birth rates, and were also more likely to reject or harm their own calves than other females (Kurt & Mar 1996). However, the statistical analyses in this study consisted of a series of one-independent-variable analyses with no blocking factors, and thus potential confounds were not explored (e.g., other factors correlating with being weaned early, or influential on birth rate and calf treatment). Thus overall, there is sparse, indirect evidence that premature maternal separation *could* have consequences beyond initial separation and therefore be a welfare issue for zoo elephants; however, no detailed studies have as yet investigated this thoroughly.

Unnatural social environments for juveniles and adults: do they cause welfare problems?

Differences between zoo and wild social structures include smaller group sizes (a few zoo elephants are even kept isolated), the grouping of unrelated animals, a flattened age structure (relatively few very young and very old animals in each group), a relative lack of adult males, and a lack of stability due to the movement of females between zoos for breeding (a treatment which obviously also involves transport, plus a change in enclosure, social companions and keeping staff). If zoo elephants regard their keepers as

herd members, as has been claimed by some, then additional instability comes from changes in keeping staff.

In wild animals, African elephants recently translocated to new reserves reportedly have higher fecal corticosteroid outputs than animals in longer-established parks (Millspaugh 2003). Obviously, however, translocation involves far more than just social changes, and there may also be differences between the original and the new physical environments which equally explain these effects. Wild African elephants do, however, generate more data showing that social stability *per se* is important. Poor maternal care of infants has been observed in herds with an abnormal social structure due to poaching (see several studies as reviewed by Bradshaw & Schore 2007). Furthermore, juvenile African elephants, especially males that are translocated at a young age to a new, elephant-free park showed behavioral problems including high aggression and the shocking killing of many rhinoceros by young bull elephants. These animals had been moved as young orphans of about eight to 10 years old, and so had matured in the absence of a social hierarchy; importing mature adult bulls to normalize the social environment rectified this problem (Slotow, van Dyk, Poole, Page et al. 2000; Bradshaw, Schore & Brown 2005; Bradshaw, Chapter 4).

For zoo animals, translocation between zoos is undoubtedly a stressor, at least in the short term. Thus it was used as the biological validation for a salivary cortisol assay by Dathe et al. (1992). The hormone peaked two days after the introduction in both a newly-moved animal and the one “recipient herd” female that was sampled, returning to normal on the following day. Translocation between zoos was also used as the biological validation for a urinary catecholamine assay by Dehnhard (2007); moving two female

elephants between zoos led to a marked temporary increase in urinary adrenaline and noradrenaline levels. Finally, one study used the transportation of a bull from the UK to a new herd in France as the biological validation for a fecal cortisol metabolite assay for Asian elephants; this animal's hormone metabolite levels increased three- to four-fold, as did his levels of stereotypic behavior (Laws et al. 2007). However, further studies have shown that the magnitude of such effects varies, both between individuals and with the details of the procedure. One study, for example, showed significant urinary cortisol elevations in only one out of four Asian female elephants when mixed with unfamiliar conspecifics (Schmid, Heistermann, Ganslosser & Hodges 2001). Furthermore, in the same study, only one out of six showed a sustained increase in stereotypic behavior, with other animals apparently integrating well. Another study followed the creation of the herd at Disney's Animal Kingdom, following animals that had already been transported and habituated to the new site, but, after a period of acclimatization, were introduced to their new group members (Burks et al. 2004). During a "sequential introduction," in which increases in contact from visual to tactile to full contact were allowed only gradually in a formalized procedure, smaller increases in fecal corticoids occurred than during a less structured and progressive "non-sequential introduction" (though it should be noted that very few animals were involved in each type of introduction, and so differences could equally have been due to the idiosyncratic temperaments and interactions involved in each instance). In this study, stress hormone levels also co-varied with submissive behavior.

As for lasting and more severe effects of social upheaval, here the evidence is far patchier. Kurt (1995) reports that across European zoos, females identified as successful

breeders were more likely to have matured with an adult female, and to have stayed in one stable herd all their adult life, than females who abandoned, harmed or killed calves. The latter females were more likely to have grown up with no adult female supervision, and to have been transferred between zoos multiple times (Kurt 1995). Because these two effects (maturing with an adult female; movement between sites) were confounded (and sample sizes are relatively small, and other aspects of the environment or management are not recorded), it is impossible to assess the relative effect of the abnormal juvenile environment versus the abnormal adult one. Still, this study does illustrate the potential importance of social interactions. Kurt and Mar (1996) also describe females that were moved between groups as having a lower birth rate. Just as for these authors' apparent finding of a weaning age effect (see above), this result emerged from a series of one-independent-variable analyses with no blocking factors to control for potential confounds. However, other authors have likewise suggested that moving a cow from her social group may cause stress that impairs conception (e.g., Schmidt 1998, cited by Rees 2003).

Overall, it is thus clear and unsurprising that mixing juveniles and adults with new peers, compounded with the other stressors involved in being moved between zoos, often causes transient stress. There also seems to be good evidence that for wild African elephants, dramatic human-induced changes in social structure have negative consequences. However, there has been little or no solid research into the lasting effects (or otherwise) of chronically being in small, unrelated and/or unstable groups in zoos, nor of being housed with non-conspecifics (i.e. Africans mixed with Asians). Furthermore, there has been no investigation of whether the absence of adult bulls affects bull calf

development, nor any study of the impact of changes in keeping staff. Without such data, it is impossible to say for sure whether zoo animals simply adapt to such environments, or instead have real lasting problems which may compromise welfare.

Physical restriction: does this cause welfare problems?

The reduced movement of zoo elephants compared to the distances traversed in the wild, from being housed in relatively small enclosures to being chained indoors, is undeniable. Such practices may perhaps be unaesthetic, but do they necessarily cause welfare problems?

Several independent studies have shown that chaining, shackling or tethering increases elephants' performance of stereotypic behavior (e.g., Schmid & Zeeb 1994; Wiedenmayer & Tanner 1995; Friend 1999; Gruber, Friend, Gardner, Packard et al. 2000). Anecdotally, shackled or very physically constrained elephants are also more likely to be aggressive to humans or to their conspecifics (Kurt 1995, citing Schmid 1993), or to reject their calves after parturition (especially if also separated from their social groups; Schaftenaar & Hildebrandt 2005). However, no studies seem to have looked systematically at such behavioral effects, or to have strengthened the case that chaining reduces welfare with, say, preference data, measures of physiological stress responses or assessment of the impact on oxytocin during labour.

Finally, some evidence exists concerning enclosure size. This includes suggestions that enlarging enclosures reduces the performance of stereotypic behavior (Rees 2003), but the sample size in this work was just two, and of course enclosure enlargement also involves other variables (e.g., novelty), not just the provision of extra space. African elephants translocated to a new area and given a choice between a pen

(625 m²) and a paddock (15,000 m²) chose the latter (Garaï 1994), but, again, sample sizes were small in this study (strictly speaking, just one, if animals in a herd are considered statistically non-independent). Finally, and perhaps most convincingly of the sparse work to date, across three groups, the one in the smallest enclosure (350 m²) had fecal cortisol metabolite levels four times higher than the group in the largest 7.5 ha enclosure (Stead, Meltzer & Palme 2000). Again, the sample size here is three (taking herd as the unit of replication), and it could be that the three groups differed in stress levels for reasons quite unrelated to enclosure size.

As for the previous sections, we must therefore conclude that evidence that physical restriction of freedom of movement causes poor welfare is sparse, simply because the few studies run to date have been so very small in scale.

Discussion and conclusions

Overall, then, what do we know (not just believe or suspect) about what elephants need for good psychological welfare? The short answer is: surprisingly little. Hypotheses concerning the activities and stimuli required for good welfare have not been well tested. There has been a scattering of opportunistic studies of acute responses to changes in husbandry; and the collection of population-level evidence on infant mortality, adult lifespan and stereotypic behavior (reviewed above and elsewhere by many other authors) suggesting that stress-related problems are common in zoo elephants. However, no large-scale, published, epidemiological-type studies have assessed the chronic impact of different types of husbandry on reproductive success, morbidity and mortality, or stress biology. There has also been no work investigating whether stress-related changes in

biology play a role in elephant morbidity and mortality; and only some work on the role of such effects in certain aspects of elephant reproductive biology (the laudable research of Brown and colleagues). There has not even been work to investigate whether controversial practices like chaining around birth cause acute stress that impairs immediate maternal care. Research is thus still very much needed, both to generate population-wide general recommendations, and to explore how welfare problems and solutions vary across individual elephants with different backgrounds and temperaments. This overall dearth of data is both surprising and depressing. It is also one reason why elephant welfare remains such a topic of controversy and of strong, diverse opinion—position statements from both “sides” often generating more heat than light.

So, why so little real research? We suggest that three factors have held back objective work on zoo elephant welfare. The first is a lack of funding for zoo animal welfare research. Research council monies (e.g., BBSRC, NSERC, NSF), if spent on welfare at all, are monopolized by farm and laboratory animals. Furthermore, drives by zoos to raise research funds themselves are extremely rare (for one exception see below)—despite the rather frequent fundraising of millions of dollars for new enclosures (whose design is thus essentially evidence-free; see e.g., Clubb, Lee, Mar, Moss et al. *subm.*). The second reason for the lack of substantial research on zoo elephant welfare is likely a difference in culture and resources between Europe and North America. European zoos typically have a less defensive attitude to welfare research—but not the resources to conduct such work well. North America, in contrast, holds the world’s few full-time, respected zoo animal scientists (e.g., David Shepherdson, Nadja Wielebnowski, Kathy Carlstead and Janine Brown), but in terms of the politics of welfare, North

America also has a much more polarized “us and them” climate (*cf.* Barber, Chapter 9)—particularly in evidence when it comes to elephants. The third and final reason consists of logistic issues that make good science on these species challenging to conduct. Many exhibits or groups of elephants differ in *numerous* ways (keeper style, social grouping, whether wild-caught or captive-born, weaning age, enclosure size, mean ambient temperature, proximity of zoo visitors, etc.), and, furthermore, elephants are often moved between exhibits (Clubb & Mason 2002); it can thus be challenging to ascertain which precise aspect(s) of husbandry, past or present, cause measured effects on welfare. In addition, there is relatively little variation across zoos for some independent variables. To illustrate, few animals live in enclosures that approximate the areas they would range in the wild, and very few animals stay with their mothers much beyond infancy. Thus investigating the impact of enclosure size or weaning age is challenging: a lack of apparent effect could indicate that all zoos are equally good, or that they are actually all equally bad compared with some optimum simply unavailable for comparison.

If these three factors have impeded objective welfare research on elephants to date, are they insurmountable obstacles for the future? Here, we try to look ahead more optimistically. Our review shows that several potentially useful techniques for assessing elephant welfare have been developed and validated, and simply await application. Furthermore, one major multi-zoo survey has been run in the UK over 2005-2006, by Sherwin and colleagues (Harris et al. 2006; Quaid et al. 2006), and was conducted with the full cooperation of and indeed financial support from the British and Irish Association of Zoos and Aquariums (BIAZA; in collaboration with DEFRA, the RSPCA and IFAW). While limited by the number and diversity of zoos in the UK and Ireland, its findings are

eagerly anticipated; its methodology could provide a prototype for more ambitious work; and it reflects a refreshing level of investment by the UK zoo community. Could similar occur in the US? The international diversity of authors contributing to this volume suggests that it is not *completely* impossible. As for the challenges of conducting good quality research on these complex zoo populations, again, we suggest these are surmountable. Future work will need to sample sites that are both numerous and diverse to allow housing effects, both past and present, to be teased apart properly: we urge for more ambitious multi-site work that includes well-provisioned, well-protected reference *in situ* populations as well as a variety of zoo and sanctuary housing, to maximize the variance in living conditions that is sampled. Such work could usefully be run collaboratively with animal welfare researchers from other fields; with epidemiologists and researchers with expertise in survivorship analyses, etc.; and, to better utilise species-typical ethological indices of state, with elephant biologists working *in situ*, plus elephant keeping staff. Past studbook data should be better utilized, perhaps in combination with the enclosure size data presented by the European Elephant Group in their 2002 response to Clubb and Mason 2002. Opportunistic studies at individual zoos should also continue wherever possible: although small in scale, if they each have similar outcomes, this would be informative; and, where opportunities have been missed (e.g., moves of elephants from one management system to another, or from zoos to sanctuaries), it is even possible that the effect on HPA activity could be reconstructed retrospectively from cortisol deposits laid down in hair.

In the meantime, practical efforts to improve elephant housing should continue—not be placed on ice due to a lack of data. While there is something very odd about

investing millions of dollars on infrastructure based on mere “hunches” that it will make a difference, so too is there something odd about doing nothing, save lamenting that “more research is needed.” *Thus the lack of good welfare data does not, we should emphasize, excuse inaction.* Several authors have suggested practical, useful rules of thumb to follow when upgrading facilities (e.g., Kane et al. 2005; Veasey 2006). Veasey (2006) suggests avenues to consider when designing facilities or management regimes for captive elephants in the absence of proper welfare data, based on elephant biology and the principles of animal welfare science. We urge that these recommendations are followed, but that *all* future changes in husbandry are also done with care, objectivity and humility. If elephants continue to be housed in zoos, their care must be evidence-based; their needs must be assessed and ranked; and strong claims should not be made about the welfare consequences of particular practices or changes in husbandry without firm scientific evidence.

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