Identifying design priorities for optimal welfare

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Abstract: For many species, zoo environments provide unprecedented opportunities to protect the physical health of animals evidenced by enhanced longevity for numerous taxa in captivity. However, the potential benefits to physical health that captivity can bring to wild animals frequently comes at the expense of their psychological wellbeing; the more control and oversight humans have over animals and their environment, the better placed they are to protect their physical well-being, but the less free animals are to experience species appropriate psychological opportunities. A mechanism capable of identifying the relative welfare significance of behaviours and cognitive process would allow zoo designers and managers to focus resources where they will have the greatest impact on welfare and to more effectively balance the psychological and physical needs of managed animals necessary to deliver peak welfare. This is likely to be one of the most fertile fields for advancing zoo animal welfare in the coming years. Here a novel methodology is outlined that has been developed to identify behavioural and cognitive priorities that should form the foundation of both habitat design principles, as well as subsequent management strategies.

INTRODUCTION

Animal welfare is a challenging concept to define and measure (see Mason & Mendl 1993, Dawkins 2006, Veasey 2006, Fraser 2008b, Fisher 2009, Ohl & van der Staay 2012, Czycholl et al 2015, Dawkins 2017, Veasey In Press), however, the centrality of the feelings or affective states of animals to their welfare is widely acknowledged (see, Dawkins 1980, Duncan and Petherick 1991, Fraser et al 1997, Bracke et al 1999, Duncan 2002, Rushen 2003, Veasey 2006, Mason & Veasey 2010, Hemsworth et al 2015, Veasey In Press).

Mason & Veasey (2009, 2010) consider poor welfare to occur when animals experience severe or chronic states of mental suffering and good welfare to occur when they experience positive emotional states and negligible mental suffering. Unfortunately, the challenges of measuring the feelings or affective states of animals are considerable (see Mason & Mendl, 1993, Duncan 2002, Veasey 2006, Mendl et al 2009, Mendl et al 2010, Ohl & van der Staay 2012, Veasey In Press) and as a result, despite their centrality to any meaningful conception of animal welfare, the affective states of animals are often secondary considerations in habitat design and animal management to the potential detriment of captive animal welfare (Veasey In Press).

HEALTH, WELFARE AND ZOO DESIGN

Zoo design whether good or bad is arguably one of, if not the most significant factor influencing the lifetime welfare of wild animals in zoos as the habitats created by zoo designers will likely have the greatest impact on the world as it is experienced by the animal sometime referred to as its umwelt (see Uexküll 1934) and its influence is typically lifelong. Zoo designers are therefore morally obliged to provide environments that allow animals to experience the positive mental states necessary for good welfare. Unfortunately, within the zoo design sector there is a surprising absence of applied animal welfare expertise exacerbated by a dearth of data on the psychological priorities of wild animals to effectively guide both zoo design and management. This is perhaps reflected by the paucity of information available on habitat design to safeguard welfare; for example, just 13% of the content of AZA husbandry guidelines is devoted to husbandry and habitat design (Veasey In Press).

These problems are further confounded by fundamental confusions over definitions of welfare, and in particular a tendency to amalgamate physical wellbeing into a broader conception of animal welfare resulting in the widespread marginalisation of an animal's psychological wellbeing as a principle consideration (see Veasey In Press).
The relative ease of quantifying health based 'welfare' metrics in comparison to those relating to the affective states of animals (see Mason & Mendl, 1993, Duncan 2002, Veasey 2006, Mendl et al 2009, Mendl et al 2010, Ohl & van der Staay 2012, Veasey In Press) has likely influenced how welfare has become defined (see Veasey In Press). Health-related welfare metrics encompass a diversity of measures that provide insights into individual or population level physical health such as longevity, body condition or fecundity as well as factors believed likely to influence an animal's health such as the availability of suitable diets, the provisioning of appropriate healthcare mechanisms and the suitability of the animal's surroundings and climate etc.

For zoo design to genuinely deliver good welfare as it is experienced by the animal, rather than how it is interpreted and defined by legislators and measured by many zoo and animal welfare practitioners, it is worthwhile briefly reviewing prevailing welfare definitions within the sector and examining how they might influence welfare outcomes.

In 2001, a group of Australian scientist reviewed the impact of housing on sow and piglet welfare based upon „widely accepted criteria of poor welfare such as health, immunology, injuries, growth rate, and nitrogen balance“ and concluded that sow stalls met animal welfare requirements and rejected concerns the general public might have had over the issue of confinement (Fraser 2008a, 2008b). Four years previously, a scientific committee of the European Union considering much the same evidence but using conceptions of welfare which included affective states in addition to physical health, formed essentially the opposite opinion concluding that „serious welfare problems for sows persist even in the best stall-housing system“ (Fraser 2008a, 2008b). Evidently, how welfare is defined can have a profound impact upon how we interpret welfare states, and in doing so influence how habitats are designed and managed in a very fundamental way.

If we consider current welfare definitions relevant to the zoo community, health remains a prominent and arguably the preeminent consideration; the World Association of Zoos and Aquariums actually defer to the World Organization for Animal Health stating "An animal is in a good state of welfare if (as indicated by scientific evidence) it is healthy, comfortable, well nourished, safe, able to express innate behaviour, and if it is not suffering from unpleasant states such as pain, fear and distress" (WAZA 2015). The Association of Zoos and Aquariums believe 'animal welfare refers to an animal's collective physical, mental and emotional states' (AZA 2016) and the American Veterinary Medical Association state protecting an animal's welfare requires attention to its physical and mental health (AVMA 2014).

Whilst an acknowledgement of mental states is evident in these definitions, the inclusion of physical health has the potential to be problematic if applied inappropriately, which unfortunately can often be the case (Veasey In Press, see also Fraser 2008b). Some argue that physical wellbeing is only relevant to animal welfare if physical states influence affective states in the animal, and thus the inclusion of physical health as a defining factor of welfare is redundant (see Duncan & Petherick 1991, Duncan 2002, Veasey In Press) and potentially confusing given the exclusion of other potentially influential factors in defining welfare such as habitat design, social environment and climate etc. (Veasey In Press).

Such concerns might appear pedantic, however, because of the challenges associated with measuring the feelings of animals directly, those responsible for animal welfare increasingly rely on more readily quantifiable metrics linked to physical wellbeing (Duncan & Petherick 1991, Rushen 2003, Veasey In Press) despite the widespread recognition that healthy states do not guarantee good welfare (Duncan & Petherick 1991, Volpato et al 2009, Koolhass et al 2011, Maia & Volpato 2016, Veasey In Press).

Veasey makes the case that there is in fact an underlying tension between physical and psychological priorities in both management and habitat design (In Press) which makes the inclusion of physical health problematic given the differential tangibility of these two defining aspect of welfare. According to Veasey (In Press) the tension between physical and psychological management priorities is such that the elevation of physical health due to its relative ease of assessment, has had a detrimental impact on the psychological wellbeing of animals which is central to any meaningful conception of welfare.

Dawkins (2012) illustrates the tension between these two defining aspects of welfare by considering the behaviour of garden warblers (*Sylvia borin*); a species that has evolved to migrate in response to seasonally deteriorating conditions. Captive garden warblers provided food and protection from extremes of climate, predation and the risks associated with migration experience higher survival rates and better body condition than wild birds free to migrate but nonetheless express frustrated attempts to migrate at a time when they would naturally do so in the wild, indicating the motivation to migrate persists beyond its physical need. In this instance, controlling the bird's actions, simplifying its environment, sheltering it from physical harms and guaranteeing access to resources means that carers are better able to protect the animal's physical health but in doing so predispose them to frustration and compromised welfare.

The conflict between physical and psychological priorities and their potential impact on the design of animal habitats and subsequently animal welfare was perhaps most startlingly illustrated by the AVMA's opposition to the State of California's Proposition 2 which required that all farm animals have the opportunity to 'lie down, stand up, fully extend their limbs and turn around freely' (California Secretary of State 2008). The AVMA opposed this legislation on the basis it would likely compromise 'factors necessary to ensure the overall welfare of the animals, especially with regard to protection from disease and injury' (AVMA 2008). It seems barely credible that the AVMA felt that environments designed to prevent animals standing up and turning around could in any form be acceptable on the basis that allowing animals to stand up and turn around might expose them to an increased risk from injury and disease (see Veasey In Press).

Clearly poorly conceived or interpreted definitions of animal welfare can result in habitat designs and management strategies that regardless of intent, might actually conflict with animal welfare as defined by the affective states of the animal (Fraser 2008b, Veasey In Press). Unfortunately, such health-centric decision-making frequently influences zoo design and management in comparably detrimental ways (see Veasey In Press).

For example, beyond simply keeping elephants alive, arguably the over-riding consideration with regards to Asian elephant management in zoos during the latter half of the 20th century and the early years of the 21st related to the management of foot health (see Mikota et al 1994 Schwammer 2000, Csuti et al 2001, Lewis et al 2010) and dealing with the challenges created by poorly designed environments. However, for many years the management of foot health centred on the physical management of the elephant's foot rather than shaping its environment to influence activity levels and reduce the detrimental impact of inappropriate substrates on the feet of elephants. At around the turn of the century, the average North American elephant received over an hour per day of 'preventative foot care' (Fowler et al 2001a), despite which poor foot health remained widespread (see Mikota et al 1994 Schwammer 2000, Csuti et al 2001, Lewis et al 2010). A survey of 84 institutions holding elephants in 1997 revealed 91% maintained elephants on concrete floored barns and 67% felt changing that substrate was a low priority (Dimeo-Ediger 2001 cf Csuti et al 2001). In Fowler and Mikota's book Biology, Medicine and Surgery of Elephants (2006) the 19 page chapter entitled 'Foot Disorders', set aside just one paragraph covering 'prevention of foot problems' through means other than medical or nutritional management and whilst according to Lewis et al (2010) it was acknowledged at The First North American Conference on Elephant Foot Care and Pathology in 1998 that 'an ounce of prevention was worth five tons of cure', prevention was described in terms of foot care and exercise plans rather than managing the elephants habitat and its occupation within it. This paradigm evidently shaped management which went on to influence design to facilitate management which led to decades of circular thinking whereby zoos got better at treating the problems their habitats created, and new habitats were designed around treating problems rather than eliminating them through design (see Figure 1).

Such circular thinking persisted because the actual delivery of healthcare was viewed as benchmark of good welfare in itself. The ability of a zoo to carry out foot care on elephants, or indeed treat penguins with bumble-foot, sea-lions with ocular lesions etc. can be considered as evidence of best practice irrespective of the potential psychological consequences of the management regimes that

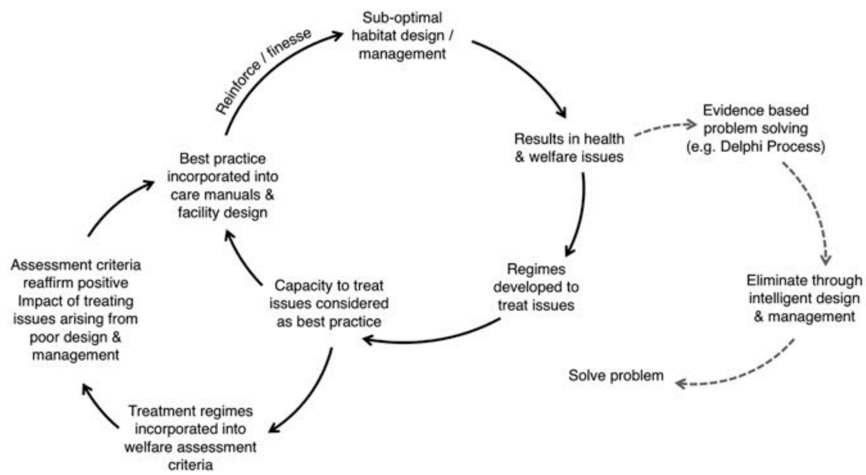

Figure 1. The vicious cycle of zoo design and management illustrating the potential consequences of focusing on treating problems (solid black portion) rather than eliminating problems through good design informed by evidence based processes (dashed grey portion).

were necessary to deliver such treatments and the evidently inappropriateness of the animal's environment in creating the condition. It was until the early to mid 2000's that and a more holistic ethological approach to the management of elephants and design of their habitats was proposed that this circular thinking began to break down with the introduction of substrate floored barns and recommendations relating to activity levels and social structures for captive elephants which more closely replicated natural states (see Veasey 2006).

Zoo design might not be the immediate solution to problems such as poor foot health in elephants, or indeed stereotypies in big cats and a multitude of other environmentally induced conditions, but in most instances zoo design is likely to be the most effective long-term solution to many of the challenges experienced by wild animals in captivity whether they be physical or psychological. As a result, having a mechanism to effectively inform zoo design is fundamental to managing animal welfare long term.

THE ANIMAL MANAGEMENT SPECTRUM, PEAK WELFARE AND THE ROLE OF ZOO DESIGN

In designing habitats for wild animals, zoo designers face the challenge of balancing efforts to protect an animal's physical wellbeing whilst also providing environments that meet their psychological needs, given the tension between these two facets of care, a fuller understanding the psychological needs of animals is essential to balancing this tension and delivering peak welfare.

Veasey (In Press) outlines a notional animal management spectrum which ranges from intensive systems emphasizing observation, intervention and control to maintain physical functioning and health through to more extensive systems where animals typically live in larger, more complex environments more akin to the species' evolutionary expectations.

All intensive systems require the animal to be captive in the true sense of the word (see Veasey In Press) and are exemplified by research laboratories, factory farming environments and within the zoo sector by habitats such as those developed to protect amphibians from chytrid fungus, or those devised to maximize reproductive output in giant panda. Here the scale and simplicity of environments enables carers to observe, intervene, manage risk and control most aspect of an animal's life. Animals are inherently more reliant upon human inputs in intensive systems where opportunities to forage or seek shelter are largely absent. Such intensively managed environments can be highly effective in safeguarding physical health for many species such that they live longer in captivity than they would in the wild (see Hill et al 2001, Korte et al 2007, Kaiser et al 2009, Fraser 2009, Lynch et al 2010, Mason 2010, Collins & Kays 2014, Larson et al 2016).

At the other end of the animal management spectrum, are those systems typified by ranching, crofting, game bird rearing and hill farming where animals are released into extensive vegetated landscapes for extended periods with little or no individual day-to-day supervision. Whilst animals in extensive systems are evidently managed they may not always be considered captive in the traditional sense of the word (see Veasey In Press). Within the zoo setting, habitats approaching extensive systems might include large safari enclosures or enclosed rainforest habitats where the relative scale and complexity of the space provided, and number of animals impinge on individual day to day supervision. Such environments are generally more comparable to the species' natural habitat in size and complexity and as such animals tend to be more reliant upon their surroundings for survival and less on daily human inputs than would be the case in intensive systems, consequently the supervision typically required in more intensive systems is to some extent redundant. Extensive environments, capable of sustaining animals for extended periods of time with limited intervention will broadly fit the evolutionary expectations of the species where animals are able to express behavioural needs, make choices and to exert control. As such, these environments are likely to be better suited to the animal's psychological needs than most intensive systems (see Lund 2006, Korte et al 2007, Veasey In Press), however, animals in extensive systems are also likely to be exposed to greater stochastic variation and risk (Veasey In Press).

In reality, most zoo environments sit between these two extremes of animal management with differing emphases on control by humans and freedoms for animals. Whilst zoo design is always context specific, where exactly zoo design should aim for on this spectrum in order to deliver peak welfare is debatable since there are challenges associated with each end of the spectrum, and the tension between physical and psychological priorities in animal management appears more less inevitable. In Figure 2 (Veasey In Press) illustrates this relationship and proposes how efforts to safeguard physical wellbeing influences the psychological opportunities available to captive and managed animals and ultimately how they interact to influence animal welfare across a population.

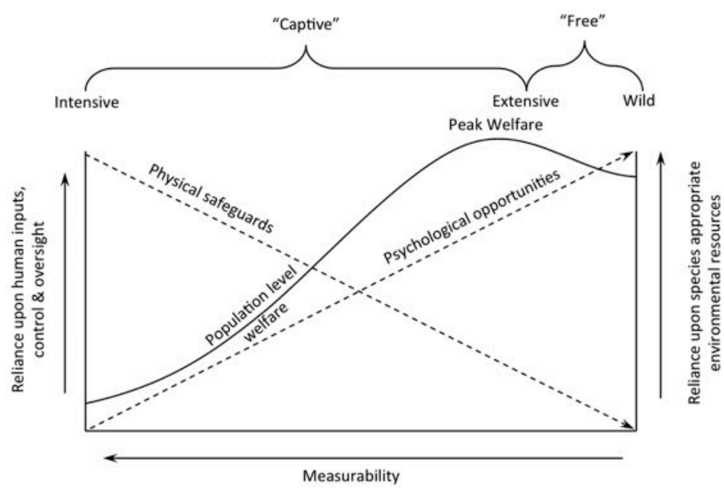

Figure 2 Schematic representation of the relationship between efforts to safeguard physical health and the availability of psychological opportunities for captive and managed animals and how this might impact population level animal welfare. The hypothetical state of population level peak welfare is predicted to occur in situations in which animals are provided freedoms essential for good animal welfare, whilst simultaneously benefiting from veterinary care and being protected from the principal natural stressors not contributing positively to their welfare. The proposed population level animal welfare curve is asymmetrical since the welfare costs associated with diminished protection from physical risks are typically short-lived whereas compromises to psychological wellbeing in captivity are frequently chronic in nature. And so, whilst peak welfare might be achievable in well managed extensive situations, the lowest levels of welfare are more likely to be experienced in intensively managed captive environments due to the more chronic nature of the challenges animals might experience, and the decreased capacity for animals to successfully react to those stressors (from Veasey In Press).

Veasey (In Press) proposes that somewhere on this conceptual animal management spectrum there exists an optimum point in which animal welfare peaks. At this point, the principal physical risks wild animals are routinely exposed to would be eliminated or effectively managed, and the principle psychological priorities catered for. Zoo environments capable of delivering population level peak welfare would be functionally comparable to the environments in which animals have evolved, replicating features necessary to allow animals to remain in a state of broad motivational equilibrium, whilst also protecting them from the physical harms and welfare challenges routinely experienced in nature. Such environments, were they to be established through good zoo design and maintained through effective management, could conceivably deliver higher standards of welfare than many animals would routinely experience in the wild where survivorship is invariably curtailed and hardship widespread (Veasey In Press).

However, it must be noted that the purpose of good zoo design is not to eliminate stress but to provide environments in which animals are empowered to respond effectively to stressors identified as necessary for good overall welfare in process such as the one described here (Veasey In Press). Korte et al (2007) make the case that welfare concerns arise when animals are unable to respond to challenges rather than when there is an absence of challenges. Under such a conception, the obligations of management is likely to shift between extensive and intensive systems reflecting the increased capacity of animals to respond to challenges in extensive systems, as well as the practical limitations on, and requirements for observation and intervention in extensive systems.
A more dynamic conception of management responsibilities to captive animals reflecting the nature of the surroundings they inhabit would be a significant step forward within the zoo world. Such a dynamic approach is reflected in the Scottish Government's code of practice on deer management which states "with increasing intervention (e.g. fencing, feeding, culling, development) comes increasing responsibility for their welfare" (SNH 2012). Within the zoo context therefore, reptiles or amphibians maintained in extensive rainforest habitats or antelope maintained in open range park environments might justify different management requirements to conspecifics maintained in discrete tanks or small zoo habitats respectively.

Whatever the circumstances, it should be the goal of zoo design to aim for the point of peak welfare in which the balance between a population's physical and psychological needs are optimized, and so the challenge lies in finding this balance against a backdrop of differential capabilities in quantifying physical and psychological needs which currently shifts zoo design and management toward the protection of physical health, rather providing for an animal's psychological needs. To achieve peak welfare therefore, the prevailing orthodoxy of maximising health as a means to secure welfare needs to be challenged and a mechanism is required to identify those facets of a species' life in the wild that are necessary for good welfare.

UNDERLYING PRINCIPLES

Up until now, there was no systematic process to identify species specific psychological priorities; instead evidence based zoo design was centred around comparative experiences of managing animals in different captive habitats together with applying knowledge of the species' wild lives in an often anecdotal or intuitive manner.

The process outlined here seeks to quantify the psychological priorities of a species by ranking behaviours and relevant cognitive processes against twelve criteria that provide insights into the evolutionary significance and the motivational characteristics of each behaviour and cognitive process, as well as examining evidence of documented welfare impacts in captivity of the expression or non-expression of each behaviour or cognitive process (see Figure 3). The output of this process is intended to complement the functional components of welfare relating to nutrition, environment and health covered in existing frameworks

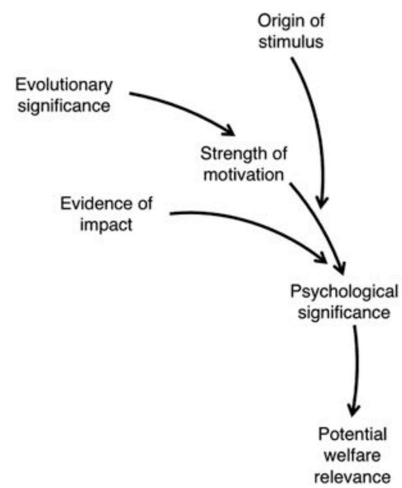

Figure 3 Outlines the principal considerations behaviours and cognitive processes are assessed by in order to establish their psychological significance and welfare relevance.

such as the five freedoms and five domains models (see FAWC 2010, Mellor & Beausoleil 2015, Mellor 2016) rather than simply replacing them.

The five freedoms state animals should be free to express (most) normal behaviours (FAWC 2010) but it is important to understand that not all normal or natural behaviours are equally important in terms of welfare (Veasey In Press). At one extreme are behaviours considered essential for good welfare which are often referred to as behavioural needs (see Dawkins 1983, Hughes & Duncan 1988, Poole 1992, Jensen & Toates 1993, Duncan 1998, Spinka 2006, Fraser 2008b, Mason & Burn 2011, Veasey In Press) and at the other end are behaviours likely to be indicative of welfare compromises (see Veasey et al 1996a, 1996b, Bracke & Hopster 2006, Spinka 2006, Mason & Veasey 2010, Mason & Burn 2011, Mason et al 2013, Veasey In Press). Understanding where behaviours exist on this continuum is fundamental to developing welfare based design criteria.

The methodology developed by Veasey (In Prep) centres around the motivational characteristics of behaviours and cognitive priorities since welfare relevance is profoundly influenced by the nature of the controlling motivation; the stronger the motivation that is frustrated, the greater the welfare compromise. As such, understanding the intensity, frequency, duration and origin of the motivation underlying each behaviour and cognitive process is central to this methodology. However, quantifying motivation, is challenging (see Dawkins 1983, Dixon et al 2014) and especially so for wild animals in zoos where opportunities for optimal experimental design are limited. Fortunately, motivation can be considered by exploring the evolutionary significance of individual behaviours and cognitive processes.

Motivation is an evolved mechanism to elicit behaviours or cognitive processes to solve evolutionary important challenges (see Darwin 1859, Hamilton 1964, Trivers 1971, Hughes & Duncan 1988, Broom 1998, Dawkins 1998, Fraser & Duncan 1998 Bernard et al 2005, Bracke & Hopester 2006, Fraser 2009, Aunger & Curtis 2013). Whilst there will be individual variations in motivational systems within a species, motivational systems like physiological, morphological and behavioural characteristics are species specific products of evolution, ultimately having their origins in survival and reproductively significant factors (see Bernard et al 2005, Fraser 2009). As such, a relationship between evolutionary significance, motivation and ultimately animal welfare emerges whereby behaviours and cognitive processes which are of high evolutionary significance will be equally highly motivated for, which in turn will broadly correlate with the potential compromise if frustrated (Veasey In Prep).

However, this relationship between evolution, motivation and potential welfare compromise is nuanced and subject to the additional consideration of understanding the origin of the motivating stimulus. Behaviours and cognitive process triggered by internal stimuli that remain regardless of the environment the animal finds itself in, are likely to be important to animal welfare in all circumstances including captive environments, whereas those triggered by external stimuli may not be essential for animal welfare if the eliciting stimuli can be successfully eliminated without any consequential welfare compromise (see Fraser 2008b, Mason & Burn 2011, Veasey In Prep).

Assessments of the relationship between evolution and motivation relate specifically to the natural / evolved state rather than the captive or other potentially artificial environments (See Dawkins 1990, Veasey In Prep). For example, the risks to evolutionary fitness associated with not migrating for wild birds may be catastrophic, whereas in captivity it may be advantageous. However, the welfare compromises for some previously migratory captive birds may be broadly proportionate to the risks to fitness of not migrating in the environment the species evolved in rather, than the costs in the environment it is maintained in (Dawkins 1990, Dawkins 2012, Veasey In Prep).

In addition to insights relating to evolution and motivation, where data exists on established welfare impacts of either the expression or non-expression of individual behaviours or cognitive processes, it is also included in the assessment process.

THE PROCESS

With the assistance of a trained facilitator, a panel of carefully selected experts review the ethogram and relevant cognitive processes of a species against twelve parameters (see Veasey In Prep). The process by which this group assessment is undertaken is based loosely around the Delphi method (Dalkey & Helmer 1963) and in part relies upon the wisdom of crowds (see Surowiecki 2005) whereby average scores from a number of informed experts are likely to closely reflect actual values were they available.

Panel members prepare for the process by reviewing data gathered by the facilitator on the behaviour and ecology of the species in the wild together with whatever behavioural, physiological and welfare related data that may be available from captive studies. Under the supervision of the facilitator, members of the panel carry out initial assessments independently, ranking each behaviour and cognitive process in relation to each of the twelve assessment criteria. Once panel members have completed their individual assessments, the facilitator collates the scores and oversees a review by the panel until consensus is reached. All scores are then aggregated into a single value for each behaviour and cognitive process which represents its probable welfare significance. For a more detailed review of the process see Veasey (In Prep).

APPLYING PSYCHOLOGICAL PRIORITIES TO ZOO DESIGN

Two assessments carried out by Veasey on Asiatic black bears utilising 20 panellists have already demonstrated the repeatability of the process (In Prep). An earlier iteration of the system described here and in Veasey (In Prep) was applied to a zoo design project for the BC Wildlife Park's Kermode Bear habitat in 2013. Kermode bears are a variant of the North American black bear that inhabit the rainforests of British Columbia and are white in colour.

At the time of the assessment, this process did not include cognitive processes, there were fewer assessment criteria, a broader categorisation of behaviours was used than in the current iteration and the panel was more limited in scope and size. The findings of this 'prototype' assessment are summarised in table 1.

Behaviour	Welfare index
Foraging	88.5
Resting	87.0
Manipulating / processing food	85.1
Maternal behaviour	82.9
Digging	71.9
Territorial behaviour	61.7
Climbing	61.2
Socialising	58.3
Mating	54.3
Grazing	52.8
Swimming	43.5
Fishing	33.3

Table 1. Welfare priorities for Kermode bear as determined by a Delphi panel process. The process used for this assessment were more restricted in the breadth of its panel and less sophisticated in its analysis than the current version outlined here and illustrated in more detail by Veasey (In Prep).

Despite the more limited scope of this initial assessment there was broad agreement between the keepers and designer in what the priorities were for Kermode bears (Pearson's correlation $n=12$, $r=0.680905192$, $p=0.05$-0.02) with both groups agreeing on the ranking of the top four psychological priorities. For the purpose of the design, the most significant suite of behaviours from a welfare perspective where those relating to feeding.

There were various clues emerging from the assessment that feed related behaviours would represent high psychological priorities, the first being that they are evidently of high evolutionary significance; wild bears that don't forage, process food or feed will evidently die. In addition, feed related behaviours take up significant proportions of a wild bear's time (Matthews et al 2006, Wilson and Mittermeier 2009) and its energy, and since time and energy are resources wild animals do not waste without good reason, this also supports the proposition that these behaviours are of high evolutionary significance. The high evolutionary significance of these behaviours in turn results in them being highly motivated for, which therefore means that if bears are frustrated in their desire to express such behaviours, it will result in welfare compromises broadly proportional to their motivational strength (see Dawkins 1990). In addition, there is abundant evidence from the captive environment that shows for many species including black bears, a relative abundance of food does not eliminate the desire to forage (see Veasey In Prep). Carlstead et al (1991) for example demonstrated the provision of foraging and food processing opportunities were effective in reducing stereotypic behaviours in zoo bears in a way the provision of adequate food alone was not. This supports the hypothesis that the motivation to forage and feed is primarily internally generated in that it persists in captivity even if the physiological requirement to forage is absent. As such, the need to forage and express and other feed related behaviours are likely to need special consideration in captive management if welfare is to be safeguarded.

Whilst all behavioural clusters fed into the design, this review will focus on how insights into the significance of feeding related behaviours influenced the design process as beyond ensuring the safety of humans and animals, this became the most important design criteria for this project.

In the wild, black bears are generalist / opportunistic omnivores and foraging dominates much of their lives (Matthews et al 2006, Wilson and Mittermeier 2009) and so to be successful in satisfying their psychological needs within this captive habitat, it was considered essential to provide an environment that allows as much of the diversity of species typical feed related behaviours to manifest and also ensures they are manifest for species appropriate periods of time.

Of all feed related behaviours, foraging takes up the most time and has the added benefit of incorporating locomotor behaviours which are good for the physical health of the bear and also benefit visitors who are more likely to encounter active bears. In order to illicit foraging behaviours whereby bears are genuinely seeking food rather than acquiring food from a known location, feeding opportunities needed to be spread out across the entire habitat and in a reasonably unpredictable manner; to achieve this effectively, the size of the habitat is highly significant.

The size of an animal's habitat is understandably referred to in terms of area based metrics, however, the effective size of an animal's habitat has as much to do with factors relating to species appropriate complexity as it does its absolute geographical footprint. By designing complexity that is of use to the bears and of assistance to the staff in managing them (as opposed to complexity for the sake of complexity), the functional space available to the animals can be increased substantially. For example, scattering a handful of treats over $1m^2$ of a smooth flat surface would not occupy a bear's time or intellect in any significant way. However, scattering the same amount of food over the same area comprised of loose river rock in an actively flowing stream results in much more biologically relevant foraging opportunities for the bear requiring dexterity, physical manipulation of their environment and cognitive opportunities such as choice / decision making, learning, concentration and problem solving etc.

Water features are widespread in zoo habitats and the impact of such simple changes in how they are constructed are all to readily ignored on the basis of modest practical management considerations for humans versus the potentially quite profound beneficial welfare impacts on the resident animals. As can often be the case in relation to healthcare, the tendency to focus on ease of management for humans rather than the psychological outcomes for the animals probably stems from the differential tangibility of the two potentially conflicting outcomes.

In this habitat, the principle of increasing the surface area available to the bears was applied to streams, pools and planting to maximise the opportunities for the bears and to increase the effective size of the four-acre design.

A key consideration to augment foraging opportunities were developing strategies to facilitate the distribution of food throughout the habitat including areas typically beyond the reach of keepers whilst bears remained in the habitat. To achieve this the design incorporated streams lined with river rock to facilitate feed distribution along their length deep and within the habitat and beyond into the bigger pools. These pools were also designed to be stocked with trout and would be sufficiently large and deep to provide a good habitat for the fish with ample escape opportunities to ensure any fishing behaviour by the bears would be incidental, and stress to the fish populations kept within or below naturally occurring limits. Whilst fishing might be an opportunity to enrich the lives of bears, its impact on the welfare of the fish should not be ignored and so it was felt vital that habitats were capable of maintaining self-sustaining fish population whereby survivorship compared favourably

Kermode bear habitat BC Wildlife Park, Kamloops Canada illustrating the river rock substrate to facilitate enhanced foraging opportunities for resident bears

with that experienced in nature, and bears were not forced to fish by the restriction of other foraging opportunities. Pool edges, like the streams that fed them were designed to have loose pebble and river rock edges to provide habitat for fish to deposit roe providing foraging opportunities for the bears in manner likely to have little impact on the welfare of the fish.

However, even with streams enabling keepers to effectively gain access to the heart of the habitat without the need to remove the bears from it, much of the exhibit would not be accessible whilst the bears were loose within. To elicit other natural and seasonally appropriate feeding behaviours in a manner that doesn't require shifting the bears to dens or other contained areas, vegetation became essential to the design which in turn dictated the choice of location for the habitat since mature trees were considered vital and they were available within the grounds of the wildlife park.

In spring, wild black bears are predominantly grazers shifting their reliance to soft fruits and berries in the summer months and on to hard fatty tree mast in autumn. To replicate this seasonal shift and provide for species appropriate foraging opportunities throughout the year the design incorporated grassland to be established for spring feeding, the planting of trees and shrubs such as dogwood, buffaloberry, blueberry, huckleberry, sasparilla, elderberry and pacific crab apple to provide summer foraging opportunities and mast bearing trees such as oak, beech, hazel walnut, hickory and pine for autumn foraging. The trees also provide valuable shade, climbing opportunities and increase the effective size of the habitat.

Leaf litter, log piles and substrate in general also increase the effective size of the habitat providing opportunities for staff to conceal food and habitats for insects to establish themselves increasing the food handling time for bears and providing opportunities for them to manipulate their surroundings, make choices, learn skills and problem solve in a species appropriate manner.

Whilst cognitive processes were not formally examined in this prototype assessment, it was nonetheless considered important to enable bears to make choices about when and how they feed in ways comparable to what they would encounter in the wild, and to ensure the functional contingency between appetitive foraging behaviours and their intended physiological outcomes (i.e. satiety) are maintained. The diversity of feeding strategies discussed here and others not discussed were essential to addressing such cognitive priorities that have subsequently emerged as being important for bears in assessments carried out on closely related species (Veasey In Prep).

Kermode bear habitat BC Wildlife Park, Kamloops Canada showing the Kermode bear Clover utilising the increased effective size of his habitat

DISCUSSION

Part of the solution to the ‘challenge’ posed by providing for psychologically important behaviours and cognitive processes such as those related to foraging in bears is to view this as an opportunity as well as a challenge. An opportunity to design environments that fulfil the psychological needs of the animals also has the potential to enhance visitor experiences and more effectively educate people about the natural world; a bear foraging amongst buffaloberries or in a stream is likely to be far more informative about the ecology of bears in nature than any zoo sign could ever be. Additionally, its important to remember that welfare and the visitor experience are not at odds, they are actually mutually dependant; very few people enjoy seeing unhappy animals at zoos as has been illustrated by the recent shift in public opinion about the welfare of captive orcas and how this has impacted visitor numbers at institutions holding them.

The framework outlined here, is perhaps the only evidence based process that sets out to identify design criteria based on the psychological priorities of a species. Achieving peak welfare through habitat design is not simply a matter of providing animals with more space, health care or complexity, it is about understanding and addressing their species specific psychological needs and designing environments and management systems carefully tailored to them.

Understanding that not all behaviours and cognitive processes are equally important or even necessary for good welfare affords zoo designers and zoo managers the opportunity to focus resources on those aspects of an animal’s life that will yield the greatest welfare returns. To achieve this understanding, systematic processes are required to effectively utilise the knowledge available from both within and outside of the zoo. The process described here is a valuable basis for zoo design and forms part of a wider process outlined in Figure 4 and as discussed previously by Veasey (2005).

One limitation of the prioritisation process discussed here is that as it has evolved, it has become more sophisticated and ultimately more challenging to undertake. This leads to concerns about potential inconsistencies in its use and implementation. A failure to fully understand how to apply each of the twelve criteria to each behaviour, identify the appropriate cognitive process and ultimately to facilitate groups toward consensus could misdirect design with substantial ramifications. It is for this reason that a centralised entity facilitating assessments akin to the Conservation Planning Specialist Group’s facilitation of their suite of complex conservation planning tools is likely to be worthwhile.

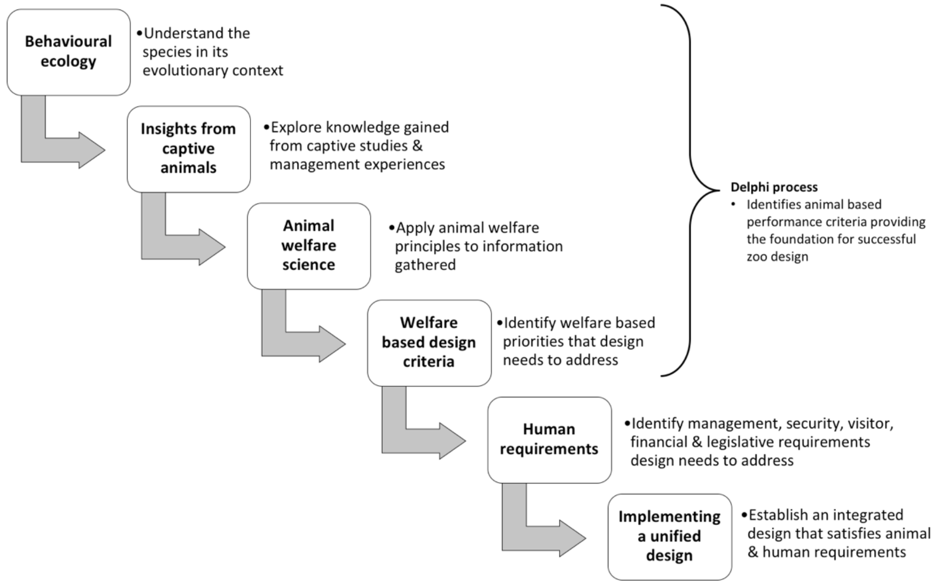

Figure 4. Integrated zoo habitat design model.

Whilst this system will likely develop further over time, a number of clear benefits are apparent over existing welfare frameworks, particularly in informing zoo design processes. It is a practical alternative to extensive and often inconclusive epidemiological or experimental studies that are exceptionally challenging to implement within the zoo environment, it facilitates more effective and practical welfare prioritization than other frameworks and better addresses the provisioning of positive emotional states than more traditional frameworks as it is centred largely around satisfying powerfully motivated needs. Crucially, it is also less constrained by existing management traditions than epidemiological research as it attempts to determine what is important to animals rather than what is the best management or housing systems of those currently employed, and as such it is likely to be far more effective at delivering radical improvements in welfare than the more iterative paradigm that has prevailed in recent times.

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