The 24/7 approach to promoting optimal welfare for captive wild animals

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Accepted for publication in *Behavioural Processes* by Elsevier. The version of record is available at: https://doi.org/10.1016/j.beproc.2017.09.010

ABSTRACT

We have an ethical responsibility to provide captive animals with environments that allow them to experience good welfare. Husbandry activities are often scheduled for the convenience of care staff working within the constraints of the facility, rather than considering the biological and psychological requirements of the animals themselves. The animal welfare 24/7 across the lifespan concept provides a holistic framework to map features of the animal's life cycle, taking into account their natural history, in relation to variations in the captive environment, across day and night, weekdays, weekends, and seasons. In order for animals to have the opportunity to thrive, we argue the need to consider their lifetime experience, integrated into the environments we provide, and with their perspective in mind. Here, we propose a welfare assessment tool based upon 14 criteria, to allow care staff to determine if their animals' welfare needs are met. We conclude that animal habitat management will be enhanced with the use of integrated technologies that provide the animals with more opportunities to engineer their own environments, providing them with complexity, choice and control.

Keywords: Animal welfare, Birth to death, Habitat management, Technology, Zoo, 24/7 across lifespan

Highlights:

- New holistic conceptual framework in caring for captive wild animals 24/7 across lifespan is proposed.
- Considers individual's life cycle needs and preferences influenced by a range of variations.
- An animal welfare assessment tool with 14 welfare criteria is proposed.
- Highlights importance of habitat management and use of technologies.

1. Introduction: A holistic approach to animal welfare

Care staff spends a limited number of hours at a zoo, wildlife centre, or sanctuary. The animals however, are there 24/7, year round for life unless they are part of a reintroduction program (or escape!). Indeed, the human working day dictates the care provided to captive animals. Husbandry activities typically occur during 6-8 daylight hours, which are not necessarily biologically relevant times for the animals. Care staff are not normally present to observe and provide for the needs and preferences of captive animals most of the time (i.e. 16-18 h/day). Given that animal care personnel are fundamental to promoting good welfare, we propose a tool for care staff to determine how well they are providing habitats that meet animals' needs.

This paper proposes a new, holistic conceptual framework to help optimise how we care for animals in zoos. We focus on the animal's perspective; how are animals affected by different aspects of their life cycle, and how do these aspects vary across, for example, day and night, seasons, and the role the animal has been assigned. We discuss how to promote good animal welfare using our proposed 24/7 across the lifespan framework. The framework (Figure 1) requires consideration and integration of life stages, in relation to species and individual differences, and the roles animals play, variations, and other factors affecting animal welfare. We start by describing how we see the concept of animal welfare within this 24/7 framework, and the challenges we face in promoting optimal welfare in zoo environments. We discuss examples of good practice and propose future directions.

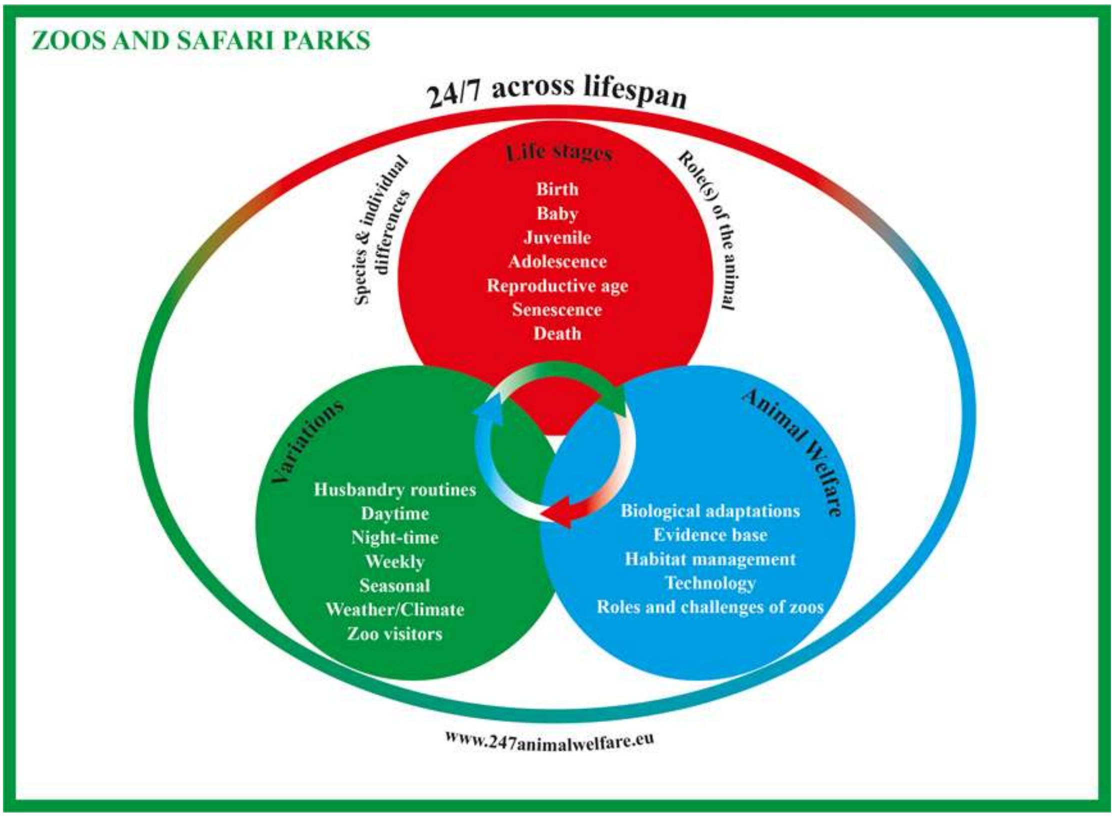

Figure 1. 24/7 across lifespan framework, illustrating the different aspects that should be considered and integrated.

1.1 Applying the concept of animal welfare

Defining and measuring animal welfare is not straightforward (e.g. Mason and Mendl, 1993; reviewed in Fraser, 2009). An animal's welfare is generally accepted to lie on a continuous scale between bad and good (Broom, 1999), and behavioural, physiological, psychological, and biochemical measures need to be integrated to provide a holistic view (Broom, 2007, 2014). Despite this agreement, there is still debate about the importance of the three different approaches to welfare that include whether the animal is able to lead a natural life (e.g. Duncan and Petherick, 1991), how the animal feels (e.g. Dawkins, 1998; Duncan and Petherick, 1991), and the biological functioning approach (e.g. Broom, 1986). Fraser (2009) provides an excellent critique of the merits and limitations of the approaches. The approaches are now seen as dynamically integrated elements within the whole animal, and methods to measure welfare should incorporate all three approaches (e.g. Mellor, 2016). Promoting natural adaptations will likely lead to better welfare reflected by the feelings and biological functioning approaches. 24/7 across the lifespan takes this holistic perspective.

More pragmatically, a range of factors influences the choice of methods to measure welfare. These include availability of technology; human expertise and time; and the relationship with the animals. We strongly recommend that when changes are made to the environment that the animals' welfare be evaluated to ensure the changes have the desired overall positive effect. Behaviour can be systematically quantified (see Martin and Bateson, 2007 for methods) or measured using a Qualitative Behavioural Assessment approach (see Wemelsfelder, 2007). Behavioural observations have many advantages for animal care staff. Unlike some physiological and physical health measures, recording behaviour is non-invasive, often non-intrusive, accessible, immediate and informative of welfare state. Behaviour is the ultimate phenotype - not only is it the result of the animal's own decision-making processes, it is also the expression of emotions (Darwin, 1872; Dawkins, 2004).

Whilst many may consider it ideal for animals only to display positive welfare states (e.g. comfort, satisfaction), we note that some (short-term) negative welfare states are essential; they are instincts that promote survival. For example, thirst encourages water seeking, or hunger promotes exploration and food seeking (Mellor, 2016). The concept of "optimal" welfare is therefore one that includes some negative welfare states.

To illustrate this, Rabin (2003) emphasizes the importance of maintaining behavioural diversity in light of conservation goals by the development of natural behaviour management programs. These programs contain naturalistic stimuli that will encourage the performance of a wide range of behaviours, some of which might be in conflict with short-term animal welfare objectives such as exposing animals to predatory stimuli. Rabin (2003) argues that animals destined for release should be exposed to both positive and negative stimuli during sensitive periods that require behaviour releasing mechanisms. Thus, some stressors are required to promote resilience and coping in animals (see Section 2.2); the key for good welfare is whether the animal has perceived control. It is the balance between positive and negative experiences that reflects the overall welfare state (Spruijt et al., 2001), and welfare is good when the balance is strongly positive (Mellor, 2016, p. 21).

Our goal in 24/7 across the lifespan is to provide environments in which animals can thrive, understanding that at any one time point welfare may vary for individual animals within the same group (e.g. dominant *versus* subordinate). However, when considering the lifespan holistically and within the framework we provide, we argue the balance of positive to negative experiences at all stages of the life cycle will improve.

1.2 Challenges in zoos

Humans are inevitably a critical part of the lives of all captive wild animals, and their actions impact animal welfare. Humans design enclosures, decide on animals' social companionship (or otherwise), have control over the type of food, frequency and method of delivery. Humans decide whether to provide dynamic challenges and environmental enrichment. Key concepts behind environments that promote good welfare are complexity and novelty, choice, and control, and their relationship to predictability (Buchanan-Smith, 2010a). These concepts underpin Poole's (1998) four basic needs of mammals, namely security (a safe area in which to rest and feel secure), complexity, achievement (control), and novelty (to satisfy curiosity and prevent boredom). Both social and physical complexity is critical to promote positive affective states. However, provision of suitably complex environments that animals can control has to be understood in the context of the many challenges zoos face to remain competitive and viable ventures.

Modern zoos have clearly defined goals reflected in their mission statements, these being conservation, research, education and recreation or entertainment (Buchanan-Smith et al., 2001; Patrick et al., 2007). Miller (2012), who surveyed zoo visitors after viewing a video of a tiger pacing, found that poor welfare and related behaviours are not only detrimental for the animals in the zoo, but they can also cause a significant decrease in people's perception of the level of care the animals receive, and their willingness to support zoos. Good animal welfare underpins zoos' goals, by providing environments that encourage visitor learning through the enjoyment and interest generated from watching animals in environments that promote natural behavioural diversity and good infant rearing conditions. Good welfare also promotes more ecologically valid research findings on healthy animals (Buchanan-Smith et al., 2001). Therefore, promoting good animal welfare is fundamental not only for the individual animal, but also to achieve high standards in successful conservation, research, education, and entertainment programs.

Besides education, research and conservation, zoos must entertain the public, as they are usually financially reliant on paying visitors. Despite best efforts, there are often financial constraints and competition from other animal-related activities the public could choose to visit (e.g. amusement park, petting farm). Building or maintaining new enclosures is extremely expensive, and staff often have limited time to engage in all animal welfare activities they might wish to (Brando, 2016a). Fulfilling both the goals of high standards of animal welfare as well as adhering to mission statements can be challenging, as the goals can be conflicting when trying to meet visitor, staff, and animal needs and preferences. Animal visibility is an important aspect in maintaining visitor satisfaction and achieving educational goals, but animals might choose to be out of sight from the public. Creative solutions such as one-way glass nesting boxes that allow for visibility while an animal is inside (without direct visitor access to avoid tapping on the glass to wake up and/or activate the animals) can help overcome some of the conflicts between different goals.

2. Considering 24/7 welfare across lifespan

2.1 Species, including developmental and social, considerations

The natural history of an animal, its biology, ecology and diet, sensory systems, natural habitat, social structure, major life history events, activity patterns, and human-animal interactions are among the many topics taken into account when developing species-specific animal welfare programs (see our website 247animalwelfare.eu for a worked example with common marmosets). Looking at the life cycle of a species, we find different life stages commonly divided into birth, baby, juvenile, adolescence, reproductive age, senescence and death (see Table 1). When we consider different life stages we can identify key features and considerations likely to be of importance to the welfare of the species. On our website, we provide a table highlighting examples of these features across a wide range of species. To manage a species appropriately in captivity, it is important to find out about each of these key considerations and develop a management plan accordingly. This includes consideration of nutritional requirements such as adequate concentrations of protein for growth and development (NRC, 2003), attention to vitamin requirements such as vitamin D for bone growth and maintenance of mature bone tissue, and calcium for growth and during lactation (Hosey et al., 2009).

A defining characteristic of a species is their social structure. Ensuring animals are housed in appropriate social groups is therefore critical to welfare. Compatible conspecifics are known to buffer stress (e.g. Smith et al, 1998), and present opportunities for positive welfare-enhancing behaviours (such as grooming, play, and mating). Despite this, most enrichment literature focuses on physical rather than social environment (e.g. de Azevedo et al., 2007). One reason may be the potential harm from social enrichment, including problems with introducing individuals, and competition for dominance and associated risks of serious injury, together with concerns about disease transmission. Additionally, acquiring sufficient numbers of individuals to form natural groups, combined with lack of available space in captivity may prevent optimal social group composition and size. None-the-less keeping animals in appropriate social groupings, and with the required space and complexity to allow individuals to choose to spend time together or apart, is likely to be the most important welfare consideration.

Social considerations 24/7 across the lifespan may require social housing to vary, depending for example on reproductive stage, or mating season. Many of the subheadings in Table 1 indicate the range of social considerations at different life stages. For example, some species require seclusion from others for the birth environment (e.g. snow leopard: O’Connor and Freeman, 1982). In other species, we know the importance of same age play mates for normal development (e.g. baboons: Cheney, 1978) or of gaining experience of rearing offspring to become a good parent (e.g. callitrichids: Buchanan-Smith, 2010b). Social considerations extend throughout the life including coping with illness and at the end of life with the death of a conspecific (e.g. chimpanzees: Anderson et al., 2010). As species do not live in isolation from each other in the wild, the formation of mixed-species groups that naturally associate may also improve welfare (e.g. Leonardi et al., 2010; Daoudi et al., 2017).

Table 1 Examples of key features at different stages of an animal’s life.

Life stage	Examples key features/considerations in captivity
Birth	Age of mother
	Mother and father experience
	Social group and infant experience (e.g. cooperative rearers; aunties)
	Nutritional requirements of mother
	Nutritional requirements of offspring
	Comfort (thermal and physical)
	Seclusion of physical birth environment (e.g. nesting materials)
	Human-animal interaction
	Infant mortality, including infanticide/cannibalism
	Imprinting
Baby	Mother's experience and dominance
	Number of other relatives/allies/foes
	Social group and members experience of infant care
	Age of weaning and mother's nutritional requirements until weaning
Juvenile	Juvenile mortality
	Availability of same age play mates
	Space and time to play
	Cognitive development opportunities
	Social learning
Adolescence	Mother's experience and dominance
	Friendships
	Social groupings (e.g. relatives/allies/foes)
Reproductive age	Social structure and possibilities to mate (e.g. social sexual suppression by dominants)
	Bachelor groups
	Inbreeding avoidance; protection of young (e.g. infanticide)
Senescence	Social structure and behaviour
	Physical decline (reduced mobility, pain)
	Behaviour and physical aspects
	Aging rates and nutrition
	Cognitive decline (memory etc.)
Death	Social aspects sickness and dying
	Euthanasia

2.2 Individual differences

We must accept that individuals, human and non-human, vary in their biological capacity for good welfare. There are genes that predispose animals to good or poor physical health (e.g. susceptibility to disease), and also those that predispose them to experience degrees of "happiness" or subjective wellbeing (SWB) (Weiss et al., 2002, 2008). For example, negative welfare states (e.g. anxiety) are strongly associated with the “Neuroticism” personality factor in humans (Costa and McCrae, 1980). Similarly, good subjective wellbeing in humans is predicted strongly by the personality dimension Extraversion (e.g. Costa and McCrae, 1980) and, less so to Agreeableness and Conscientiousness (e.g. DeNeve and Cooper, 1998; McCrae and Costa, 1991). A personality structure similar to humans has been found in chimpanzees and other primates (chimpanzee: King and Landau, 2003; capuchin: Morton et al., 2013). In chimpanzees, the “Dominance”, “Extraversion” and “Dependability” factors predict SWB (King and Landau, 2003). These traits are genetically inherited (chimpanzees: Weiss et al., 2002), and there is an association between happiness and longevity (orang-utans: Weiss et al., 2011).

Individual differences can also have an effect on social relationships and breeding success. Carlstead et al. (1999) did a cross-institutional analysis of environments and breeding success, in combination with behavioural profiling of black rhinoceros. They found that both individual temperament traits such as “dominant” and “fear”, and characteristics of the captive environments such as wall and enclosure size, have an impact on a pair’s breeding success. Personality has been shown to influence the quality of social relationships (e.g. capuchins; Morton et al., 2015) and breeding success (e.g. cheetahs: Wielebnowski, 1999; pandas; Martin et al, 2017). As such, it is likely that personality profiling will be used in the future, together with genetic considerations from studbook analyses to determine social compatibility in breeding programmes.

Understanding the development of individual animal personalities is still a new field, as is integrating gene and experiential factors including individuals' control over their own environment (Stamps and Groothuis, 2010). Our approach in 24/7 is to attempt to provide animals with an environment that is designed on an understanding of individual differences. An environment that provides sufficient complexity, choice and control will allow animals to thrive within their own capacity, and to develop abilities to cope with the challenges they may face in a captive environment. Early life is a critical stage in this regard.

Early experiences affect the brain, given its plasticity when developing (Knudsen, 2004). For example, there is considerable research using non-human primates and rodents as models that shows that early life stress (e.g. parental loss, neglect, or abuse) can enhance fear and anxiety. It can also lead to impaired cognition, loss of sensitivity to reward, abnormal brain neurochemistry and neurobiology, and alter hypothalamic-pituitary-adrenal (HPA) axis baseline activity, as well as reactivity (Pryce et al., 2002; reviewed in Parker and Maestripieri, 2011). Although there is ample evidence that severe early life stress can have deleterious consequences, there is also some empirical research that illustrates that exposure to some mild or moderate early life stress may provide resilience to subsequent stressors encountered in adulthood (reviewed in Parker and Maestripieri, 2011). It is a fine balance to provide the best early life care to enable the animal to cope as an adult in their future environment.

2.3 The role of animal

Animals do not choose the role they get assigned in a zoo, people do this for them. Some of the common roles animals are assigned to fulfil are: exhibit animal, petting zoo/touch pool animal, ambassador, interaction (e.g. photo opportunity) and show animal, research animal, breeder, and reintroduction candidate, but this list is by no means exhaustive. Roles may require animals to move between zoos regularly, as they are important to the genetic diversity of the captive populations. Roles may require a predominately hands-off approach when animals are raised in environments that prepare them for successful release, such as the “mother condor puppet” feeding method for California condor chicks (Kasielke, 2007, p.151). Alternatively they may receive anti-predator training, as is used with the greater rhea, to improve introduction success (de Azevedo et al., 2012). Other roles take animals into human arms, when children and adults in petting zoos cradle rabbits, or dolphins are kissed in interactive programs. It is important to emphasize that animals can have multiple roles (simultaneously and/or consecutively), such as the bottlenose dolphin being part of a breeding program, a participant in research projects and an interaction/show animal. The impacts of cumulative stress on animals that are assigned multiple roles need to be considered.

To illustrate the impact of the role assigned, we shall use an example of domestic rats. Rats are often bred in zoos as food for other animals, and mostly housed in simple and small cages. The same rats can also be display animals in zoos however, housed in larger and complex exhibits with reversed light-cycle, showcasing the highly adaptable, curious, active and social nature of the animal. These same rats can become food for other animals in the zoo when they are old and not suitable to be on display anymore. The role the animal is assigned by humans will affect his/her quality of life, and we need a better understanding of what the implications of role(s) on animal welfare are and how it affects an animal 24/7 across the lifespan. Some well-known animal roles are briefly discussed with examples.

2.3.1 *The use of animals in education, interactive exhibits and shows*

The purpose for outreach and interactive programs through touch pools and other education programs with hands-on experiences may be laudable. It is important to educate children that, for example, snakes are not slimy, but should be admired and protected. There is also evidence that keeping animals in the classroom improves the children’s learning outcomes, for example using more science facts and vocabulary in student writing (Trainin et al., 2005). It also positively affects the cognitive and/or emotional impact and welfare of humans participating in interactive programs and petting zoos (e.g. DebRoy and Roberts, 2006; Sahrmann et al., 2016).

Staff are likely to select animals that tolerate being touched and handled, and can cope with the loud noises and sudden events. However, despite efforts to ensure proper handling, inexperienced children may scream, drop, scare, or hurt animals. Animals may be transported to schools, during which their welfare requires careful consideration, whilst others live semi-permanently in classrooms (e.g. Trainin et al., 2005). Many ambassador animals used in interactive programmes with humans may have compromised welfare. Such environments may limit their range of movements, provide them little choice and control, and force them to live in social groups that are not species-specific. Schools may have inadequate knowledge of how to best keep them, for example with regards to nutrition, or how to assess their welfare, especially of exotics (e.g. reptiles, invertebrates). On the other hand, the programs might provide opportunities for positive human-animal interactions and relationships, opportunities to gain access to desirable activities, such as foraging and interactions with environmental enrichment, and therefore have a positive effect on animal welfare (Miller et al., 2011).

Dogu et al. (2011) claim that "*Animals in touch exhibits are usually tough enough to be touched often without experiencing high levels of stress, however management at touch exhibits and safe touching practices are important to ensure the safety of the animals by guests*" (p. 4). Robust evidence to support the claim that the animals are not experiencing high stress is lacking. It is unfortunate that with the amount and variety of species of zoo animals being used in the many types of programs, such as touch pools, petting zoos, interactive and education programs, there are only a handful of peer-reviewed publications describing research on the impact on animal welfare.

Supporting a lack of negative effect, Baird et al. (2016) found no direct welfare issues, measured by behaviour and faecal glucocorticoid metabolites (FGM) in armadillos used as education animals. However, they found the overall amount of handling that an animal experienced (for education programs or for husbandry) had a positive correlation with FGM. These findings show that handling negatively impacts welfare, but was not related to maintaining the animals for educational purposes in this study.

Many zoos have exhibits, such as petting areas, where humans are allowed close proximity, and often, physical contact with the animals. These species are usually domesticated, or semi-domesticated and some zoos sanction feeding. Research into the welfare effects is inconsistent. Anderson et al. (2002, 2004) found that visitors negatively influenced the behaviour of goats and sheep in a petting zoo, specifically when no retreat area was available. In contrast, Farrand et al. (2014) found that the public did not affect the behaviour of goats and llamas. However, pigs showed decreased inactivity and social behaviour, both affiliative and aggressive. The presence of a retreat area, which the public cannot enter, gives the animals some control over their interactions with visitors and may have ameliorated some negative effects. Majchrzak et al. (2015) found that performing rides did not increase cortisol levels in camels, claiming the rides were more akin to environmental enrichment. However no behavioural data were collected to help interpret the findings. It is widely accepted that the use of cortisol as a sole measure does not provide enough information to understand animal welfare and caution against using a one-method approach (e.g. Novak et al., 2013). There are many reasons that glucocorticoid measurements may increase including but not limited to seasonal variation in sex hormones, activity levels, and/or the stress response. A multi-method integrated approach is fundamental for a holistic understanding of animal welfare (Mason and Mendl, 1993).

Public presentations and shows are popular with the public and still commonplace. Whilst the chimpanzee tea party is an event of the past in modern zoos, displays with birds of prey, parrots and small mammals, as well as various marine mammal shows still take place. Although such displays can be educational, highlighting and showing skills and adaptations, they also raise specific welfare concerns (Brando, 2016b). Shows can often attract large and noisy crowds, and the method of showing animals has the potential for negative impact.

For example, with birds of prey, frequently used old-fashioned and classical falconry methods require that the diet is restricted to ensure the birds are hungry and “work” during the shows and return to the handler (Ford, 1992). Bird of prey training focusing on positive reinforcement is on the rise and weight management to the detriment of the bird is recommended against (IAATE, 2008). Birds of prey may be hooded (eyes covered to limit sensory input) to prevent them becoming distracted or frightened (Ford, 1992), and parrots might be feather clipped to prevent them from flying away. Housing may be designed to make interactions easy and quick with high visitor visibility, and birds of prey are often tethered to perches limiting movement, or held in small crates and holding areas between presentations and shows. Whilst many birds appear to adapt as long periods of being stationary and without food intake may be part of their natural history, food restriction, tethering and hooding, may have negative welfare consequences. Scientific research on these topics is currently lacking. Their participation in shows may disrupt their desired activity patterns, but often provides the only opportunity for the animals to fly freely. Restricted housing for easy access and handling is not limited to birds of prey, but is also common in other species used in education programs, including small mammals such as rats and armadillos.

Marine mammal shows are popular and California sea lions are a frequently used show animal. Their participation in presentations is usually voluntary and rewarded with food. Indeed, there is evidence from a range of species that positive reinforcement training can be beneficial for animal welfare (e.g. Brando, 2010, 2012; Desportes et al., 2007; Kastelein and Wiepkema, 1988; Melfi, 2013). However, the use of sea lions in shows may lead to physical and social access being restricted at certain times (including night-time) to facilitate shows and their preparation. The effects of shows, interaction and “swim with” programs are still ill understood and different effects have been reported (e.g. positive effects: Miller et al., 2011; negative: Kyngdon et al., 2003). Allowing animals choice (i.e. independent of food reward) to not engage with shows, in petting zoos or other activities should be available. Animals who do not want to participate, for example, could go to a certain place in the exhibit, or request another enrichment activity by pressing a lever.

2.3.2 *The use of animals in research*

As well as education, one of the roles of zoos is to engage in research to further our scientific understanding of the animals themselves, and many animals are the subject of intensive research on behaviour, nutrition, reproduction and genetics. Most data are collected non-invasively through observations, analyses of studbooks, or biological samples are collected during veterinary interventions, so no additional handling or restraint is required. Indeed, many animals are trained to cooperate with research (e.g. hydro-dynamic trail following in seals: Dehnhardt et al., 2001; underwater visual acuity in manatees: Bauer et al., 2003; shape representation in a grey parrot: Pepperberg and Nakayama, 2016). Animals are increasingly being tested individually in purpose-built research centres within zoos (e.g. chimpanzees: Herrelko et al., 2012; capuchins: Morton et al., 2016). The animals volunteer to participate, which suggests it is enriching for them, and their social interactions and natural activity budgets on research participation days suggests their welfare is better than on non-research days (e.g. baboons: Fagot et al., 2014; chimpanzees: Yamanashi and Hayashi, 2011). However, we must continue to monitor their behaviour (and other parameters where possible) during research. Whilst some research is automated, much still requires interactions with humans and this has been shown to have a negative impact on welfare, increasing agonistic behaviour, and decreasing pro-social behaviours (chimpanzees: Chelluri et al., 2013). The authors emphasise the importance of understanding the influence of all forms of interactions, and to include positively intended interactions in animal welfare assessment. Research participation may also impact welfare negatively if it causes the animal frustration through unfairness of reward (e.g. Brosnan and de Waal, 2014), and if the task challenge is too difficult (Meehan and Mench, 2007). For example, Leavens et al. (2001) found that anxiety-related self-directed scratching increased with cognitive challenge in chimpanzees, and Wagner et al. (2016) found it increased when the response was incorrect in both gorillas and chimpanzees. The length of time away from the group is also critical, as it may affect normal conspecific social interactions, and return to the group after individual testing has been shown to increase both positive and negative interactions, which could be related to the food reward used and received during testing and shifting (capuchins: Ruby and Buchanan-Smith, 2015).

2.3.3 *The role of animals: Conclusion*

To conclude, the role an animal gets assigned needs to be decided as soon as possible in his/her life, to ensure they are best prepared. Ideally, the role should be one they enjoy and not just tolerate. Regular handling and feeding of animals, starting early in life promotes better human animal interactions (e.g. cattle: Jago et al. 1999; chickens: Jones, 1993; rats: Cloutier et al., 2012; rabbits: Podberscek et al., 1991; red-tailed hawks: Baird et al. 2016), and may make the animals more suitable as candidates for outreach or petting zoos. However, too much human contact, as is often the case during hand-rearing, can lead to imprinting on humans, inability to integrate successfully with conspecifics, development of stereotypies, and problems with successful reproduction (e.g. parrots: Schmid et al., 2006; gibbons: Pirovino et al., 2011). Some decisions on how to treat animals are not easy, as the animal's welfare may conflict with educational or entertainment goals, and a decision not to hand-rear (e.g. after a mother dies, or neglects the young) may lead to the animal dying. If we are to take animal welfare seriously, we should consider whether early interventions are required, and critically review the whole life experience from the 24/7 perspective of the animals.

2.4 Variations

As we have noted, the hours caregivers and veterinarians are at the zoo are limited to, on average, approximately 8 hours a day, and predominately during daytime hours. Additionally, the time at the zoo is divided over many tasks such as cleaning, preparing food, maintenance, meetings, activities such as ‘zookeeper for a day’, as well as coffee breaks and lunch. This leaves little time to observe, interact and dynamically provide for animals and their environments. Daytime hours at the zoo can also vary with regards to the seasons, as opening and closing times change with daylight hours in some geographical areas (see Figures 2A and 2B which illustrate the longer operating hours in summer compared to winter).

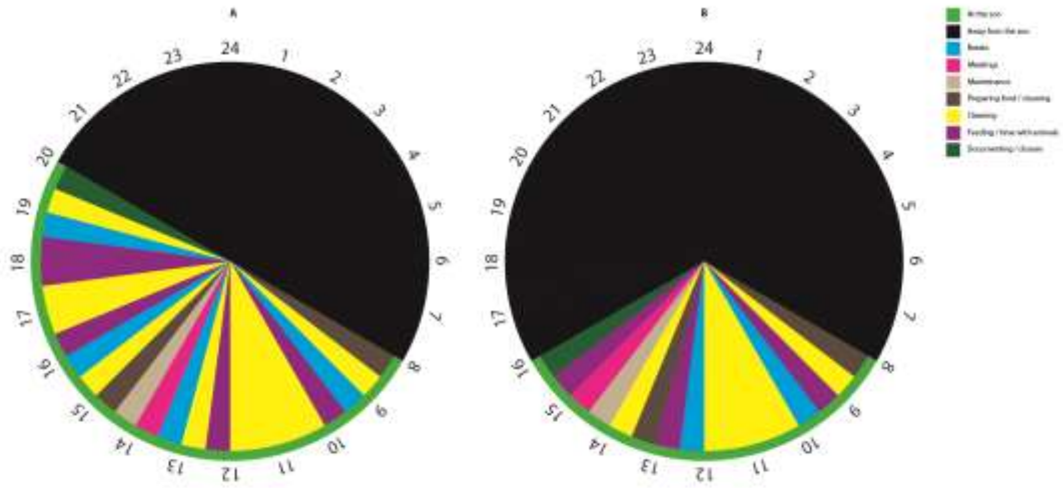

Figure 2. Example of an average (A) summer and (B) winter day considering different activities and time with the animals (personal observations, Brando, based on 25 years of practical experiences in zoos).

There are many variations to consider over a 24-hour period, over the week and across the seasons, which are influenced by the geographical location and climate.

Animals can be categorised in relation to their activity patterns: diurnal, nocturnal, crepuscular (active at dawn and dusk), matutinal (dawn and morning), verspertine (dusk and night) and cathemeral (when activity is distributed roughly evenly throughout the 24-hour cycle). It is important to acknowledge differences within activity budgets, and these in turn can differ per individual. Disruption of natural circadian rhythms can create welfare issues, including increased susceptibility to disease (humans: review in Bechtold et al., 2010) and mood disorders. For example, rats exposed to constant light for 8 weeks, or constant darkness developed depression- and anxiety-like behaviour, characterised by anhedonia – the inability to feel pleasure in normally pleasurable activities (Tapia-Osorio et al., 2013). Abou-Ismail et al. (2008) found that rat welfare is better if husbandry routines are performed during the dark (active) rather than light (inactive) phase.

Nocturnal animals are usually kept on reverse light cycles under artificial light (i.e. dark during the day so visitors may see their active period), but it means they can rarely use outdoor enclosures which are in daylight and may overwhelm their sensitive visual systems (Erkert, 1989). The effect of artificial blue light may also have negative effects on the activity budgets, health and reproduction of nocturnal species (Fuller, 2014). In addition to visual adaptations, there are other biological adaptations to fit with their activity patterns. One example, is the afternoon gum-eating behaviour performed by saddle back and moustached tamarins, likely to be a strategy to prolong the time that the gum stays in the gut (i.e. overnight), so the tamarins benefit from microbial fermentation (Heymann and Smith, 1999). Such examples highlight the importance of the range of considerations required to optimise animal welfare in management practices.

2.4.1 Variations in relation to husbandry routines

Human induced variations, as well as variations in animal activity patterns means there are numerous husbandry aspects and management routines to consider in relation to animal welfare. Kawata (2008) emphasises the need to understand the feeding ecology of animals in the wild to promote their welfare in zoos. The way animals feed, what they feed on, under which conditions, frequencies and time spans, what the seasonal variations are, and other relevant information should be obtained and integrated into husbandry programmes.

We will illustrate this with an example of animal feeding repertoires. Many species housed in zoos would naturally be feeding, or engaging in their natural feeding repertoire, at times that zoo care professionals are not usually at work. In the wild, some animals start feeding very early, other species feed when the sun goes down or at night, while other species might forage throughout a 24-hour timeframe. The feeding repertoire may include many facets like feelings of hunger, anticipating food, gathering, manipulation, hiding and recovering food, to digestive behaviours and processes. Animals could be eating throughout the day and every day, or gorge feed with meals spread weeks apart, and this in turn can be seasonally dependent. Feeding can be a solitary or social event, and can have social functions to strengthen bonds or maintain hierarchies. These are only a few of the many considerations regarding an animal’s feeding repertoire.

Due to caregiver routines and working hours, species-specific and appropriate feeding presentation might be different to what is preferred or necessary for the species in question. Unless provided for through the use of technology, such as timed feeders and foraging opportunity devices (e.g. Brando, 2009; Krebs and Watters, 2016), animals might want to forage and eat but will not have access to food until the caregiver arrives. Non-technology solutions are also possible, such as providing food in ice blocks for the slow release of food after the keepers have left for the day. Not being able to forage and feed when the animal desires and/or food not being presented in species-appropriate manners can result in undesired behaviours such as stereotypies (e.g. okapi and giraffe, Bashaw et al., 2001).

Providing opportunities that prolong exploring and increase foraging time, processing and the consumption of food are some of the aims of food related environmental enrichment programs. Modifying the spatial or temporal distribution of food can increase the duration of feeding related behaviours in chimpanzees, bears and elephants (Morimura and Ueno, 1999). The provision of a species-specific foraging diet for rhinoceros can reduce obesity and avoid over supplementation of energy and minerals found in grain and pellets (Clauss and Hatt, 2006).

Unpredictability of feeding times due to changing caregiver routines can increase or induce stress-related behaviour (Waitt and Buchanan-Smith, 2001). However, food delivered on a very predictable schedule can also result in undesired behaviours. Bloomsmith and Lambeth (1995) studied the response of chimpanzees to predictable and unpredictable feeding schedules and found more abnormal behaviour and inactivity in the pre-feeding period in the predictable schedule due to anticipation. Feeding enrichment designed to increase temporal variability of feeding times (change from feeding at set times), and to increase the number of feeding times/day is proposed by Swaisgood and Shepherdson (2005).

Altman et al. (2005) found that changing the feeding schedule of lions from daily feeding to a gorge and fast schedule was beneficial. The lions paced less on fasting days, as compared to being fed everyday, and showed an overall increase in digestibility and an increase in appetitive active behaviours. Feeding routines can therefore have overall animal welfare benefits on non-feeding days.

Furthermore, staff shortages, extended maintenance of the enclosure, weather, presence of infants and visitor considerations all impact on whether animals are granted access to indoor and/or outdoor areas, and the effects on animal welfare vary. Locking or keeping animals inside can result in behaviours associated with negative welfare (e.g. gorillas, Hoff et al., 1994). Some animals are required to be 'locked out' on exhibit during zoo opening hours to increase the chance that animals can be seen by visitors. Giving animals the choice to move between on- and off-exhibits is important. Giant pandas displayed fewer signs of behavioural agitation and lower urinary cortisol in a free choice condition between off- and on-exhibit enclosures, than when they were locked outside on exhibit (Owen et al., 2005). The use of preference and choice tests will aid our understanding of what animals want, and provide the necessary information for suitable conditions for indoor-outdoor environments, rather than blindly following traditions or species guidelines (i.e. input parameters described in guidelines have not all been empirically tested using animal-based parameters).

2.4.2 *Variations between day and night*

Although the use of night cameras is increasing, it is remarkable how little practical and scientific knowledge is available of what animals do when animal care staff is not there. The majority of research on zoo animals has been conducted during daytime, therefore biasing the research evidence towards human working hours rather than following the animal's life cycle and activity budget. When we are considering animal welfare over the 24-hour period, the question arises, ‘what do animals do at night’? It is likely that most caretakers and curators do not know.

Sleep occurs in mammals, birds, and invertebrates (Vorster and Born, 2015). Many functions of sleep remain unclear but they are likely to relate to energy conservation and nervous system recuperation (Siegel, 2005). The quality and quantity of sleep an animal has can have physiological, behavioural and psychological consequences, and affects the vast majority of body functions, including immunity, hormonal regulation, metabolism, thermoregulation and pain thresholds. Sleep also supports consolidation of newly acquired information in memory (Diekelmann and Born, 2010). Sleep deprivation, or disturbance can affect attention in many animals (Kirszenblat and Swinderen, 2015), decrease cognitive performance (Alhola and Polo-Kantola, 2007), and increase sensitivity to pain (Karmann et al., 2014). Sleep and rest are therefore fundamental to good welfare and a lack of sleep, or repeated disturbances, can lead to bad welfare and impaired performance.

Provision of appropriate sleeping sites is critical. Features such as height, concealment, lack of disturbance, hygiene, and comfort, together with required nest/bedding materials, must be considered (e.g. Anderson, 1998, 2000; red-bellied tamarins, Caine et al. 1992). Sleeping site preferences may vary in relation to risk and season (e.g. gorillas, Lukas et al., 2003), and in relation to evening events held in zoos.

Understanding how social factors affect sleeping and sleeping site selection is also important to ensure that the captive environment has appropriate and sufficient resting and sleeping areas for different kin groups. Vessey (1973) observed sleeping clusters to consist mainly of kin in free-ranging macaques. Similarly, snub-nosed monkeys of the same matriline slept in the branches of the same sleeping tree, and night-time grouping patterns were generally similar to those observed during daytime (Cui et al., 2006). Therefore, plenty of sleeping sites should be available to accommodate social sleeping behaviours.

Open access between indoor and outdoor areas can influence sleeping patterns. Drury and Buchanan-Smith (2008) found that captive giraffes showed a pattern for longer sleep in more frequent bouts, a more natural sleep architecture, when they had open access between the indoor and outdoor area. They recommend that giraffes are not confined indoors overnight, but are given the choice to access outdoor areas. Another aspect to consider is light. Fading artificial light in and out is beneficial, so diurnal primates are not plunged in and out of lightness and darkness in enclosures without natural light (Buchanan-Smith, 1997).

The examples above illustrate that sleep and rest have predominantly been studied in relation to behaviour, social aspects, and how environmental parameters such as the location of nest boxes, impact animal sleep. More research is needed to understand how animals spend their time at night, whether animals are hungry or overfeeding, and to evaluate the value and use of the provided environmental enrichment. We need a better understanding of whether the sleeping and resting places offered are adequate for good quality rest and sleep, social requirements and/or individual preferences, and how this relates to welfare.

2.4.3 *Weekly variations*

Visitor numbers often change between weekdays and weekends, usually with more visitors on the weekend. Sometimes certain weekdays are busier than others when it comes to school groups, educational programs, and animal presentations. Availability of care staff and veterinarians may also vary across the week. There are 102 days per year of 'weekend days', when time for optimal care might be significantly reduced.

Although fewer care staff at weekends may have negative consequences for welfare, it can also have the opposite effect, and record analyses is a fruitful database to analyse weekly variations. Lambeth et al. (1997) found laboratory-housed chimpanzee wounding was reduced on weekend days when human husbandry activities were lower. In zoo-housed chimpanzees, Wagner and Ross (2008) found parturitions were equally distributed across the week, indicating that there was no effect. These examples of record analysis illustrate the breadth and wealth of information contained within them and analyses can provide insights for practical applications.

2.4.4 *Seasonal variations in relation to husbandry routines, visitors, geographical location and weather*

Depending on geographical location, many seasonal variations exist, such as daylight hours and climatic variations, with the changing seasons also affecting enclosure quality, quantity and outdoor access. For example, in countries in northern Europe (e.g. Finland) days can be very long, even having 24-hour daylight in summer, while winter days are shortened to a few daylight hours. If zoos operate with the closed access policy (i.e. animals do not have free access between indoor and outdoor areas whenever they want to), the length of opening hours will have an effect on the animals opportunity to choose where they want to be. There is evidence that a combination of indoor and outdoor housing does improve welfare for a variety of primate species, and for some outdoor access is of particular importance (e.g.

common marmosets; Pines et al., 2007). Outdoor facilities should provide shelter, heating and protection to allow access in inclement weather. Particular care must be taken for smaller monkey species like the Callitrichidae, or carried infants, particularly those unable to return inside of their own volition when they get cold.

Geographical area and associated weather also influences the amount of time that animals can spend outdoors, and may impact on adaptations for seasonal breeding. Indoor illumination by artificial fluorescent lighting may be operated by automatic time switches that are adjusted seasonally to mimic the natural changes in day length in the species' habitat, and technology can be used to increase the options for control over environmental parameters (additional light and localised heat for common marmosets: Buchanan-Smith and Badihi, 2012). Animals are likely to spend less time in outdoor exhibits during heavy rains, snow, strong winds, hail, and very cold spells, or if temperatures rise and shade is unavailable. Provision of features like heat lamps, shade, vegetation, misting systems, different humidity zones, a fan, spray showers, and open access between indoor and outdoor areas allow animals to choose different thermal zones and to optimise enclosure use.

Variations across day and night, the week, year and seasons can be geographically dependent, and should be reviewed for each species on an individual facility basis. Tailored programs to suit an individual facility will assist in providing the most optimal environment to promote animal welfare.

2.5 Zoo visitors

Visitor numbers the type of audience, behaviour and noise levels varies across the seasons, with spring and autumn seeing more people at the weekends, while school trips are mostly planned on weekdays. The summer season is often busier with activities such as photo opportunities and night-zoo events, and in winter visitor numbers decrease or are reduced to none if the zoo closes for the season, ceasing all public activities like sea lion or bird of prey shows.

Visitor effects have predominantly been studied in primates, with effects ranging from negative and neutral to positive (Davey, 2006; Fernandez et al., 2009; Hosey, 2000). There are species and individual differences in response to visitors, with life experience influencing how animals respond. Enclosure design, and allowing animals to choose not to be on view to visitors (or using camouflaged nets to conceal and quieten visitors) can be effective at reducing negative behavioural consequences (Blaney and Wells, 2004; Davey, 2007).

However, there is sometimes a conflict, with management worried about animal visibility when animals choose to spend time out of view, or sleep hidden in their favourite spot in the back of the enclosure. Sometimes the use of a sprinkler system or other deterrent is used to reduce the time animals spend in areas where they are not visible for the public. Although this might achieve the goal of increasing visibility, we encourage methods that positively achieve goals for both animals and people, with animal welfare at the heart of considerations and solutions. When animals spend time in places that are off-limit to the public or in harder to observe areas technology, such as live-streaming cameras and plasma screens, can be used to make the animals visible for the interested public (as used in the giant panda enclosure at Ocean Park in Hong Kong). Enclosure design offering a variety of concealment options like vegetation, open dens, and providing shaded elevated platforms while maintaining the animals in view can be designed to meet both animal and visitor needs.

3. Animal welfare assessments: A practical evaluative framework

Within the constraints of attempting to take the animal's perspective (but supporting critical anthropomorphism, Burghardt, 1985), understanding individual differences and seasonal changes, we developed an assessment criteria framework as a tool to assist care staff consider the experiences of animals, through a thorough understanding of natural history and biological adaptations. In this section we compare our framework with others available, and introduce a practical online tool.

3.1 Animal Welfare Frameworks

The first welfare framework was developed for farm animals (Brambell, 1965). Farm animals make up the majority of kept animals (e.g. Fraser and MacRae, 2011) and the early attempt to promote welfare was encapsulated in the Five Freedoms (Brambell, 1965). More recently these have been extended to a Five Domains model (Mellor, 2016) and a 12 welfare criteria (Welfare Quality, 2009). We have combined these two approaches, and adapted and extended the 12 welfare criteria to assess any captive animal in our 24/7 approach (see below). We focus here on zoo-housed animals, but the approach is applicable to any captive animal.

Other zoo welfare frameworks have also been developed recently. We recognise that efforts to promote optimal welfare in zoos must be comprehensive, coordinated and there must be commitment at all levels for it to be successful at institution level. Kagan et al. (2015, p. S2) provide an excellent high-level framework, with "four major components: institutional philosophy and policy, reflecting values commitment and capacity building; pragmatic structure and resources; execution and evaluation". Capacity building, staff training, leadership and communication feature as key concepts, and we fully recognise and support this in our 24/7 approach. Kagan et al. (2015) also provide the Detroit Zoological Society assessment checklist for both the Institutional Policies and Programmatic Structure. If completed, this should provide the basis for the development of a clear action plan if deficiencies are identified.

Justice et al. (2017) have adapted the Animal Welfare Assessment Grid (AWAG), originally developed for animals in research programmes (Honess and Wolfensohn, 2010), for use in zoos. The AWAG takes four components into account: Physical parameters (e.g. general condition, clinical assessment); Psychological parameters (e.g. positive and negative behaviours in a range of contexts); Environmental parameters (e.g. enclosure design, group size); and Procedural parameters (e.g. restraint, sedation). This type of approach has been validated with laboratory-housed macaques used in research (Wolfensohn et al. 2015). The welfare assessment grid has a distinct advantage of providing a visual representation of an animal's welfare, and provides a temporal component to allow changes to be tracked over time (Honess and Wolfensohn, 2010). A specific scoring system has also been developed to evaluate quality of life in geriatric zoo-housed mammals to support decision-making for euthanasia (Föllmi et al., 2007).

Our 24/7 approach has several features in common with those of Kagan et al. (2015) and Justice et al. (2017). They all feature a wide range of considerations (including social, physical and husbandry considerations, human-animal interactions) and with an important focus on individual animal agency. Their checklists can be applied to any animal, and their use will be helpful in the development of an action plan for improvement, and to set priorities. We fully support both of their evidence-based approaches. What the 24/7 approach adds is the need to fully research the natural history and adaptations as a starting point prior to any assessment, and to consider welfare across the life-course and the impact of variations described in this paper.

For 24/7, we propose that welfare assessments should be planned at specific times, at important changes and/or transitions (e.g. particular requirements such as shelter, heating or cooling might be necessary with a change of season). A change in the care staff is another example. When someone who has cared for certain individuals for many years is retiring, early planning and continued animal welfare assessment can help identify, prevent and address possible negative impacts. Assessment is also needed when an animal is moved in or out of the group (through death or transfer). Revisiting the workshop questions at pre-determined times would increase the likelihood that an animal's needs and preferences are attended too as much as possible.

3.2 The 24/7 across the lifespan approach

Understanding how to assess and promote captive wild animal welfare from a 24/7 approach is one of major challenges and responsibilities of modern zoos and sanctuaries today. Preferably, animal welfare assessment decisions and their implementation is informed and based on science, considering both resource (input) and animal-based (outcome) parameters. Gaps in knowledge, as well as concerns and conflicts need to be identified to produce an Institutional philosophy and policy (e.g. see Kagan et al., 2015) that can be consistently applied through a culture of care.

To develop these high standards and professional animal care programs, it is critical to understand an animal's ecology, behaviour, biology, sensory systems, social life, and nutritional needs. We base our approach on the 12-point welfare assessment criteria framework. In 2004, a large multi-country and multi-institution project in Europe was initiated, named Welfare Quality®, science and society improving animal welfare in the food quality chain (Welfare Quality, 2009). The goal of the project was to develop European standards for on-farm welfare assessment, product information systems that create transparency about the welfare of farm animals during production, as well as practical strategies for improving animal welfare. The project took five years to complete and identified four key principles: good feeding, good housing, good health and appropriate behaviour. The principles incorporate, expand and update the Five Freedoms. Within these 4 key principles, 12 animal welfare assessment criteria were defined.

We have adapted these 12 welfare assessment criteria to be more relevant to zoo animal welfare. We propose two additional criteria (Table 2: criteria no. 2 on feeding and no. 7 on perceived control) to determine whether welfare needs are met.

The orange-winged Amazon parrot was chosen as an example species, to illustrate the adapted animal welfare assessment criteria (Table 2). The reason for choosing this species is that there has been a considerable amount of research done on different aspects of the behaviour, biology and care in captivity, such as environmental enrichment, feeding, and health, which makes completing the criteria easier and decisions for care evidence-based (Melfi, 2009). This parrot species is a resident breeding bird in South America, Tobago and Trinidad, reaching up to sixty years of age. In the wild, the diet consists primarily of all types of fruits, nuts, seeds, blossoms, leaf buds and berries, feeding solely during the day, early in the morning or late in the afternoon (Pet information Animal World, 2016). They travel in social groups and live in large communities, in semi-open country and forests (Austin, 2014). They are a popular species in zoos and as companion animals. However, a species dedicated husbandry manual for the orange-winged Amazon parrot could not be located at the time of writing and should be professionally developed to ensure a standardized approach to promoting good welfare for orange-winged Amazon parrots (or any other animal species kept in captivity for that matter).

Table 2

Illustrated example of the 14 welfare criteria with the orange-winged Amazon parrot (adapted from Welfare Quality ®).

Orange-winged Amazon parrot (*Amazona amazonica*) (unless otherwise stated).		
Welfare Principles	**Welfare Criteria**	**Example evidence reference**
Good feeding: Are the animals properly fed and supplied with water?	1. Absence of prolonged hunger (i.e. mimic natural feeding intervals). Other end of the spectrum should also be considered, i.e. prevention of obesity.	Over-sized pellets provide foraging-like opportunities reducing inactivity and encourages a more naturalistic activity budget (Rozek et al., 2010). These parrots usually feed early morning (30 minutes after sunrise when leave roost) and late afternoon so attempts should be made to mimic these intervals in captivity.
	2. Access to appropriate food and species-typical foraging opportunities (i.e. they should have a nutritionally suitable and appropriate diet & delivery).	Information on breadth of diet and utilisation of palms for fruit foraging (Bonadie and Bacon, 2000). Captive parrot nutrition: Interactions between anatomy, physiology, and behaviour (Matson and Koutsos, 2008). Over-sized pellets elicit comparable podomandibulation (handling with beak and foot) behaviour (Rozek and Millam, 2011).
	3. Absence of prolonged thirst (i.e. they should have a sufficient and accessible water supply).	Clean drinking water must be available at all times and refreshed at least daily (Kalmar et al., 2010).
Good housing: Are the animals properly housed?	4. Animals should have comfort when they are resting and sleeping (i.e. physically comfortable and relaxed, not always vigilant).	On Trinidad palms function as roosting and nesting sites (Bonadie and Bacon, 2000).
	5. Animals should have thermal comfort (i.e. they should neither be too hot nor too cold, and have thermal zones to choose from).	Temperature, humidity, and environmental housing parameters (Kalmar et al., 2010).
	6. Animals should have enough space to be able to move around freely in relation to natural locomotion (e.g. leap distance, orientation of substrates etc.), and in context of indoor-outdoor space restrictions.	Habitat use in and around two lowland Atlantic forest reserves in Brazil (Marsden et al., 2000).
	7. Animals should have perceived control (i.e. complex enclosure giving them choice over what and when they do things).	Preferences for cage enrichment devices (Kim et al., 2009).

Good health: Are the animals healthy?	8. Animals should be free of major injuries (e.g. skin damage and locomotory disorders).	Development of a reference for xeroradiographic and conventional radio-graphic anatomy and its importance to clinical evaluation (Smith et al., 1990).
	9. Animals should be free from disease (i.e. appropriate standards of hygiene and care).	The basic cage care includes daily cleaning of the water and food dishes. Weekly wash of all the perches and dirty toys, and the floor should be washed about every other week. A total hosing down and disinfecting of an aviary should be done yearly, replacing anything that needs to be freshened, such as old dishes, toys and perches. Normal haematological parameters (Tell et al.,1997).
	10. Animals should not suffer pain induced by inappropriate management, handling, catching, or transport.	Capture, restraint, sample collection, high-quality nutrition, and intellectual stimulation: An overview of avian care and husbandry (Schulte and Rupley, 2004).
	11. Animals should be treated well in all situations (i.e. care staff should promote good human-animal relationships, with the animal's perspective as the focus).	Short neonatal handling of parent-reared birds increases tameness and improves adaptation to life in captivity (Aengus and Millam, 1999).

Appropriate behaviour: Does the behaviour of the animals reflect optimized emotional states?	12. Animals should be able to express normal, non-harmful, social behaviours (e.g. preening, breeding).	Pair housing significantly improves environmental quality and positively affects animal welfare (Meehan et al., 2003). Captive animals show a preference for morning bathing compared to other times of the day (Murphy et al., 2011). Environmental enrichment and social manipulations (including misting, fruit supplementation, nest hole restriction, enlarged nest boxes, and pair separation/reunification) increases reproductive performances (Millam et al., 1995). Social play behaviour of two juvenile white-fronted Amazon Parrots (*Amazona albifrons*) includes bill-nibbling, pseudo-copulation, play-solicitation, play-biting and fighting and foot-clawing, possibly to increase social ties between birds and develop adult behaviours used in epigamic and agonistic contexts (Skeate, 1985).
	13. Animals should be able to express other normal behaviours (i.e. it should be possible to express species-specific natural behaviours such as exploring, problem solving).	Cognitive flexibility, memory, lateralization and individual differences (Cussen and Mench, 2014). Colour, hardness, size and material all influence environmental device use (Kim et al., 2009). Level of novelty experienced during early life affects neophobia development (Fox and Millam, 2004).
	14. Negative emotions such as fear, distress, frustration or boredom/apathy should be avoided whereas positive emotions such as security or contentment should be promoted.	Social play analysis in different species of parrots, e.g. play chases, play fighting, wild careering flights, physical interactions (rolling on the back and jumping on the belly) (Diamond and Bond, 2003). Novelty and individual differences influence neophobia (Fox and Millam, 2007). Genetics, environmental aspects, and neighbours affect the severity of stereotypies and feather picking (Garner et al., 2006).

As previously noted, we have a dedicated website for the 24/7 welfare across lifespan approach: www.247animalwelfare.eu. Amongst other materials, this website provides a link to an interactive and evaluative workshop using common marmosets as an example. The “Wild *versus* Captive” workshop provides an evidence base to highlight where there may be a mismatch between the wild and captivity, and so potentially highlight a welfare problem.

4. Conclusion and future directions

The essence of care for any animal is habitat management (Ahlering and Faaborg, 2006). The concept of habitat management is well known in species conservation, although this term can have different interpretations. What is of interest to zoo professionals is the approach used in planning and designing environments, including microhabitats that incorporate the needs of a particular animal. Habitat management, such as features used by adult animals during nesting, requires an understanding that animals have specific habitat requirements at different life stages (Berkeley et al., 2007). Habitat management in zoos provides for species-specific needs and should be modified to reflect and respond to individual needs and preferences over time.

Rather than caregivers providing the bulk of the care, the environment can be designed to provide for activities and opportunities to the animals to choose. The shift to habitat management should be further developed in zoos, reflecting a 24/7 across lifespan approach. Coe (1989, 1996, 2003, 2011), an experienced landscape and zoo architect, has long designed and written about the importance of environments that strongly contribute to the mental and physical wellbeing of animals, including urban wildlife in zoos. Coe (2009) describes the design of environments that specifically suit particular life stages, such as an exhibit for bachelor groups of gorillas. Coe

(2006) proposes naturalistic and functional enrichment through built in features that elicit enduring interest for animals, reflecting biological relevance, such as a basking rock, shade and cooler places, artificial mound feeders, swaying branches, and (infrared) motion detector or lever activating water jets as provided for otters, penguins, chimpanzees and elephants. Coe recently designed the trail systems at the Philadelphia Zoo, when he wondered, "Why stop with rotating exhibits? Why not just connect everything in the zoo to everything else and let the animals have the run of the place?" (Philly.com, 2015). Although final control obviously is in the hands of professional zoo staff, ensuring practical aspects such as the health and safety of animals, staff and visitors, these trails provide additional complexity, choice and control to animals as they have more habitat options available, views and inter-species interactions.

Habitat management will also be more optimal with the use of integrated technologies. Partly self-sustaining environments that function in a semi-autonomous manner provide a wide variety of opportunities, choice and control for animals over 24 hours (Brando, 2009; Krebs and Watters, 2016). The implementation of different types of technologies, such as: timers (lemurs: Sommerfeld et al., 2005); infra-red motion sensor beams (otters and other aquatic species: Coe, 2006); touch sensors (marmosets: Buchanan-Smith and Badihi, 2012); lever pulling (elephants: Markowitz reviewed in Maple, 2007); automated feeding stations with individual transponder chip (common brushtail possum: Isaac et al., 2004); automated showers (cows: Legrand et al., 2011); echolocation activated devices to activate a water jet stream (dolphin: Amundin et al., 2008); and computer screens to play games or request fish or toys (primates: Fagot and Bonté, 2010; dolphin: Starkhammar et al., 2007) are some of the available options. Such technologies give animals control over their environments, and direct reliance on humans is reduced.

Decision-making with regard to animal welfare should preferably be done from an evidence-based approach (Melfi, 2009), even if many practical, although not officially researched and tested handling and care strategies are already being successfully used with a variety of species. We believe it is important to verify these long-standing practices through systematic research, and analyses of long-term and cross-institutional records. Data should be collected for all species, including at night using 24-hour observations, and across the weeks and seasons.

Decisions about animal care should also be revisited in the light of ethics to ensure appropriate treatment when caring for and interacting with animals, and used to defend high quality of care being provided. For example, decisions to cease keeping certain species could flow from ethical considerations with regards to providing, or failing to provide, an environment that allows for good animal welfare. A decision not to keep a certain species often originates from restrictions and limitations, as in the case of being a smaller city zoo, or a zoo without the necessary expertise, or due to geographical location, and not because the species is unlikely to thrive even in the best captive conditions. This philosophy reflects the commitment to high animal welfare standards above the need to house species because the public wants to see them.

In conclusion, caring for zoo animals involves considering the cradle to grave experience of individual animals. It is a dynamic process requiring changes to accommodate individual needs and preferences, which may change over time, as well as constant updating as more evidence becomes available. Those caring for zoo animals should therefore aspire to promote predominantly good animal welfare, 24/7 across their entire lifespan using the criteria proposed.

Acknowledgments

We thank Dr. Lou Tasker for her enthusiasm, critical insights into the concept, and constructive editing of a draft of the paper. Dr. Hayley Ash, Mark Kingston Jones, Martina Schiestl and Chris Lucas also provided valuable feedback on earlier versions of this concept and manuscript. We thank Remco van Asch for designing the artwork and figures. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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