The Bear Necessities

Priorities in Polar Bear Welfare, Management & Facility Design

Yorkshire Wildlife Park

Care for the Rare

Wild Life Foundation

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CARE FOR THE RARE

Innovation at the nexus between conservation,
animal welfare & public engagement

The Bear Necessities -

Priorities in Polar Bear Welfare, Management & Facility Design

A Report Commissioned by
Yorkshire Wildlife Park
and the WildLife Foundation

Dr Jake Veasey
Care for the Rare

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Now is the time to progress our knowledge further by pulling together the expertise of the international polar bear community for one of the most ground-breaking investigations ever to be carried out on polar bear welfare.

John Minion: CEO Yorkshire Wildlife Park
Cheryl Williams: MBE WildLife Foundation

Foreword:

"Yorkshire Wildlife Park undertook to build a polar bear facility in 2016 - the first-time polar bears would be kept in England for nearly 20 years. We knew that it was vital to get this right and to design the extensive reserves of Project Polar around the needs of the bears or we would quite rightfully be criticised by the world. Now is the time to progress our knowledge further by pulling together the expertise of the international polar bear community for one of the most ground-breaking investigations ever to be carried out on polar bear welfare. We hope this will be a significant step forward in our collective endeavours to improve the welfare of bears in zoos around the world, and ultimately in the wild."

John Minion: CEO Yorkshire Wildlife Park
Cheryl Williams: MBE WildLife Foundation

"Manitoba is known as the "Polar Bear capital of the world" here at Assiniboine Park Zoo we find ourselves in the unique situation of managing a group of nine bears all within a single habitat!! We are continuously looking for ways to improve their welfare and we want to remain at the cutting edge of conservation and research techniques. We welcome this opportunity to put our collective minds together and produce something tangible, that will assist Polar Bear husbandry well into the future and give them a future at the same time!!"

Grant Furniss: Senior Director Animal Care & Conservation Assiniboine Park Zoo

"According to Canadian government data, Canada is home to at least two-thirds of the world's polar bears, one the most culturally important animals to Canada's Indigenous people. In consideration of this unique national responsibility, Canada's Accredited Zoos and Aquariums (CAZA) support this valuable undertaking to help identify the psychological needs of polar bears."

Jim Facette:
Dirécteur Executif | Aquariums et zoos accrédités du Canada (AZAC)
Executive Director | Canada's Accredited Zoos and Aquariums (CAZA)

"As zoo designers, we are always looking for the best information to guide our thinking in creating vibrant permanent homes for the many species that are in human care in the world's zoos and wildlife sanctuaries. This report, and the process that was undertaken to arrive at it, underscore the massive potential of expert collaboration to achieve and communicate a fine grained understanding of a species' welfare needs and the many different, non-prescriptive ways that this can be achieved. It is a brilliant tool for bringing people together and achieving creative, concrete results."

Becca Hanson: FASLA, Director, Studio Hanson|Roberts

Introduction:

Aims:

To identify the psychological priorities of polar bears (*Ursus maritimus*) to guide animal centred solutions to elevate the welfare of the species in managed environments.

Defining animal welfare:

Animal welfare is the overriding theme throughout this document which is intended to provide a tool for the enhancement of polar bear welfare. For this reason, it's important to briefly consider what animal welfare is.

Animal welfare is a nuanced concept influenced by, and manifest in multiple factors (Mason & Mendl 1993, Dawkins 2006, 2017, Fraser 2008a, 2008b, Veasey 2017, 2019, 2020a, 2020b, Webb *et al* 2019, Weary & Robbins 2019), and which currently lacks a universally accepted definition (see Hewson 2003, Fraser 2008a, Veasey 2017, 2022, Robbins *et al* 2018, Marinova & Fox 2019). However, most welfare scientists agree that animal welfare is all to do with the feelings of animals (see Duncan & Petherick 1991, Sandøe & Simonsen 1992, Gonyou 1995, Mench 1998, McMillan 2000, Bracke 2001, Dé́sire´ *et al* 2002, Duncan 2002; Mason & Veasey 2010, Hemsworth *et al* 2015, Mellor 2016, Webster 2016, NG 2016, Veasey, 2017, 2022, Robbins *et al* 2018, Webb *et al* 2019).

To provide context for this report, a definition of animal welfare is used that reflects this prevailing scientific consensus known as the hedonistic, or feelings school of animal welfare science (Robbins *et al* 2018) which views the psychological wellbeing of animals as paramount. This conception is one used by the World Association of Zoos and Aquariums and the South East Asian Zoo Association, however, it is important to acknowledge the Association of Zoos and Aquariums (AZA), the Canadian Association of Zoos and Aquariums (CAZA) and the European Association of Zoos and Aquariums (EAZA) consider animal welfare to be synonymous with both physical and psychological wellbeing (see Veasey 2022).

While the state of animal's health directly impacts its welfare as it is defined by AZA, CAZA, and EAZA, so does the suitability of its thermal, social, and physical environment, its behavioural and cognitive opportunities, its access to appropriate food etc. Furthermore, all these factors and others, including an animal's health, only truly impact an animal's welfare when they impact how the animal feels; if none of these factors alter the feelings of the animal, as might be the case with asymptomatic yet serious health conditions, or physical trauma inflicted under anaesthesia, they do not impact the animal's welfare at that time. And so, despite its relatively widespread use, physical health is arguably redundant in defining welfare, if not in influencing and assessing welfare. This may seem like a pedantic distinction; however, it is important because the pursuit of good health can be detrimental to an animal's welfare (Veasey *et al*.,

Wide ranging species such as polar bears face a double jeopardy; they are exposed to an increased risk of extinction in the wild as well as welfare challenges in captivity. We have a duty to address both challenges.

1996a, 1996b Fraser 2008a, 2008b, Duncan 2002, Veasey, 2017, 2022) as would appear to be the case in some of the prevailing nutritional management priorities for captive polar bears detailed later in this report. For the purpose of this assessment therefore, good welfare is considered to occur when animals experience positive emotional states (happiness, enjoyment / pleasure, satiation, excitement, contentment, relaxation etc.), and negligible mental suffering, and poor animal welfare occurs when animals experience severe or chronic states of mental suffering (unhappiness, distress, depression, pain, anxiety, hunger, thirst, frustration etc) (Mason & Veasey 2009a, 2009b, 2010).

Whatever the welfare definition individuals subscribe to however, the output of this assessment is intended to be used in conjunction with established knowledge relating to the management of physical health and other welfare inputs, not to supplant such knowledge. The assessment focuses on psychological priorities recognising the centrality of feelings to an animal's welfare, and to help provide balance in decision making where there is a tension between the physical and psychological needs of animals.

The welfare of captive carnivores:

Polar bears and other large carnivores are often seen as emblematic of welfare compromises experienced by wild animals in captivity in part because they are iconic species which attract attention, but also because as a group, they have a propensity to express stereotypic behaviours in captive environments (Clubb & Mason 2003, 2004, 2007, Mason 2010), which are widely understood to be indicative of compromised welfare (Mason 1991, Clubb & Mason 2003, 2007, Mason & Latham 2004, Vickery & Mason 2004, Mason 2006) including to the public.

Amongst the Carnivora, rates of stereotyping have been shown to be sensitive to several environmental and behavioural ecological characteristics. This support the proposition that stereotypies are indicative of compromised welfare and is also suggestive of taxonomic and ecological welfare vulnerabilities amongst the group. Stereotypies are more prevalent in barren environments than enriched ones, they are exacerbated by food deprivation, disturbance, and other aversive situations (Clubb & Vickery 2006), and between different carnivore species, a large home range size, and higher median daily travel distance are risk factors for stereotypies (Clubb & Mason 2003, 2007). It has also been observed that activity levels and a tendency to form routines and repeat actions (perseveration) increase species and individual predispositions to stereotypies (Mason 2006, Campbell *et al* 2013).

While perservation and an ability to remain active to cover an extensive home range in search of dispersed food sources has a logical relationship with enhanced survival in wild polar bears, it appears to also expose them to an increased risk of expressing stereotypies in captivity. Diverse data sets suggest a particular susceptibility of polar bears to expressing stereotypic behaviours in captive environments; a review of seven published papers covering a total of 19 polar bears, showed they paced for an average of 32% of the observed time, with a further 5% of time spent expressing other stereotypic behaviours such as swaying or oral stereotypies (Clubb & Mason 2007). Another study reviewing the behaviour of 55 polar bears across 20 facilities, found that 85% of them exhibited stereotypic behaviours, devoting approximately a quarter of the time they spend alert and moving to pacing, with one in ten bears stereotyping for more than 50% of their active time (Shepherdson *et al* 2013). The pacing of captive polar bears appears to be such an intransigent and widely recognised phenomenon amongst the public that the Dutch have even created the verb "ijsberen", literally, "to polar bear" when describing restless, pacing people.

Amongst captive polar bears, stereotypies are also associated with elevated cortisol (a hormone intimately associated with stress), and appear to be reduced by environmental enrichment (Shepherdson *et al* 2013, Skovlund *et al* 2021), further reinforcing the hypothesis that stereotypies are likely associated with welfare compromises in captive polar bears. In addition to stereotypies and elevated cortisol, polar bears experiences high rates of infant mortality in captivity with just 30.4% of zoo born North American polar bears reaching four years of age (Curry *et al* 2015), and mortality in the first year exceeding 50%, compared to just over 20% for captive black bears (*Ursus americanus*), around 25% for captive brown bears (*Ursus arctos spp*) (Roller *et al* 2021). Current rates of infant mortality for wild polar bears have likely risen as a result of the impacts of climate change, however, historical records from the late 80's suggest mortality in the first year was around 35% (Butler 2006). It would typically be expected that survival rates and longevity amongst captive species would equal or exceed those seen in wild populations unimpacted by anthropogenic harms, if captive care and welfare were optimised (see Kitchener and McDonald 2002, Veasey 2017, 2022, Tidière *et al* 2016, Roller *et al* 2021). As such, the comparatively high levels of infant mortality amongst captive polar bears in comparison to other bear species in captivity, together with lower historic mortality rates in the wild, has been cited as further evidence of captive polar bears experiencing poor welfare (see Clubb & Mason 2003).

Clubb & Mason (2007) speculated the dramatic reduction in spatial opportunities for captive polar bears from an average wild home range of ~80,000 km^2 to an average enclosure size of less than $1{,}000m^2$ combined with a lack of regular decision-making, navigation opportunities and a lack of exposure to ever-changing environments results in compromises in the welfare of captive polar bears. However, such speculation cannot readily be tested within the constraints of the current physical, ecological, behavioural, and cognitive opportunities available to captive polar bears, further complicated by the array of confounding variables and small sample sizes available for this species in captivity. The multi-institutional analysis undertaken by Shepherdson *et al* (2013) suggests that enrichment, larger group sizes, having views and increased dry land area are likely to improve welfare, but making inferences regarding the welfare impacts far beyond the "biggest and best" of existing captive polar bear habitats are problematic, and the value of opportunities currently not afforded polar bears in captivity impossible to assess.

Some argue that the propensity of species such as wide-ranging carnivores to experience compromised welfare in captivity should result in them not being kept in zoos (Clubb & Mason, 2003, 2007; Mellor *et al* 2018). However, the behavioural ecology of polar bears and other large, wide-ranging apex carnivores also makes them vulnerable to conservation challenges in the wild; they occur at naturally lower densities in comparison to smaller, herbivorous and omnivorous species, they are less compatible with human populations, often considered as high value species to hunt, and being at the top of the food chain, are highly susceptible to ecosystem disruption. Wide-ranging carnivores therefore face a double jeopardy; they are at risk of extinction in the wild and exposed to welfare challenges in zoos which poses an ethical dilemma for societies concerned about both conservation and animal welfare.

Captive management of wild animals has reportedly played a role in more than half of the cases where extinction has been prevented for birds and mammals (Bolam *et al* 2020) and so discarding captive breeding programs for species considered to be at risk of compromised welfare in captivity as some suggest (see Clubb & Mason 2003, 2007; Mellor *et al* 2018) is not without potentially significant consequences. In order for zoos to maintain captive breeding programs for species such as polar bears and to leverage their reach to drive conservation action amongst their general public, it is essential to maintain the social licence for keeping such species through ensuring good welfare; zoos cannot easily advocate for species conservation if they cannot demonstrate their capacity to care for individuals (see Veasey 2020b, 2022). It is for this reason that a proactive methodology such as the Animal Welfare Priority Identification System (AWPIS©) is necessary to undertake what amounts to a gap analysis of the welfare priorities of species such as polar bears that is independent of the existing constraints of captive environments and management ideologies.

Animal Welfare Priority Identification System:

Background:

Historically, evidence-based animal welfare improvement has primarily relied upon proving specific management practices or aspects of facility design are associated with good or bad welfare. For wild animals in non-experimental conditions not only are there fundamental challenges inherent in assessing welfare (see Mason & Mendl, 1993, Duncan 2002, Veasey 2006, Mendl *et al* 2009, Mendl *et al* 2010, Ohl & van der Staay 2012, Veasey 2017), there are additional challenges associated with establishing cause and effect, and also in experimental design in a real-world multi-institution setting. However, perhaps the biggest constraint relates to the limitations of existing facilities and management practices; it is for example difficult to assess the value of a specific opportunity to a species' welfare, if that species is universally denied the opportunity in all captive facilities to experience it. In other words, relying on welfare assessments undertaken in existing facilities does little to empower animal managers and facility designers to reimagine animal care beyond the constraints of current welfare management paradigms. AWPIS© seeks to overcome these challenges by systematically considering the fundamental needs of the species rather than relying exclusively on what welfare assessment data is available.

The methodology:

If we understood the psychological value of the opportunities animals encounter in the wild to their welfare in captivity, it would transform how we care for them. While the wild is an obvious reference point in identifying those priorities, it's neither possible nor necessary to provide animals all the opportunities they'd encounter in the wild to optimise their welfare in captivity; for example, while predators might appreciate opportunities to hunt, it's unlikely widely predated species benefit similarly from opportunities to be hunted, and yet both are equally natural.

AWPIS© attempts to quantify the relative importance of natural behavioural and cognitive opportunities to captive animal welfare by harnessing the collective knowledge of area experts, using a variant on the Delphi technique. AWPIS© is premised on the existence of a relationship between evolution, motivation, and animal welfare; the more important a behaviour or cognitive processes is to an individual's evolutionary fitness, the more motivated the behaviour or cognitive process will be, and the greater the welfare challenge an animal will experience if it is frustrated in expressing it by virtue of its impact on the animal's affective state. This is modulated by the origin of the stimulus; internally motivated behaviours or cognitive processes are likely to arise regardless of the environment an animal is in, whereas those triggered by external stimuli (such as being chased by a predator) are less likely to arise in environments in which the stimuli are not present (see Figure 1).

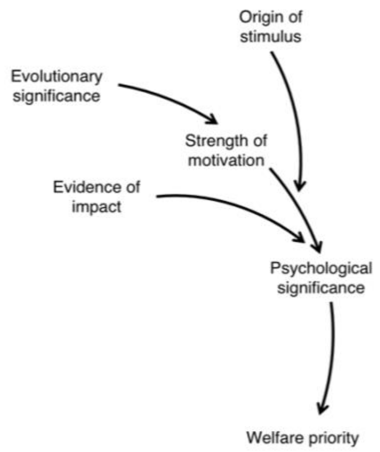

Figure 1. Outlining the principal considerations in identifying welfare priorities according to the AWPIS© methodology from Veasey 2019

In undertaking the assessment, panellists are asked to consider each behaviour and cognitive process according to twelve criteria to help understand their evolutionary significance, motivational characteristics and potential welfare impacts in captivity, which will collectively contribute to their overall AWPIS© score. Seven criteria consider insights from the species' behavioural ecology in the wild or where its considered appropriate, that of its close relatives (impact on survival, impact on reproductive success, energy expenditure, duration, population prevalence, risk of expression on both morbidity and mortality and frequency of expression), three criteria draw on insights from both captive and wild populations (innateness, motivational strength and motivational origins), and two criteria consider insights on the species' welfare in captivity (positive impacts of expression, negative impacts of expression). In addition, panellists are asked to consider the extent to which the captive environment curtails the expression of behaviours and cognitive process under prevailing management paradigms to determine the extent to which important behaviours and cognitive processes are currently catered for.

In attempting to establish psychological priorities, the list of behaviours and cognitive processes AWPIS© considers are selected to represent biologically meaningful categories that could inform management practices and facility design. As a result, the list won't include every conceivable posture, gesture, vocalisation, or even activity, but will include cognitive processes that might be expressed simultaneously with behaviours, as well as behavioural and cognitive opportunities that may not currently be available to the species in captivity. It is therefore quite different in both form and function from a conventional ethogram which are typically made up of mutually exclusive behaviours used to study the activity of individual animals.

Cognitive processes exclusively linked to a specific behaviour are not considered independently from their associated behaviour as they are effectively considered through that behaviour. For example, foraging will also include the cognitive state associated with seeking food. However, some cognitive processes are considered in isolation where they are associated with multiple behaviours and where they likely have an inherent value that is independent from any specific behaviour. These include cognitive processes such as choice / decision making, learning, observing and problem solving. Due to their nature, not all assessment criteria applicable to behaviours are applicable to cognitive processes, these include energy expenditure, duration and risk of expression.

During the assessment, panellists are asked to consider the lifetime impacts of the behaviour or cognitive process on adult animals of both sexes. While juveniles will have different behavioural and cognitive needs to adults, their needs are not considered independently on the basis that by catering for the needs of adults, and advocating for parent rearing, the needs of juveniles will be met. Where behaviours or cognitive processes are unique to a specific sex (such as mothers nursing young), or potentially differ between the sexes (such as intraspecific aggression) this is identified in the assessment.

AWPIS© objectively considers the needs of a species independently from prevailing management paradigms, allowing us to identify new and improved standards of care.

While many of the assessments panellists are asked to make are to some degree unquantifiable or currently unknown, AWPIS© utilises the "wisdom of crowds", albeit carefully selected crowds of species experts from a range of disciplines to provide invaluable insights with which to help identify priorities for species that might otherwise be effectively unobtainable, and thus far, assessment outputs have been consistent among the experts from different disciplines. Once the data from all panellists has been collated, an algorithm is applied to the panel's collective input placing a differential weighting on specific assessment categories. This ultimately yields an AWPIS© score for each behaviour and cognitive process representing its relative welfare significance / psychological value. The maximum AWPIS© score possible is 1 (100%).

Part of the strength of AWPIS© is that it considers the relative ranks for each behaviour and cognitive process rather than their absolute values. As a result, there is no need to correct for the overlap between some of the categories such as exist between foraging and walking for example. Furthermore, so long as panellists are consistent in how they assess each behaviour and cognitive process, there are no issues if some panellists are consistently more conservative in their assessments than others since the final values derived from the pooled data are relative rather than absolute. As a result however, comparing AWPIS© scores for behaviours / cognitive processes between species is less informative than comparing ranks.

Ongoing development:

AWPIS© is a tool that has been developed over the course of a decade or more and will continue to evolve and improve. It is anticipated that algorithms, assessment criteria and assessment formats will continue to develop to improve accuracy in light of subsequent validation exercises. The principal role of AWPIS© is to enable stakeholders to consider the needs of animals through the lens of the animal independent from prevailing management standards and practices, regulations, and existing welfare measurement criteria, and in doing so, to provide a tool to stimulate improvements in welfare management and assessment.

The assessment:

Behavioural and cognitive categories:

Prior to initiating the workshop, a list of 35 biologically meaningful behavioural and cognitive categories that could inform management practices and facility design were drawn up in consultation with a core group of experts. Of these, one was exclusive to females (parenting / nursing) and three were broken down according to sex (den building, fighting and olfaction / scent tracking). During the assessment, panellists were also invited to add up to three additional behaviours or cognitive processes they felt were missing. Subsequently, three behaviours were added by three or more panellists (predator evasion, seasonal migration and stereotypies) and so all panellists were subsequently invited to review these additional behaviours, of which 15 of the original 35 panellists completed the review of the additional behaviours.

Of these three, stereotypies were eliminated since AWPIS© is configured to identify natural behavioural and cognitive opportunities as opposed to impacts of the captive environment or behaviours and cognitive processes "unique" to captive settings. Furthermore, and likely a consequence of the scope of AWPIS© and how it is configured, stereotypies emerged as a significant outlier with an AWPIS© score of 0.334 compared to a range of 0.579 - 0.897 and an average of 0.723 for all other behavioural and cognitive categories. Additionally, the outputs of fighting and olfaction / scent tracking were sufficiently similar between the sexes that these were consolidated between the sexes and so only den building and parenting / nursing remained separate according to sex.

Panel demographics and outputs by cohort:

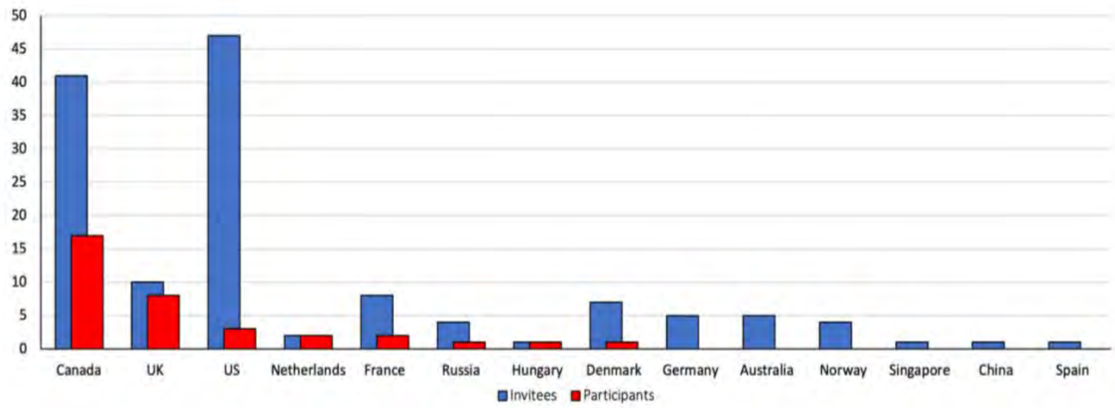

Figure 2. Nationalities of invitees and participants in AWPIS© assessments

The assessment took place between 6th December 2021 and 8th February 2022 with invitees selected based on their experience with the species in management or research. In total 35 experts, representing 26 organisations from 8 different countries participated in the assessment and collectively provided 16,137 individual data points. Experts included nine panellists representing five AZA Species Survival Plan (SSP) facilities, nine panellists representing eight EAZA European Endangered species Program (EEP) facilities and a further six non-AZA, CAZA participants from three facilities. Despite extensive efforts to engage with relevant stakeholder groups, representation differed markedly on a regional and sector basis with Canada and the UK being the most engaged nations amongst those invited (see Figure 2) and with the ex-situ community being significantly better represented than the in-situ and welfare science community (see Table 1).

Cohort	Total panellists	Average years of experience				
		In-situ management	In-situ research	Ex-situ management	Ex-situ research	General welfare research
Welfare research	6	0.00	0.33	3.33	2.33	13.67
In-situ management & research	6	2.83	4.67	6.83	5.67	7.33
Ex-situ management & research	23	0.04	0.09	11.61	4.96	9.57

Table 1. Panel composition according to duration of experience in each sector

Based on self-reported years active in each area of polar bear research or management, there was extensive overlap in experience amongst panellists who were subsequently grouped into three cohorts; the in-situ cohort comprised all experts with three or more years in-situ management and / or research experience, the welfare specialist cohort comprised all of those with more generalised welfare research experience than species-specific in-situ or ex-situ experience, and finally the ex-situ cohort was comprised of those whose captive management and research experience exceeded their generalised welfare research experience and who had less than three years in-situ experience (see Table 1).

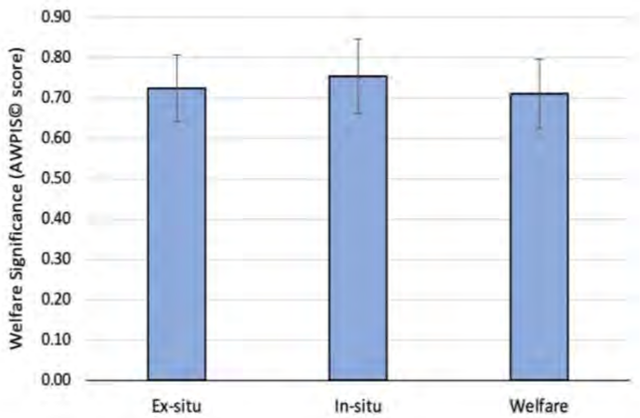

Figure 3. Average AWPIS© scores according to panellist cohort based on self-reported sector experience.

If we understood the psychological value of the opportunities animals encounter in the wild to their welfare in captivity, it would transform how we care for them.

As previously noted, it is the relative ranking of behaviours and cognitive processes based on their AWPIS© scores rather than absolute values that is key, and so even if one individual or even an entire cohort ranked more highly than another, so long as they did so consistently, it would not alter the overall final ranking. Regardless, a one-way repeated measures ANOVA revealed there was no significant difference in mean AWPIS© scores between the different cohorts of experts [F (2, 114) = 2.636, *p* = 0.0782] (see Figure 3), and multiple linear regressions demonstrated that each cohort's AWPIS© scores for each behaviour and cognitive process strongly correlated with each other cohort's score (see Figure 4), confirming that the data from all 35 panellists could be safely pooled.

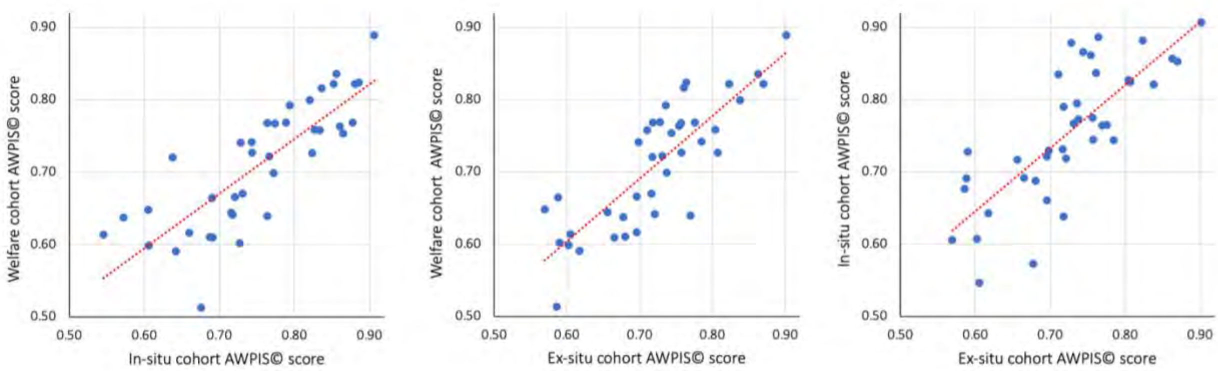

Figure 4a) The correlation of AWPIS© scores for behaviours and cognitive processes provided by welfare experts and in-situ experts; Pearson's correlation n = 39, r = 0.816, p <0.0001.

Figure 4b) The correlation of AWPIS© scores for behaviours and cognitive processes provided by welfare experts and ex-situ specialists; Pearson's correlation n = 39, r = 0.832, p <0.0001.

Figure 4c) The correlation of AWPIS© scores for behaviours and cognitive processes provided by in-situ experts and ex-situ specialists; Pearson's correlation n = 39, r = 0.776, p <0.0001.

Summary output:

Before considering the consolidated output of the assessment, it is worth reiterating that AWPIS© does not seek to identify physical needs or welfare priorities as might be determined according to non-hedonistic definitions of welfare. Instead AWPIS© seeks to understand the psychological priorities of a species based on their behavioural ecology and evolutionary heritage in the wild. This output is intended to complement established knowledge in relation to maintaining physical wellbeing to optimise welfare management in captivity. Furthermore, as previously stated, the output establishes the relative importance of behaviours and cognitive processes within a species, rather than generating absolute values for inter-specific comparisons.

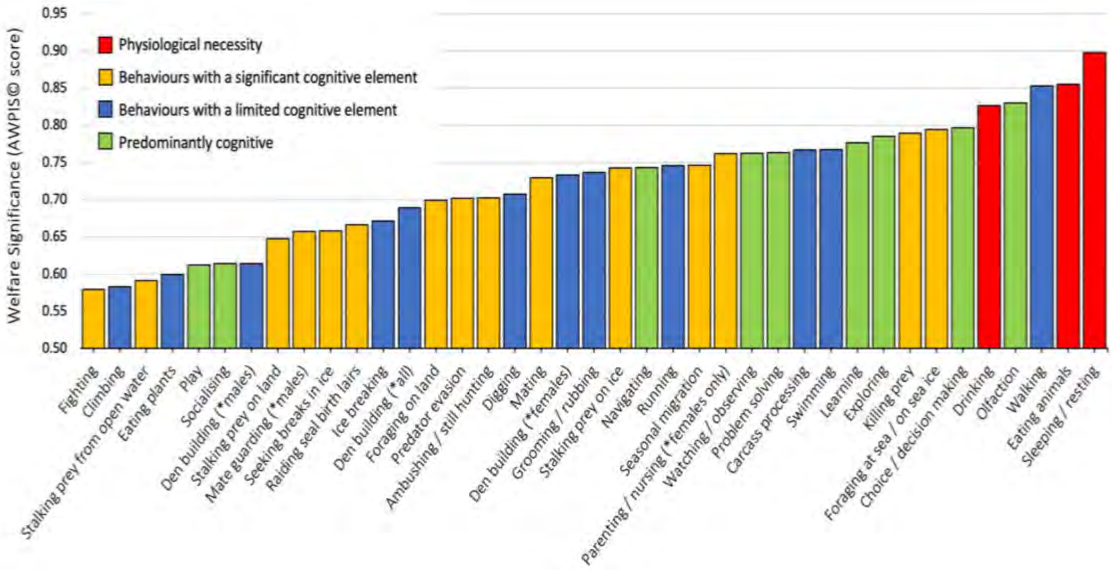

Figure 5. AWPIS© scores of behaviours and cognitive processes.

Behaviours and cognitive process can be clustered into overlapping groups according to their form (cognitive processes, behaviours with limited cognitive requirements, behaviours with a significant cognitive element and physiological necessities), or their function (behaviours and cognitive processes related to reproduction or sociality, those related to the acquisition of food etc). However, since the purpose of the assessment is to help improve welfare, behaviours and cognitive processes will be grouped primarily according to solutions potentially deployed in captive environments.

Output from the assessment is summarised in Figure 5 with colour coding according to key characteristics relating to the form and function of the behaviours and cognitive processes assessed. The results are also set out in Table 2 in the Appendix. A one-way ANOVA revealed that there was a significant difference in average AWPIS© scores between the different categories of behaviours and cognitive processes [F (3, 38) = 4.733, p = 0.0071], with a post-hoc Tukey HSD test confirming AWPIS© scores for behaviours tied to physiological needs were significantly different from behaviours with limited cognitive aspects to them (Q = 4.7491, p = 0.0098) and behaviours with significant cognitive elements (Q = 5.0650, p = 0.0054) see Figure 6 with all

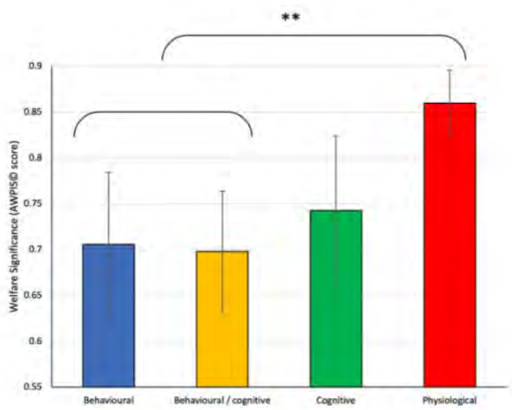

Figure 6. Average AWPIS© scores according to category of behaviour / cognitive process

other pairings revealing no significant difference. These results are consistent with previous assessments where broadly speaking, behaviours linked to physiological needs are shown to be of high welfare significance over and above their direct survival impact, and that cognitive processes and behaviours with significant cognitive aspects to them, are more important than behaviours with limited cognitive aspects to them (see Veasey 2020a, 2020b).

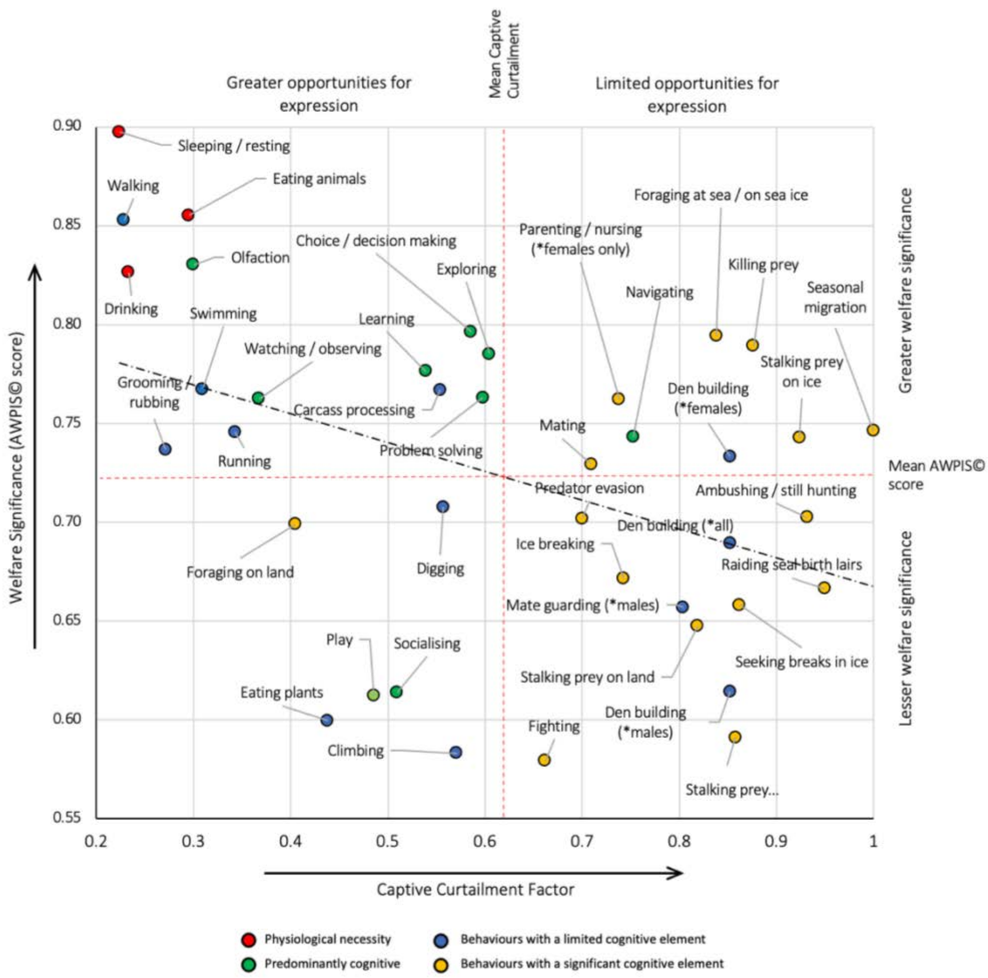

Figure 7. AWPIS© scores of behaviours and cognitive process in relation to curtailment in captive environments

When considering the raw output of the assessment, it is not necessarily the case that the highest-ranking behaviours or cognitive processes require the greatest attention in improving captive polar bear welfare since this does not consider the extent to which captivity already caters for these priorities. To address this, panellists were also asked to estimate the extent to which behaviours and cognitive processes are curtailed in captive environments. The relationship between AWPIS© scores and captive curtailment is set out in Figure 7, with behaviours and cognitive processes of high welfare significance towards the top of the graph and those most constrained by the captive environment towards the right of the graph. Reassuringly there is a negative correlation between AWPIS© score / welfare significance and

If we can create environments and management solutions that empower captive polar bears to chose to travel to experience rewarding, natural outcomes and in doing so encounter variation along the way, it would transform their welfare.

the extent to which behaviours and cognitive processes are curtailed in captivity (Pearson correlation n-39, r=-0.425, p=0.007). This either suggests the prioritisation of the needs of polar bears broadly reflects the needs of the species as determined by the AWPIS© methodology, or that captive management shapes perceptions of the needs of polar bears. Whilst it's not possible to exclude the latter interpretation, the fact that in-situ and welfare science cohorts agreed on the priorities with each other and the ex-situ cohort who are the group most likely to be influenced by current priorities in captive management, tends to suggest that the needs of the species are, to greater or lesser extents, reflected in current management, if not definitively being satisfied by them.

Accordingly, behaviours and cognitive processes in the top right quadrant of figure 7 are flagged for particular attention in terms of their potential for delivering improvements in welfare. However, the extent to which it was possible to assess captive curtailment was limited to estimates of the degree to which the captive population can express behaviours or cognitive process; it was not possible to undertake a qualitative assessment regarding the extent to which behaviours and cognitive priorities are satisfactorily expressed from a welfare / psychological perspective. As a result, while captive curtailment is useful in identifying areas likely to be deficient in captivity, it does not necessarily follow that important behaviours and cognitive processes that can routinely be expressed in captive environments are adequately catered for. Subsequently, high scoring behaviours and cognitive processes will be considered regardless of the estimated curtailment in captive environments.

Applications to welfare management and improvement

It is worth acknowledging that for enrichment, and more broadly management to be effective in improving welfare and reducing the incidence of stereotypic and other abnormal behaviours, augmented strategies should be applied early in the lives of young animal to normalise brain development and preclude stereotypies becoming "hardwired" (see Mason & Latham 2004, Jones *et al* 2011a, 2011b). Furthermore, such strategies should continue throughout the animal's life, seek to tackle specific sources of frustration proportionate to their likely impact on welfare (as identified here), and they should also seek to reduce stress and boredom generally, by for example increasing the extent to which bears are able to exert control over their lives.

In this regard, AWPIS© demonstrates two important points, firstly not all natural behaviours and cognitive processes are equally important to wild animals in captivity and secondly, no single behaviour or cognitive process can be considered in isolation when attempting to develop welfare augmentation strategies. Collectively these two points should encourage management solutions to be established around broad themes while remaining mindful of the relative importance of the constituent behaviours and cognitive processes within each focus area as identified here. For polar bears, these have been clustered into four focus areas reflecting likely solutions-based strategies, and each will be considered in turn:

1) Behaviours and cognitive processes linked to the acquisition of food and hydration
2) Behaviours and cognitive processes linked to movement, navigation and long-distance travel
3) Behaviours and cognitive processes linked to sociality and reproduction
4) Cognitive processes not necessarily tied exclusively to any of the previous areas

1) Behaviours and cognitive processes linked to the acquisition of food and hydration:

Behaviours and cognitive processes linked to physiological needs ranked the highest of the four form-based categories as set out in Figures 5, 6 and 7, with sleeping, eating and drinking identified as being amongst the top five priorities (average AWPIS© = 0.860 compared to an overall average of 0.722, see Figures 5 and 6). Whilst these behaviours are invariably catered for sufficient to satisfy the physiological needs of captive polar bears, there is no guarantee the psychological / cognitive needs associated with those behaviours are catered for (see also Veasey 2020a, 2020b). Further consideration of the psychological and cognitive aspects of those behaviours and cognitive processes, and in particular, in relation to feeding is therefore warranted reflecting their high AWPIS© scores and ranking.

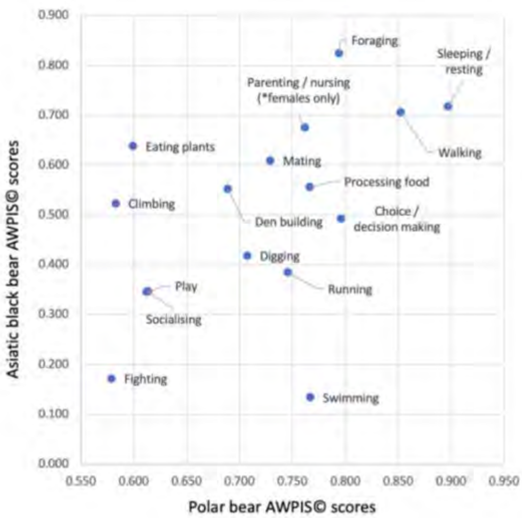

Figure 8a) The correlation of AWPIS© scores for comparable behaviours and cognitive processes for polar bears and Asiatic black bears; Pearson's correlation n = 16, r = 0.4830 p = 0.0575.

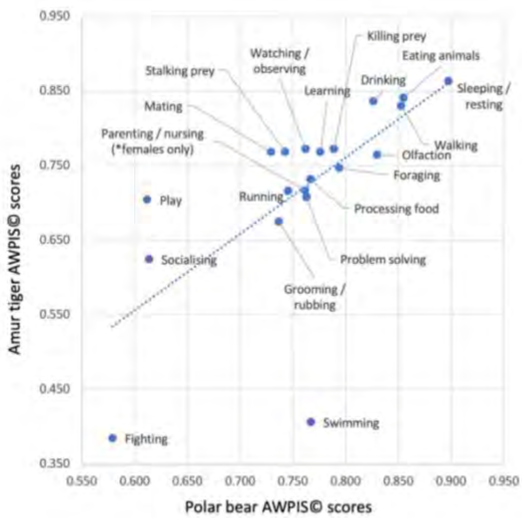

Figure 8b) The correlation of AWPIS© scores for comparable behaviours and cognitive processes for polar bears and Amur tigers; Pearson's correlation n = 20, r = 0.6657, p = 0.0014.

When considering the feeding ecology of polar bears, one of the most striking observations resulting from the assessment is that despite their taxonomic relatedness, there is a stronger relationship between the relative AWPIS© scores for comparable behaviours and cognitive processes between polar bears and Amur tigers (*Panthera tigris altaica*) than there is between polar bears and Asiatic black bears (*Ursus thibetanus*), two species of Carnivora for which assessments have been completed (see Figures 8a and 8b). It is most likely this similarity results from the dietary parallels between polar bears and Amur tigers and their dietary distinctiveness from Asiatic black bears and other Ursidae (see Figure 9, derived from Wilman *et al* 2014). With the exception of the polar bear, Ursids are by and large surrounded by comparably low-calorie food sources, comprised primarily of seasonably predictable plant and invertebrate based foods, supplemented with occasional meat consumption. This is gathered from a relatively modest patchwork of habitats averaging just ~45km^2. In contrast, but much more like Amur tigers, polar bears hunt sparsely distributed, high value, large mammalian prey, forcing them to range up to ~80,000km^2 (Clubb & Mason 2007).

Similarly, in marked contrast to other Ursids, but much more like Amur tigers, wild polar bears regularly gorge on large volumes of animal fat and protein which can equate up to 15-20% of their body weight at a time, with kills occurring roughly once every five days or so (see Stirling 1988, Nowak 1999, Wilson & Mittermeier 2009). Veasey argued that whilst smaller, more frequent meals may be sufficient to maintain the physical health of large carnivores such as Amur tigers and polar bears, they are less likely to be optimised for the psychological needs of such species in captive environments, particularly since stomach distension is so important in naturally suppressing the motivation to forage (see Jeschke 2007, Veasey 2017, 2020b). Thus, polar bears fed frequent “snacks” as opposed to rarer meals equivalent to those they would consume in the wild, will likely be chronically motivated to forage, whilst simultaneously being frustrated in being able to do so. The provision of carcass feeds to captive polar bears on a schedule comparable to kill frequency in the wild is therefore likely to aid in the regulation of highly motivated and largely frustrated foraging and hunting behaviours by allowing for greater stomach distension (Jeshcke 2007). Moreover, such feeding strategies will facilitate the expression of important, highly motivated species-specific behaviours such as carcass processing, and provide opportunities to experience positive affective states (Bashaw *et al* 2003, Shyne 2006, Young 2003), including satiety.

Note: Both the author and one of the panellists believe the proportion of fish in the diet of wild polar bears is significantly less than the 10% noted by Wilman *et al* (2014) and the proportion of meat, significantly higher, nearing 100% (see Figure 9)

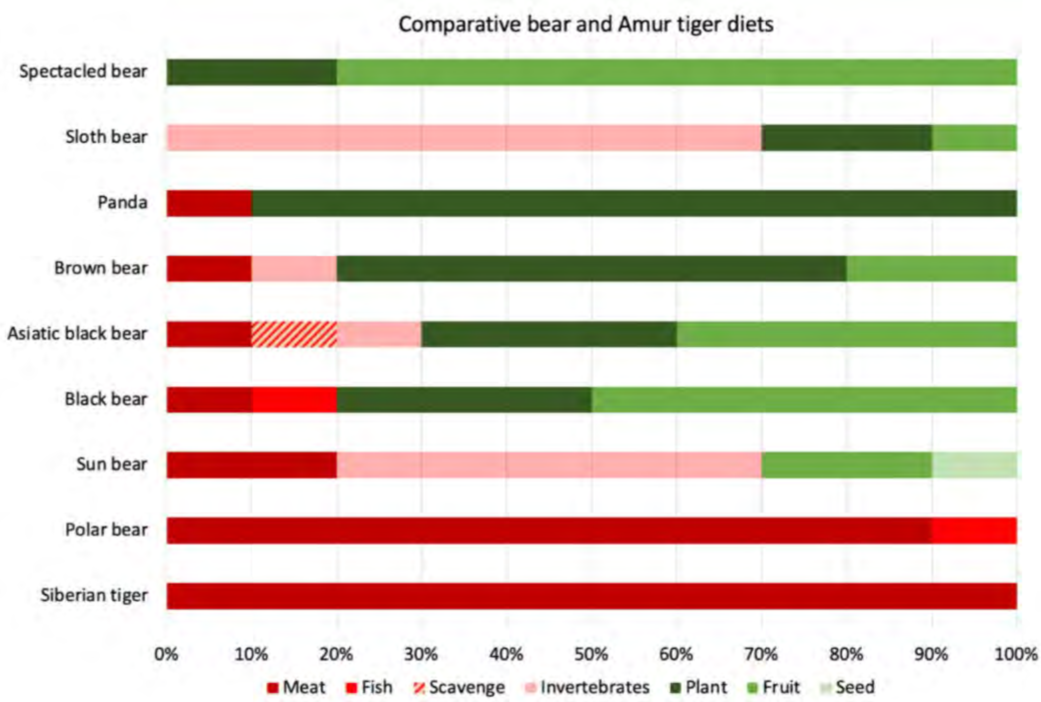

Figure 9. Comparative diets of the Ursidae in relation to the Amur tiger

And so, whilst smaller frequent meals and scatter feeding used widely for the species might be appropriate for omnivorous bears species less dependent on meat consumption, it is likely unsuitable as a core feeding strategy for captive polar bears. However, the increase in the extent to which wild polar bears forage inland in response to increasing ice-free periods (Derocher *et al* 2000, NWT Joint Secretariat 2015, Rode *et al* 2015) is suggestive of an innate behavioural ecological flexibility in regard to such behaviours, and should therefore caution against eliminating scatter feeding entirely. Nevertheless, whilst polar bears can forage inland as other omnivorous bears do in response to sea-ice retreat, it may be associated with elevated stress by virtue of the reduced caloric intake and should not be the basis with which to establish dominant, year-round captive management parameters.

A review of husbandry guidelines and relevant legislative frameworks provides useful insights into existing captive polar bear management practices and dietary provisioning. Manitoba's Polar Bear Protection Act (PBPA 2002) mandates captive polar bears be "provided with a balanced diet that includes hard and soft foods, such as prepared dog chow, organ meat, carrots or apples, or reasonable substitutes". AZA husbandry guidelines, which draw heavily upon the Polar Bear Nutrition Guidelines (Lintzenich *et al* 2006) recommend a **maximum** of 2.5% of a polar bears diet be comprised of whole prey which is identified to be large rats and rabbits in captivity (AZA Bear TAG 2009). Further, the guidelines recommend that between 30-75% of their diet should be comprised of a "nutritionally complete" raw meat chow and 5-50% comprised of a "nutritionally complete" dry chow (AZA Bear TAG 2009). While the AZA guidelines acknowledge the desire of zoos to feed carcasses based on the behavioural benefits, they state, "The AZA Nutrition SAG cautions institutions that choose to carcass-feed about numerous hazards (pathogenic and parasitic) that exist for collection carnivores" (AZA Bear TAG 2009). Similarly Lintzenich *et al* (2006) actively discourage carcass feeding, evidently in favour of processed chow. In terms of feed related enrichment, AZA list live feeding of insects and fish, browse, treats squeezed into crevasses, soft bones, digestible nylabones and scent (AZA Bear TAG 2009). Finally, AZA note twice daily feeding schedules to facilitate shifting in and out of the enclosure as being the norm, and that on a dry matter basis, daily food intake equates to 0.5-1.1% of body weight (AZA Bear TAG 2009). In contrast, the EAZA Ursid Husbandry Guidelines (EAZA 2007) stated "that polar bears prefer fat horse meat to fat beef, probably because the fat of pastured horses contains higher amounts of unsaturated fatty acids than beef. If the meat is provided in large quantities, the bears will eat approximately every 4 - 5 days, as in the wild". They go on to acknowledge the difference between carnivorous and omnivorous bears "Fasting days are inappropriate for bears. However, if large amounts of meat (e.g. such as beef carcasses or large portions of them) are offered to polar bears, and occasionally to brown bears, the animals can rapidly fill their guts, so that the next meal might perhaps be given 2 or 3 days later." (EAZA 2007).

Evidently, existing North American guidelines and legislation on polar bear management, if they are in anyway reflective of prevailing management practices suggest the feeding of captive polar bears shows remarkably little resemblance to what we know about the behavioural ecology of polar bears in the wild and appears better suited to a generic omnivorous Ursid, though far from perfectly aligned for those also. Furthermore, it appears these guidelines also diverge from European best practice recommendations. The basis of this disconnect is either a greater emphasis on perceived nutritional outcomes and risk mitigation than on the psychological benefits of a biologically appropriate diet (see Veasey 2017, 2020a, 2020b), reservations about visitor attitudes to carcass feeding, or simply a failure to understand or acknowledge the importance of the ecology of this species in the wild to its management in captivity. The emphasis on nutrition and risk mitigation is perhaps to some degree understandable; it is hard to quantify the psychological benefits of carcass feeding to captive polar bears if none are fed carcasses, whereas it is far easier to speculate on the direct risks of eating carcasses as well as the potential impacts of nutritional imbalances (Veasey 2017, 2020b). However, what is not clear is whether there is any evidence that carcass feeds complemented with appropriate supplementation would inevitably result in compromised health or that any of these tangible risks do not exist in the wild.

Furthermore, it appears that the focus on nutritional requirements with scant regard for psychological and behavioural needs has not actually been successful in replicating the basic macronutrient needs of polar bears.

Captive polar bear diets were estimated to be comprised of an average 51% dry matter protein content, compared to 32% dry matter protein content consumed by wild polar bears, a disparity which has been implicated in the high incidence of kidney and liver disease and cancer in captive polar bears of 37% and 32% respectively, as well as the consistently higher levels of serum urea, phosphorous and creatinine in comparison to non-diseased wild polar bears (Rode *et al* 2021). Furthermore, fat consumption was also found to be markedly different; a sample of captive North American polar bears were shown to derive an average of 55% of their metabolisable energy content from fat, whereas for wild polar bears it was over 80% (Rode *et al* 2021). Since feeding and the behaviours and cognitive processes associated with the acquisition of food ranked so highly, the stark disconnect between the natural feeding ecology and macronutrient composition of the species' diet in the wild and its management in captivity, likely compromises the welfare as well as the health of captive polar bears (Robbins *et al* 2021, Rode *et al* 2021).

Intimately linked to diet is hydration, and it is likely there are also clear differences between the wild and captive state. Drinking ranked highly in the assessment and while polar bears in captivity can of course drink, they are faced with an overabundance of freshwater in comparison to wild polar bears who effectively live in a frozen desert, where freshwater in liquid form is rare and only seasonally available, and the consumption of snow and ice, metabolically expensive. As such, wild polar bears rely heavily on the metabolism of fat in their own reserves and from the carcasses they eat to produce water. And so, considering the high ranking of drinking (or more accurately hydration), this is evidently a priority that needs to be carefully considered on a more holistic basis in conjunction with a review of captive diets.

The disconnect between wild and captive diets on a behavioural / psychological and macronutrient basis, combined with the likely impact on hydration modalities for captive polar bears suggests further investigation is warranted into a readily obtainable high fat mammalian carcasses that could help; a) increase average meal size to allow for species-specific satiety amongst captive polar bears, b) decrease the animal's reliance upon drinking water in recognition of the high AWPIS© score of drinking (hydration) and the rarity of water in the wild, c) improve on macronutrient composition in relation to wild type diets, d) establish a more temporally appropriate feeding regime and e) provide appropriate behavioural opportunities in recognition of their welfare significance / AWPIS© score. Since no readily available farmed animal has comparable fat levels to marine mammals routinely consumed by polar bears, it is likely some processing of carcasses may be required, potentially involving supplementation with animal fats or oils. Whilst it is possible that the more southerly latitudes and warmer climates of captive environments require polar bears to drink more regardless of the quality of their diet, this does not preclude the need to consider the role of fat metabolism in hydration. The production of a higher fat kibble (see Robbins *et al* 2021), in response to the nutritional disparity between wild and captive diets (Robbins *et al* 2021, Rode *et al* 2021) fails to consider the broader ramifications of dietary provisioning beyond nutrition, and further underlines the need for a more holistic approach encompassing physical and psychological considerations.

Note: One of the panellists advises that some captive polar bears have refused seal carcasses and blubber but that wild born captive polar bears did not. It may therefore be necessary to allow some captive polar bears time to acclimate to fat enriched carcass diets under appropriate nutritional / veterinary supervision.

Such a holistic approach if it is to be effective, must consider the appetitive and consummatory phases as part of a broader behavioural and cognitive chain associated with feeding / drinking that reflects their relative welfare significance, and their intimate relationship with other behaviours and cognitive processes. Too often enrichment is compartmentalised to specific phases such as chasing, or foraging (see for example Young 2003, Shyne 2006), but rarely, if ever, as part of a complete behavioural / cognitive chain for large mammals.

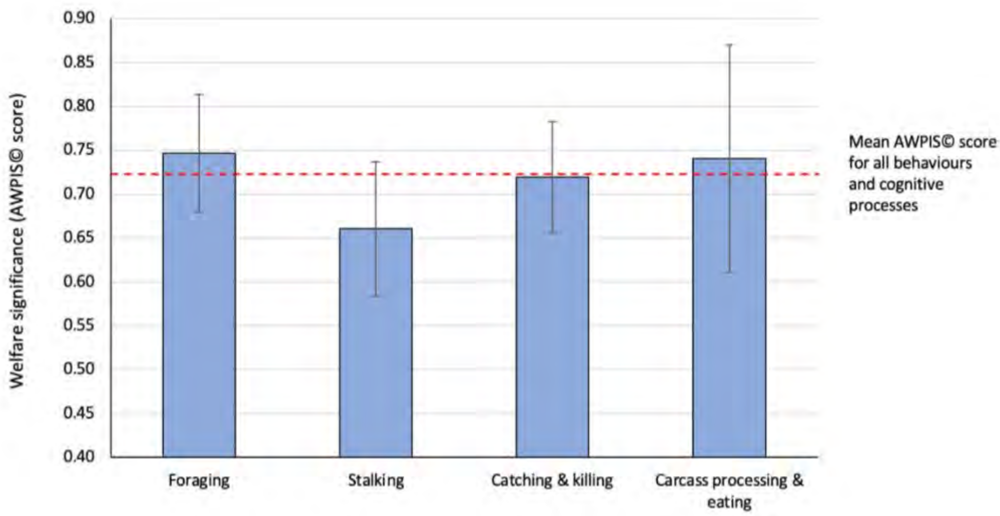

Figure 10. Average AWPIS© scores of behaviours and cognitive process linked to each stage of the food acquisition process with the mean AWPIS© score for all behaviours and cognitive processes provided as a reference.

The assessment revealed there was no significant difference in mean AWPIS© scores between the different categories of feeding related behaviours and cognitive processes aggregated according to the different phases of food acquisition (see Figure 10, [F (3, 7) = 0.5181, p = 0.6830]). However, it is noteworthy that the early appetitive phases (foraging on ice, on land and from the sea) and the consummatory phase (processing and eating) rank more highly than

Guidelines on polar bear nutrition show remarkably little resemblance to the natural feeding ecology and diet of the species' in the wild. This likely compromises both the welfare and health of captive polar bears.

the hunting elements (stalking, catching and killing), a result that is broadly similar to that of Amur tigers (Veasey 2020b).

Behaviours linked to the acquisition of food are already the principle focus of most enrichment programs for carnivores (Young 2003, Shyne 2006) and for which improvements in welfare have been reported for polar bears (Shyne 2006, Skovlund *et al* 2021, Fernandez 2021). However, for wild polar bears, who rely largely on still hunting at breathing holes and raiding seal birthing dens, the process of securing food is underpinned by a diverse array of behaviours and cognitive processes beyond simply killing prey, a common focus area of carnivore enrichment (see Young 2003, Shyne 2006, Law & Kitchener 2019). Most obviously, these will include appetitive behaviours associated with hunting, including finding, and selecting opportunities to catch prey; seeking dens or breathing holes using olfactory, auditory, and visual cues, waiting for prey or breaking down dens, catching and killing prey, carcass processing, eating and digestion. Each stage of the food acquisition process will be influenced by the individual's experience, learning, preferences, and ability, and is typically dependent upon the successful fulfilment of a previous stage in a behavioural / cognitive chain. Beyond these behaviours and associated cognitive processes, the bears must also maintain a real-time awareness of probable prey distribution and density, likely linked to the detection and interpretation of potentially subtle and ever changing climatic and seasonal cues, whilst also maintaining an awareness of competitors, and for mothers, potentially predatory males. Collectively, beyond the obvious behavioural activities linked to food acquisition, wild polar bears are required to navigate, predict outcomes, make decisions, act upon them, and where necessary, learn from those choices and actions to secure meals consistently, underlining the need to consider cognitive and behavioural opportunities holistically.

Whilst it may seem surprising that hunting related behaviours (stalking, catching, and killing prey [average AWPIS© = 0.690]) were ranked as lower psychological priorities than foraging (AWPIS© = 0.747) and also below the average scores for all behaviours and cognitive processes combined (AWPIS© = 0.722), this is reflective of the brevity such behaviours and their limited energy demands compared to more protracted foraging behaviours. Furthermore, a case can be made that hunting behaviours may even have a lesser fitness impact than foraging; without interfacing with their environment in a thinking, dynamic manner, polar bears would not encounter opportunities to hunt sufficient to ensure survival, nor access mates frequently enough to maximise reproductive output. In contrast, wild polar bears will readily scavenge on both natural food sources such as marine mammal carcasses, and anthropogenic sources such as rubbish dumps, and so it is conceivable that wild polar bears might survive without stalking, hunting or killing prey for a period of time, but less likely that they could survive as long without foraging.

Furthermore, the motivation to hunt is likely sated instantaneously by the extrinsic stimulus of an opportunity to eat, whereas the motivation to forage is likely dependent upon more multifaceted intrinsic and extrinsic factors, ranging from stomach distension (Jeschke 2007) through to duration since last expression and other multisensory external cues that will likely persist in captivity, and so cannot be so easily eliminated. It should be noted that while stomach distension can sate foraging motivation (Jeschke 2007), animals do not wait till they are starving to forage since the lag between action and reward could prove fatal under those circumstances. And so, whilst large meals might temporarily eliminate the motivation to forage and hunt, it would not be possible to fully eliminate the motivation to forage without chronically overfeeding the animal. However, because foraging is a precursor for most feeding opportunities, but hunting need not be in both the wild and captive environments due to scavenging or being fed by animal carers, it is possible that the motivation to hunt may not routinely be triggered in captive environments. Nonetheless, catching and killing still scored highly enough in the assessment that they should not simply be disregarded as they are likely to be inherently rewarding to express and as such, opportunities that replicate specific behavioural and cognitive elements of hunting could help provide captive polar bears with positive experiences; an essential component of good welfare (see Bashaw *et al* 2003, Mellor & Beausoleil 2015, Mellor 2016).

2) Behaviours and cognitive processes linked to movement, navigation and long-distance travel:

Walking was ranked as the highest behaviour considered as not being a physiological need (AWPIS© = 0.853) and was also considered to be one of the least curtailed behaviours or cognitive processes in captivity. This somewhat flattering estimate of captive curtailment stands up well to scrutiny, but a deeper analysis reveals there is no room for complacency regarding this important behaviour. Captive polar bears do indeed walk considerable distances if pacing is included; captive polar bears are reported to pace for 32% of the time observed (Clubb & Mason 2007) and with an estimated walking speed of 5.6kmh (Stirling 1988), the average captive polar bear may travel as much as 43km/day. Satellite telemetry revealed that female polar bears can move as little as 82 km during the whole summer, with locomotion increasing in winter when searching for prey on sea-ice (Parks *et al* 2006). Whilst wild polar bears have the capacity to cover large distance in any given day (Durner *et al* 2011), according to Clubb & Mason (2007) wild polar bears are typically active for 15% of the time, with daily travel distances averaging just 8.8km. Lunn & Stirling (1985) estimate wild polar bears to be active for 10% of the time, which with an estimated walking speed of 5.6kmh (Stirling 1988) would equate to 13.4km travelled daily. Even if estimates of pacing amongst polar bears are overestimated as a result of a skew due to the timing of observation periods, it is clear captivity does not unduly restrict the distance walked / paced for polar bears.

Whilst captivity does not restrict biomechanical processes akin to walking and may even increase it through pacing, it is worth noting that pacing is quantifiably different from non-stereotypic walking in terms of gait structure and variability (Cless *et al* 2015). Furthermore, captivity does restrict purposeful travel establishing contingency between decisions and rewarding outcomes, creating distance from points of origin, opportunities to encounter novelty, make choices and encounter variability and unpredictability. Walking is in many respects a behavioural thread connecting important aspects of the lives of wild polar bears; all nutritional, social and reproductive behaviours are in some way or other deeply dependent upon walking and it would be foolhardy to ignore its importance in the context of other behaviours and cognitive processes simply because captive polar bears likely walk / pace considerable distances in zoos. Addressing all of the associated behaviours and cognitive opportunities that are connected to walking within the constraints of a “traditional zoo” environment represents a challenge, but an awareness of the importance of this behaviour and suite of associated behaviours and opportunities to the welfare (and health) of polar bears, will help ensure it can be more effectively catered for in management and design, a point that will be considered later.

As captive environments improve in their capacity to provide for the psychological needs of polar bears resulting in more consistent states of motivational equilibrium, it is conceivable that the bears will become less active than they currently are, with a reduction in pacing reducing overall distances travelled. As a species that has evolved to be energetically conservative in the wild, it should not be surprising, or necessarily considered as inherently negative if captive polar bears with high welfare become less active. Furthermore, the tendency to consider non-stereotypic activity as a sign of positive welfare (see Fernandez 2021) should be treated with a modicum of caution for species like polar bears that are innately, powerfully motivated to conserve energy.

Swimming also scored highly (AWPIS© = 0.767), and similarly, simply providing opportunities in which polar bears can submerge themselves will not adequately address the species’ needs regarding this important behaviour. The USDA Animal Welfare Act’s Animal Welfare Regulations (AWR 2005) require polar bear pools be at least 1.5m deep with a surface area of at least 9m^2 and the Polar Bear Protection Act (PBPA 2002) requires a pool with an area of 70m^2 and a depth of 3m. Given a polar bear standing is around 3m tall and is capable of swimming 687km over nine days in a continuous swim (Durner *et al* 2011), a pool with a surface area of 9m^2 (3mx3m) must be considered as sufficient to enable polar bears to swim as a wardrobe is to allow a human being to sprint. It is genuinely surprising that such a lowly standard could be set by any regulation claiming to have relevance to polar bear welfare, particularly for such an important behaviour. The standards set by the Manitoba Polar Bear Protection Act would at least allow a polar bear to swim, but likely in an inherently repetitive / stereotypic way. EAZA guidelines state for Ursids generally “In enclosures without water moats, a pool sufficiently deep for bathing the whole adult bear must be provided. A stream and waterfall may also provide an interesting feature" and for polar bears specifically "the ratio of water to land should not exceed 1:3" (2007). The AZA Polar Bear Care Manual (AZA Bear TAG 2009) states "pools containing cool saltwater (12.7- 21° C /55-70°F) with live fish, smooth walls and ledges, an island, polar themed floats, moving logs/trees, waterfalls or streams, changing currents, and a wave machine, are suggested". Whilst this sounds aesthetically appealing, the cost of constructing, filtering and salinating such a facility (not to mention the associated carbon footprint) inevitably constrains its size, whereas a natural or excavated lake can be constructed and maintained at a much lower cost and environmental impact on a fundamentally larger scale. In circumstances where there is a choice between a relatively small concrete filtered pool and large living lake system, given the importance of swimming to polar bears, it is recommended that facilities should consider the merits of a larger lake system. However, further research is needed into the potential health impacts of captive polar bears having access to freshwater versus saltwater pools before an unreserved recommendation can be made.

Navigation (AWPIS© = 0.743), exploring (AWPIS© = 0.785), seasonal migration (AWPIS© = 0.746) all ranked above average, and combined with walking (AWPIS© = 0.853) and swimming (AWPIS© = 0.767), collectively represent the requirement for polar bears to live a nomadic life responding to the dynamism imposed by the seasonal shifts in ice and prey distribution. As has previously been alluded to, and identified elsewhere (Clubb & Mason 2007), the wide-ranging nature of polar bears is a risk factor for poor welfare, but it is not necessarily the lack of space *per se* that creates the welfare challenge since it does not appear to constrain walking (though it likely constrains swimming). It is more likely the lack of appropriate cognitive and behavioural opportunities that are associated with travel, and reflected in the high scoring of these cognitive priorities, that likely covaries with captive habitat size that impacts welfare. As a result, simply increasing habitat size without investing in species appropriate complexity and cognitive and behavioural opportunities, will result in sub-optimal results.

3) Behaviours and cognitive processes linked to sociality and reproduction:

Sociality scored relatively low in the assessment (AWPIS© = 0.614) which considering the widely reported solitary nature of polar bears, is unsurprising. However, this finding and what we know of their behavioural ecology in the wild would appear to be at odds with the findings of Shepherdson *et al* (2013) which found that group size was associated with decreased stereotypies in captivity. They suggested that the solitary existence of wild polar bears may be more a function of their natural surroundings than of an innate desire. However, the desires of wild animals are shaped by evolution to ensure the animal's behaviour is optimised to the environment in which it exists. As a result, it would be normal / natural for the social wants and needs of a species to coincide and it would be highly unlikely that sociality could exist

We need to think of how pools and lakes can be spaces in which captive polar bears can travel to achieve outcomes rather than simply places in which they can swim without any obvious purpose.

as a preference if it had a negative survival impact. There are several potentially overlapping explanations for this seeming divergence in welfare significance as determined by the low scoring of sociality in the assessment, and the perceived positive welfare impact as determined by Shepherdson *et al* (2013). Firstly, it's possible that large numbers of bears aggregating around rubbish dumps or whale carcasses reflect an innate tolerance to being social when circumstances dictate or allow, much like grizzly bears (*Ursus arctos horribillis*) tolerate others around salmon (*Salmo sp*p) runs, but this need not be considered to equate to a preference. Furthermore, the alleged benefits of sociality reflected in reduced stereotypies may not be a function of group size *per se*, but other factors that covary with it. It is conceivable for example that larger social groups are more likely to include mothers and young, both of which may be less stereotypic than other captive polar bears. For mothers caring for young this might arise because maternal care is associated with both a rewarding occupation and distraction from the limitations of the captive environment, reducing the time and need to stereotype, and for juveniles, because they tend to develop stereotypies as they age (see Mason 1993, Greenwald & Dabek 2003, Jones *et al* 2011a, Jones *et al* 2011b). Furthermore, larger social groups are likely associated with bigger habitats reflecting their greater carrying capacity, and it is possible that the size of habitats drives the welfare benefits as Shepherdson *et al* (2013) already established independently from group size. Finally, social situations increase the dynamism and unpredictability of environments and may reduce boredom (see Skovlund *et al* 2021), which may in turn reduce stereotypies whether bears prefer to be around other bears or not. Regardless, based on the output of the assessment and the evidence of Shepherdson *et al* (2013), it can be concluded that increased group size should not be viewed as a goal *per se*, but so long as social groupings are compatible, there may be welfare benefits associated with sociality in captive environments.

Note: One of the panellists advises that in the absence of an effective reversible contraceptive, the need to separate males from females in oestrus in captivity is believed to be stressful to both sexes. This should therefore be considered in the decision-making process regarding social composition and facility design.

The principal purpose of social interactions for the largely solitary polar bear is reproduction which evidently has high evolutionary impacts for both males and females. The benefits of parenting / nursing to females are perhaps intuitively understandable, but also confirmed by the output (AWPIS© = 0.762). Similarly, mating also scores above average (AWPIS© = 0.729), and reflects the risks as well as time and energy males in particular invest in securing reproductive opportunities. While decisions relating to reproduction in captive programs will reflect the needs of the regional program and capacity of the facility and partner zoos to accommodate offspring which likely transcend other considerations, the output of the assessment suggests reproductive opportunities could enhance captive polar bear welfare.

Furthermore, the high score for maternal den building (AWPIS© = 0.733) underlines the importance of providing expectant mothers opportunities to have some control over where, when, and how they den, and ideally, the opportunity to construct their own den. In the wild, providing shelter to cubs will be essential to the survival of young and subsequently maternal reproductive success and as a result, nest-building / denning behaviour will be highly motivated for. Providing an area designated as a maternal / nursing den which meets the needs of carers and resembles a room far more than it does the burrow / chamber complex excavated by expectant wild polar bear females in snow or soil will be unlikely to negate the needs of expectant females to express denning behaviours under the influence complex hormonal cues linked to gestation. In addition to meeting the evolutionary expectations of the bears and providing for their behavioural needs, an opportunity to exert control over such fundamental aspects of their lives is not only relevant to their welfare, but the health of their offspring and subsequently, the performance of conservation breeding programs. The frustration of important maternal behaviours such as these likely equates to a significant prenatal stress which has been shown to result in a range of negative long-term impacts on juveniles across a range of species (see Braastad 1998) and likely contributes to reduced juvenile survivorship (see Malmkvist & Palme 2008). It is probable therefore, that further efforts to address the innate needs of polar bears in denning would assist in improving on the current rates of juvenile survivorship which are significantly lower than those of most other captive Ursids, and historically experienced by wild polar bears (see Butler 2006, Clubb & Mason 2003, Curry *et al* 2015, Roller *et al* 2021). Furthermore, it is likely that the benefits of polar bears being able to construct their own maternity dens to maternal welfare and juvenile survivorship will outweigh the impacts of a reduction in the capacity of animal care staff to observe and intervene (see Veasey 2017, Veasey 2022). Providing polar bears earthen banks in which they can construct their own dens, and allowing them to do so, should therefore be considered as a legitimate alternative reproductive management strategy for zoo operators. The improvements in reproductive success following a shift to a more hands off approach to captive elephant parturition illustrates the potential benefits to polar bears from a similar ideological shift (see Veasey 2006, Schmidt & Kappelhof 2019).

Note: One panellist shared experience that a captive female that had access to a custom-built cubbing den and a large natural hillside in which she was free to excavate a den, chose the cubbing den. This successful cubbing den guaranteed privacy, freedom from noise and disturbance including not being offered food, the exclusion of other polar bears, and the opportunity to create a burrow within the den using hay. The adoption of such recommendations within the EEP have also apparently resulted in the need to curtail breeding due to improved reproductive success in the population. The author proposes that key to the success of such management is offering the female the opportunity to choose where to den, how to den, and circumstances in which her fundamental needs for seclusion and an opportunity to construct a den to her requirements can be met. Furthermore, it is also possible that a combination of soil type and climate may have made the construction of a suitable cubbing den impossible.

4) Other cognitive processes:

The assessment indicates that cognitive priorities are broadly speaking, as equally important as behaviours associated with the acquisition of food. Given the ultimate dependency of food acquisition on both a wide range of behaviours and interconnected cognitive processes, this is perhaps unsurprising. However, the results do indicate that foraging and other cognitive processes are likely of greater importance to polar bear welfare than might have been previously acknowledged based on enrichment typically used for carnivores (Shyne 2006, Meehan & Mench 2007, Skovlund *et al* 2021) and that scatter feeding might not satisfy the foraging needs of polar bears as effectively as it may do for omnivorous bears. Whilst polar bear enrichments such as the provision of manipulable objects or mechanical feeders may provide some beneficial behavioural enrichment loosely linked to food acquisition and hunting as they do for other species (see Shyne 2006, Ruskell *et al* 2015, Law & Kitchener 2019, Skovlund *et al* 2021), their cognitive benefits may be limited (Meehan & Mench 2007, Veasey 2020b), and the dispersal of food in time and space (see for example Fernandez 2021) bears little resemblance to the natural feeding ecology of polar bears and so its impacts are likely sub-optimal.

Shepherdson *et al* (2013) found that having a view appeared to decrease stereotypies in captive polar bears, a result which is consistent with their Arctic existence ensuring a predominance of largely uninterrupted views to the horizon. Moreover, this is also consistent with the output of the assessment which ranked watching / observing above the average (AWPIS© = 0.762 versus 0.722). Collectively, this evidence strongly supports the case that positioning polar bear habitats in locations with extensive vistas is likely important to captive welfare and the provision of elevated viewing areas, likely beneficial. Shepherdson speculated the benefits of having a "view" may have as much to do with olfaction as actually being able to see, certainly something the high score for olfaction (AWPIS© = 0.830) also supports. This does not change the recommendation regarding the provision of vistas but should probably also influence the positioning of food outlets as well as keeper pathways and routines when feeding other carnivores.

Learning also scored highly (AWPIS© = 0.776) reflecting its impact on all aspects of survival in the wild. Whilst learning occurs throughout the life of most higher vertebrates to greater or lesser extents, learning will peak in the period leading up to the completion of an individual's first season as a reproductively active adult, since exposure to novelty naturally declines from this point onwards. As a result, the single biggest step in enhancing learning opportunities for captive polar bears is to ensure wherever possible, they are parent reared in environments in which maternal needs are met to the highest possible degree, a management practice that will also likely insulate offspring from stereotyping in adulthood (Jones *et al* 2011a, Jones *et al* 2011b, Lewis & Kim 2009, Langen *et al* 2011) including adopting maternal stereotypies in polar bears (see Greenwald & Dabek 2003).

Whilst the quality of habitats may be more important than their size to captive polar bear welfare, its clear that size is a key determinant of quality. No captive polar bear habitat will ever be too big, but many are likely too small.

Beyond learning opportunities associated with early developmental stages, consideration should also be given to the appropriateness, quality, and amount of opportunity available to captive polar bears to learn rather than merely considering the presence or absence of learning opportunities. Learning associated with animal carer mediated training will provide learning opportunities but must be considered inferior to opportunities to learn skills or gain knowledge associated with other important species-specific behavioural and cognitive opportunities such as hunting or navigating. Learning must not be viewed as an objective independent from other behaviours and cognitive processes, but connected to them all, and environments that allow for the refinement of natural motor and cognitive skills throughout the life of captive polar bears, should be considered as a worthy objective.

Sleeping ranked highly (AWPIS© = 0.897) reflecting its physiological necessity and duration. As with other physiological necessities, captivity provides for such states, but there is likely a value considering the extent to which polar bears are empowered to choose where, when and how they sleep, and so further consideration should be given to, amongst other things, the denning opportunities for captive polar bears beyond the maternal denning requirements previously discussed.

Recommendations:

1) Individual welfare priorities cannot be viewed discretely:

A recurring theme in the analysis of the assessment's output is the interconnectedness of behaviours and cognitive processes. As a result, treating each important behaviour and cognitive process as an independent goal will not be as effective in enhancing welfare as considering them as part of a broader suite of interconnected priorities; they are not discrete in nature and nor should they be in captivity. The desire to change one variable at a time according to typical experimental best practice to validate the impacts of change should be resisted in favour of maximising welfare gains for the animals.

2) Management priorities should reflect AWPIS© rankings:

Effectively considering important connected behaviours and cognitive processes as part of a collective set of priorities requires a nuanced understanding of the importance of each component, as AWPIS© is intended to provide, together with a broader understanding of how each priority interrelates to each other. Generic enrichment approaches such as those that might be used with omnivorous Ursids may well reduce stereotypies (see for example Fernandez 2021), but without tailoring management to the unique behavioural ecology of the polar bear, such initiatives will inevitably be suboptimal. With the baseline information provided here, stakeholders are encouraged to consider their own strategies for optimising polar bear welfare in captivity, reflecting these insights and the importance of integrated solutions and strategies.

3) Enclosure size:

Immediately following the assessment, the author was approached for guidance on minimum enclosure sizes from a number of stakeholders in captive polar bear management and facility design. The reticence in definitively stating a minimum habitat size comes down to three principal reasons: i) Minimum standards can often become conflated with best practice, and what is of greater significance to the welfare of captive polar bears than the size of their habitat, is the extent to which the needs of captive polar bears as identified here, are met. ii) While habitat size is likely fundamental in influencing the extent to which the needs of captive polar bears can be met, it is also true that a large, poorly designed habitat will likely be less conducive to good welfare than a well-designed smaller habitat. However, a large well-designed habitat will always be better than an equally well-designed smaller habitat. The argument that habitat quality may be more important than habitat size might hold true, but it is essential to acknowledge habitat quality is in no small part a function of habitat size, just not size alone. iii) No enclosure will ever be too big for a captive polar bear, whereas it is likely that most captive polar bear facilities are currently too small to adequately safeguard polar bear welfare as the incidence of stereotypies in the species in captivity demonstrates.

It is also likely that incrementally increasing habitat size will be inadequate in eliminating welfare challenges and that a more fundamental paradigm shift in habitat design and scale is required. Following the publication of three critical reports on the welfare of polar bears in British and Irish zoos in the latter part of the twentieth century, (Horsmann 1986, Ormrod 1992, Ames 1993), there followed a dramatic reduction in the number of zoos holding polar bears coinciding with a twentyfold increase in average polar bear habitat size as the species was transitioned from largely urban zoos to more extensive wildlife parks such that the smallest British polar bear habitat, is reportedly more than four times the size of America's largest. This step was likely essential to retaining the social license for keeping this species in captivity in the UK (see Veasey 2020) and is of the order of magnitude likely necessary to mitigate prevailing welfare challenges. However, even these large facilities, should be viewed as a step on a journey of continual improvement and that improvements in scale need to be matched by targeted welfare provisioning such as are outlined in this document.

4) Climate:

AWPIS© assessments are intended to consider behavioural and cognitive priorities based on the species' behavioural ecology in the wild rather than considering the impact of specific captive variables such as climate on welfare. However, it is self-evident polar bears are uniquely adapted to an Arctic climate, both behaviourally and physiologically, and that even at the most southerly extent of their range, temperatures rarely exceed 20°c; the temperature at which faecal cortisol levels increase in captive polar bears (Leishman *et al* 2022). While, days above 20ºc are becoming more frequent in the Arctic and this is not necessarily above a critical threshold of adaptability for the species, it is a noteworthy threshold nonetheless. Considering the effects of elevated cortisol from different stressors can be cumulative, facilities which experience temperatures above 20ºc for prolonged periods of time, and particularly those which also experience high humidity (Leishman *et al* 2022), arguably have an even greater responsibility to maximise the various drivers of good polar bear welfare. The provision of refrigerated refugia within captive habitats should not be considered as effectively negating the impacts of warmer climates since a reliance upon these thermal refuges inevitably constrain other behavioural and cognitive opportunities and typically has a carbon footprint which is at odds with polar bear conservation. Locations where temperatures exceed 20ºc for extended periods of time or by a significant extent, are therefore strongly encouraged to carefully consider the suitability of housing polar bears in those locations.

5) A holistic conceptual framework for welfare improvement:

Outwith the behaviours and cognitive processes linked to reproduction which are to a significant degree under the control of regional breeding programs, how polar bears find and acquire food is self-evidently the single biggest overarching priority encompassing an array of cascading behaviours and cognitive process over and above those related specifically to hunting. These include making decisions, undertaking seasonal migrations, navigating, walking and swimming to name but a few. This in itself is not a novel hypothesis, the emphasis of carnivore and indeed polar bear enrichment acknowledges this (Shyne 2006, AZA Bear TAG 2009, Fernandez 2021), however, what is self-evident is that the approach taken so far hasn't been targeted enough to the unique species-specific needs of wide-ranging, intermittent feeding, predatory carnivores such as polar bears (see Veasey 2020b).

The concept described here has a number of specific aims, which is collectively intended to improve captive polar bear welfare and physical wellbeing.

1. To enable captive polar bears to undertake purposeful travel (walking and swimming) for distances comparable to those undertaken in the wild.
2. For polar bears to make goal directed decisions which influence route, distance and modality of journeys undertaken.
3. For polar bears to be required to express a variety of species typical food acquisition behaviours to secure meals with a natural contingency whereby not all attempts to acquire food are successful.
4. For polar bears to process multisensory information (sight, sound and scent) to inform their decision-making process in seeking to secure feeding opportunities.

5. For polar bears to experience opportunities to learn routes, associations between rewarding outcomes and specific cues such a scent, sight and sound, as well as improve species-specific motor skills throughout their lives.
6. To consume a greater proportion of their diet on a more natural contingency with larger, more fat dense meals consumed on a less frequent basis.

To achieve these goals, which reflect the output of the AWPIS© assessment within the confines of a captive environment will be challenging, but a targeted approach along these lines would likely yield considerable benefits to captive polar bears in the coming years.

Similar challenges were identified for Amur tigers, however, because of their propensity to use 'game trails' within forests, the solutions described for that species are not readily transferable to polar bears (see Veasey 2020b). For polar bears, a three dimensionally complex network of vegetated paths would not be appropriate, however it is conceivable that dynamic trails that elicit complex, purposeful locomotion and species appropriate learning, could be established within more open, yet topographically diverse captive habitats. This could theoretically be achieved using a variety of waypoints distributed throughout the space which elicit visual, auditory and olfactory signals encouraging bears to locomote throughout their habitat along flexible / programable routes with which the bears have some control over, with choices effecting outcomes. Bears would arrive at specific waypoint eliciting a learnable species appropriate cue, where the bears may or may not have the opportunity to perform a task replicating species appropriate behaviours such as breaking ice or caving in a seal den (pounding on a surface according to prescribed force or frequency-based criteria), still-hunting (remaining still and quiet for a period of time), hauling out a carcass (pulling on a tension gauge device) etc. Successful completion of the behaviour either provides a reward, or more typically, triggers the signal to travel to the next waypoint within the habitat which may or may not require a task to be completed before transit to the next waypoint, and so on. To add an element of choice and decision making beyond simply deciding whether to participate or not, simultaneous cues could be linked to differing outcomes or opportunities, which also create capacity for learning, navigation and choice. Moreover, waypoints can also incorporate opportunities to harvest data for animal care teams and researchers such as body mass and body temperature, movement, stress hormone levels etc.

Ideally, such a solution requires advanced animal computer interactions engineered into a large naturalistic landscape with sufficient waypoints to establish a diversity of routes through the space, which also require swimming as well as walking, elevation gain and utilises a variety of substrates, ideally including ice and or snow. Polar bears have already been trained to use treadmills (see for example Best 1982, Hurst *et al* 1982), and so the prospects of using flow-based training pools to increase swimming duration between waypoints is an intriguing one and would likely represent a better investment in welfare than acrylic viewing tunnels.

Clearly, once the technical challenges have been overcome, the impact of such a holistic approach will be enhanced by the space made available to the bears, a point already established by Sheperherdsen *et al* (2013). It is perhaps reassuring that space doesn't limit mobility of captive polar bears and that it is more likely cognitive and behavioural opportunities that impact welfare more directly than surface area, however it is also clear that cognitive and behavioural opportunities will be easier to provision for in larger habitats. A recent review of 37 polar bear facilities around the world, showed that just two exceed two acres, including non-animal space. Whilst reduced access to space may be central to compromised welfare for captive polar bears, marginally increasing habitat size is unlikely to achieve the welfare improvements desired. However, the targeted complexity and anticipated solutions required to meet the behavioural and cognitive needs of these species, likely requires markedly more space than is currently provided to the majority of captive polar bears.

Future work:

Development of an integrated system to augment polar bear welfare:

The loss of sea-ice on which the survival of polar bears currently depends makes the need to develop a diversified approach to their conservation urgent, including inland climate adaptation and improved care in captivity. Care for the Rare in conjunction with the department of Animal-Computer Interaction at the Open University's School of Computing and Communications and Yorkshire Wildlife Park Foundation intend to collaborate in developing an innovative bear-centred approaches to welfare challenges that integrates monitoring and interactive technologies with machine learning to determine the requirements and solutions for optimal polar bear care in captivity.

Further validation of the AWPIS© methodology:

It is also planned that polar bear habitats from which extensive behavioural and welfare related data has been collected will be ranked according to their capacity to provide for the priorities established here. The extent to which the AWPIS© based ranking correlates with recorded welfare indicators from those habitats will then be assessed in order to help validate, and where necessary improve the AWPIS© methodology, and to further our understanding of the needs of captive polar bears.

Because behaviours and cognitive processes are intimately interconnected in the wild, they can’t be considered in isolation in captivity when attempting to optimise welfare.

Summary:

1) Wide-ranging carnivores are understood to be more likely to experience poorer welfare in captive environments than less wide-ranging species. Polar bears are the most wide-ranging terrestrial carnivore and frequently exhibit signs of compromised welfare in captivity.
2) Attempts to overcome welfare challenges experienced by captive polar bears has been constrained by the limitations of existing habitats and the difficulty in evidencing causal relationships between novel management and habitat paradigms with welfare states.
3) Thirty-five experts from the animal welfare research, in-situ research and captive management sectors participated in an AWPIS© assessment for polar bears in an attempt to overcome these constraints by seeking to understand the fundamental needs of polar bears based on their behavioural ecology in the wild. The output provided by experts from different backgrounds were shown to be highly consistent allowing data from all experts to be pooled.
4) Following the assessment, behaviours and cognitive processes were grouped into four thematic areas; i) behaviours and cognitive processes linked to the acquisition of food and hydration, ii) movement, navigation and long-distance travel, iii) sociality and reproduction, and finally, iv) cognitive processes not necessarily tied exclusively to any of the previous categories.
5) Behaviours and cognitive processes linked to the acquisition of food and hydration ranked highly and whilst they are catered for to the extent necessary to maintain life in captivity, it appears likely they are not catered for adequately enough to optimise captive welfare nor nutritional health. A review of husbandry guidelines suggests there maybe regional variation in dietary provisioning, however, it is evident that many captive polar bears will experience smaller, more frequent meals with a higher protein and lower fat content than is experienced by wild by polar bears. Furthermore, the feeding modality in captive environments with more frequent smaller meals that are markedly lower in fat than typically consumed by wild polar bears is considered better suited to a generic omnivorous bear species than it is to a true carnivore such as the polar bear. The consequence of this dietary mismatch is a reduction in kidney and liver health, the frustration of important motivated behaviours and the prevention of foraging motivations being sated causing a state of chronic frustration and compromised welfare.
6) Walking and swimming were identified as high priorities that were not considered to be unduly curtailed in captivity. Whilst stereotypies may result in captive bears walking longer distances than their wild counterparts, the form and function of stereotypic pacing and most likely swimming supports the case that non-stereotypic locomotion needs additional prioritisation in management. Efforts to connect non-stereotypic, purposeful locomotion to important and rewarding natural contingencies such as nutritional, social, behavioural or cognitive outcomes and opportunities is recommended. The inadequacy of the standards established for pool size which in some cases allow for submersion but not

meaningful travel, is noted and research into the potential benefits of allowing polar bears access to larger lakes versus smaller filtered or salinated pools is recommended.

7) The high incidence of juvenile mortality amongst captive polar bears has been previously interpreted as a sign of poor welfare related to the compression of their home range in captive environments. However, the high ranking of maternal denning behaviour suggests an alternative explanation; few captive polar bears are provided the opportunity to express such highly motivated natural denning behaviours, likely resulting in acute prenatal stress, a state that has been demonstrated to have impacts on both juvenile development, juvenile survivorship as well as maternal welfare for a range of mammal species. It is suggested that the benefits of providing polar bears the opportunity to make choices in relation to where and how they construct their own maternity dens will outweigh the reduced capacity to observe and intervene by animal care staff.
8) Behaviours and cognitive processes linked to the nomadic life of a polar bear in the wild (walking, exploring, swimming, seasonal migration and navigation) all ranked highly, with seasonal migration identified as the most curtailed, high priority behaviour. Such behaviours and cognitive processes allow polar bears to respond to seasonal shifts in ice and prey distribution to ensure their survival in the wild. The wide-ranging nature of polar bears is a recognised risk factor for poor welfare, but addressing these important opportunities within the constraints of captive environments will necessitate innovative thinking since it is not necessarily the lack of space *per se* that creates the welfare challenge, it is more likely the lack of appropriate cognitive and behavioural opportunities that are associated with travel in the wild. Since it is the distanced moved from one point to another and the variability encountered in that journey that is constrained by captivity rather than the distance walked / paced *per se*, increasing the size of habitats and retaining prevailing management paradigms will likely create only marginal improvements in welfare. However, such larger habitats will inevitably provide more scope to meet the evolving management paradigms and the needs of bears.
9) Cognitive process and behaviours with significant cognitive elements associated with them also ranked highly. Olfaction and learning were amongst the most important cognitive process not exclusively tied to food acquisition. It is recommended that learning must not be viewed as an objective independent from the behaviours and cognitive processes identified as priorities here, but connected to them all. Management and facility design should seek ways to allow polar bears to refine natural motor and cognitive skills throughout their life in captivity.
10) In order to provision for the cognitive and behavioural priorities identified here, it is necessary to explore the establishment of dynamic environments in which polar bears can gather information and establish rewarding contingencies between their choices, actions and the outcomes they experience. It is possible that captive polar bears with improved welfare may be less active than captive polar bears with compromised welfare as a result of the reduction in stereotypies and the species' predisposition to conserve energy.

11) Whilst the cognitive and behavioural priorities identified here are more important than habitat size alone, the capacity to provide for those priorities likely improves with increasing habitat size. Moreover, whilst it is unlikely that any captive polar bear habitat will ever be too big, it is likely that most are currently not big enough to optimise captive polar bear welfare. In developing new facilities, zoos and wildlife parks are encouraged to acknowledge this reality, be ambitious in their aspirations for polar bears and realistic in what they can achieve within their physical constraints; building the best polar bear facility a zoo can achieve is not good enough if it fails to meet the needs of the bears as a result of its lack of space.
12) Captive facilities which experience temperatures significantly above 20^{o}c, or above 20^{o}c for prolonged periods of time, are encouraged to consider the suitability of housing polar bears.
13) Specific goals for the development of new habitat and management strategies include enabling captive polar bears to:
    a. undertake purposeful travel for distances comparable to that seen in nature
    b. make goal directed decisions
    c. express a variety of species appropriate food acquisition behaviours
    d. process multisensory information to inform decision-making
    e. experience opportunities to learn throughout their lives
    f. consume fewer, larger, more fat dense meals

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Appendix:

Behaviour / Cognitive Process	Category	AWPIS© score
Sleeping / resting	Physiological need	0.897
Eating animals	Physiological need	0.855
Walking	Behavioural	0.853
Olfaction	Cognitive	0.830
Drinking	Physiological need	0.826
Choice / decision making	Cognitive	0.796
Foraging at sea / on sea ice	Behavioural / cognitive	0.794
Killing prey	Behavioural / cognitive	0.789
Exploring	Cognitive	0.785
Learning	Cognitive	0.776
Swimming	Behavioural	0.767
Carcass processing	Behavioural	0.767
Problem solving	Cognitive	0.763
Watching / observing	Cognitive	0.762
Parenting / nursing (*females only)	Behavioural / cognitive	0.762
Seasonal migration	Behavioural / cognitive	0.746
Running	Behavioural	0.746
Navigating	Cognitive	0.743
Stalking prey on ice	Behavioural / cognitive	0.743
Grooming / rubbing	Behavioural	0.737
Den building (*females)	Behavioural	0.733
Mating	Behavioural / cognitive	0.729
Digging	Behavioural	0.708
Ambushing / still hunting	Behavioural / cognitive	0.702
Predator evasion	Behavioural / cognitive	0.702
Foraging on land	Behavioural / cognitive	0.699
Den building (*all)	Behavioural	0.689
Ice breaking	Behavioural	0.671
Raiding seal birth lairs	Behavioural / cognitive	0.666
Seeking breaks in ice	Behavioural / cognitive	0.658
Mate guarding (*males)	Behavioural / cognitive	0.657
Stalking prey on land	Behavioural / cognitive	0.648
Den building (*males)	Behavioural	0.614
Socialising	Cognitive	0.614
Play	Cognitive	0.612
Eating plants	Behavioural	0.600
Stalking prey from open water	Behavioural / cognitive	0.591
Climbing	Behavioural	0.583
Fighting	Behavioural / cognitive	0.579

Table 2. AWPIS© based ranking for behaviours and cognitive processes for polar bears

Participant / Supporting Institutions:

AQUARIUM DU QUÉBEC

ZOO Assiniboine Park

DIERGAARDE BLIJDORP ROTTERDAM ZOO

BROOKFIELD ZOO

BUDAPEST ZOO

CAZA AZAC – CANADIAN ASSOCIATION OF ZOOS AND AQUARIUMS – ASSOCIATION DES ZOOS ET AQUARIUMS DU CANADA

CHURCHILL NORTHERN STUDIES CENTRE

COCHRANE POLAR BEAR HABITAT

ZOO COPENHAGEN

EEP

RZSS HIGHLAND WILDLIFE PARK

Marineland CÔTE D'AZUR

Milwaukee County Zoo

МОСКОВСКИЙ ЗООПАРК 1864 2019

NTU NOTTINGHAM TRENT UNIVERSITY

The Open University

POLAR BEAR REFUGE – A Care for the Rare Initiative

Seneca Park Zoo

toronto ZOO

University of BRISTOL

UBC

University of Central Lancashire UCLan

UNIVERSITY of GUELPH

WILDLANDS ADVENTURE ZOO EMMEN

WILD WELFARE

YORKSHIRE WildLife PARK

Zoo and Wildlife SOLUTIONS

ZOO SAUVAGE de St-Félicien

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– Valérie Bégin	Aquarium du Québec -SÉPAQ
– Félix LaBrosse	Aquarium du Québec - SÉPAQ
– Marie-Ève Godbout	Aquarium du Québec - SÉPAQ
– Grant Furniss	Assiniboine Park Conservancy
– Paul Woerner	Assiniboine Park Conservancy
– C-Jae Breiter	Assiniboine Park Conservancy
– Chris Enright	Assiniboine Park Conservancy
– Endre Sós	Budapest Zoo and Botanical Garden
– Dylan McCart	Churchill Northern Studies Centre
– Cecilie Ravn Skovlund	Copenhagen Zoo and University of Copenhagen
– Stefan Timmermans	Diergaarde Blijdorp
– Vickie Larkin	Highland Wildlife Park
– Christopher Scala	Marineland Cote D'Azure
– Gary Lunsford	Milwaukee County Zoo
– Irina Voschanova	Moscow Zoo / EEP Coordinator
– Amy Baxendell	Polar Bear Habitat, Cochrane Ontario
– Emma Mellor	University of Bristol
– Ron R Togunov	University of British Columbia
– Heather Bacon	University of Central Lancashire
– Miranda Bandeli	University of Guelph
– Job Stumpel	Wildlands Adventure Zoo Emmen
– Simon Marsh	Wild Welfare
– Charlotte Macdonald	Yorkshire Wildlife Park
– Kim Wilkins	Yorkshire Wildlife Park
– Matt Hartley	Zoo and Wildlife Solutions
– Stephanie Grenier-Laroche	Zoo Sauvage de St-Félicien
– Christine Harvey	Zoo Sauvage de St-Félicien

Disclaimer:

The content provided here represents the opinion of the author unless otherwise stated, based wherever possible on the data collected in the AWPIS© assessment carried out between 6th December 2021 and 8th February 2022, peer reviewed scientific publications, feedback from participants and personal experience. Participants in the workshop are not accountable for the opinions expressed herein, and their participation in the assessment should not be assumed to reflect their approval of the report or its conclusions. The author confirms he is the sole author and that funding provided to support this work has in no way influenced the conclusions expressed herein.


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