Moving forward with zoo welfare assessment; a response to Cooke (2017).

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Abstract

We show how the points raised in Rose, Nash, and Riley (2017) are relevant across taxa. The aim of this paper reviewed literature on three basic "groups" of animal, with a specific remit of identifying welfare needs within these groups. The focus of this paper does not intend to exclude other types of animal, but to show the extent of research needs in those already studied. The ideas presented are relevant to those studying other taxa; scientists and zoo biologists with more expertise and knowledge of invertebrates. We feel that there is much to be gained from collaboration between individuals and institutions to fit the questions that Rose et al. (2017) suggests to a wider range of captive vertebrate and invertebrate taxa.

Keywords: zoo, welfare, evidence-based husbandry, under-studied taxa

Discussion commentary

We thank Cooke (2017) for the thorough review of our paper, and we are glad to see this paper agrees with many of the points in Rose et al. (2017), e.g. on how zoos can apply welfare measurement and assessment in relation to stereotypic behaviours, and that Cooke (2017) can use our paper to pose extra areas for research. Whilst this paper clearly states that it has a focus on three basic groups of animals (mammals, birds, other vertebrates), it provides areas for welfare assessment and measurement that can be used across taxa. As such this paper has the aim of being extended away from "common" taxa to be used a tool for those wishing to investigate welfare needs in other, less studied species. Rose et al. (2017) approached a review of welfare information that was currently available in the scientific literature as of December 2015, when the manuscript was completed. it aimed to show the scope of literature available for the taxonomic groups identified and to use these sources to develop areas of welfare investigation based on behavioural ecology and key evolutionary traits that zoos should cater for. We selected key species that have had empirical welfare research conducted on them, as well as to show the scope of research that has been conducted on common zoo species. However, as not all species and not all papers could be included, Rose et al. (2017) uses examples that have extension to other animals and show the range of abnormal repetitive behaviour (ARB) that are present.

We feel that our paper provides useful and relevant information that can drive zoo animal husbandry forwards. We show the scope of ARB that can be present in a manner that is useful to zoos when they are attempting to identify causal factors and therefore to reduce or eliminate ARB performance. It is clear that ARB can occur across the taxonomic spectrum, and be similar in the behavioural signs that we can observe. This suggests that animals respond in a similar manner to deficiencies in their environments. We support the idea that zoos should have a zero-tolerance approach to abnormal behaviours (Mason, Clubb, Latham, & Vickery, 2007) and we structured our paper to provide zoos with evidence on how and why ARBs are performed by an individual animal (and why they can be common, and similar in performance) across a particular species or genus.

We hope that those reading Rose et al. (2017) can take the ideas for welfare research that we present on the species examples that we use, and can apply such questions and approaches to other species that we have not included. The paper on rays that Cooke (2017) recommends was not available to us at the time of writing, but we have included detail in our paper on how specialized fish species with key appetitive behaviour patterns should have their welfare investigated in captivity. We have deliberately posed open welfare questions to direct future research that is applicable across taxa. Cooke (2017) mention's anecdotal evidence of behaviours indicative of

poorer welfare states, and we have noted observations of our own (e.g. captive finch stereotypic actions) that can be used as foundation for zoo animal welfare assessment. It is well-known that anecdote can lead to interesting discussions on how zoo animals are kept, and therefore Cooke (2017) has provided a useful starting point for novel research into how invertebrates can provide behavioural (observational) aspects of their welfare state in the environment that they are maintained in.

To extent the subject area it would be useful to have a review on these invertebrate taxa. We agree with Cooke (2017) that more work is needed to identify the welfare needs of all taxa found in the zoo and we encourage him to lead this work into invertebrate welfare assessment, and to provide similar areas of welfare investigation that we have done in our paper. We feel that the questions posed in Table 2 of Rose et al. (2017) can be applicable across captive vertebrates and invertebrates and we feel that Cooke (2017) could this information to commence in-depth welfare investigation into invertebrate species. As has been noted in previous research, extending collaboration between zoological institutions and academic institutions can lead to the generation of data useful to both parties (Fernandez & Timberlake, 2008). Such an approach can be especially beneficial to advancing welfare states in captive species, and both Cooke (2017) and Rose et al. (2017) provides relevant questions for such collaborations to be based around.

New research has shown diverse control of behavioural repertoires in invertebrate species, for example a link between cognitive state and personality has been demonstrated in carpenter ants, *Camponotus aethiops* (d'Ettorre et al., 2017). The implications of such research are important for zoos to consider when designing enclosures for such species, providing enriching conditions, and considering how best to display these species to the public. Such considerations that are commonplace when discussing vertebrate taxa but clearly need more emphasis in invertebrates too. We agree with Cooke (2017) that for a zoo to be a complete "positive welfare" environment all taxa need to be considered, assessed and evaluated to check that provision within the zoo meets behavioural needs and evolutionary traits.

As zoos continue to evolve and to work on the scientific basis for evidence-based husbandry (Melfi, 2009) and engage with stakeholders to improve knowledge of species' ecology and biology, and hence husbandry and management techniques (Melfi & Hosey, 2011; Rose, Brereton, & Gardner, 2016) ARB performance will reduce. However, the need to expand the research across taxa remains and many species are still understudied. Novel approaches to welfare assessment are relevant to all taxa. For example, biological relevance of enclosure usage can be assessed by knowledge of natural foraging ecology and applying such knowledge to feeding locations (Troxell-Smith, Watters, Whelan,

& Brown, 2017), thereby encouraging a wider use of available space. Also, new insights into apathy and lethargy- that boredom can severely reduce positive welfare states in zoo-housed animals (Burn, 2017)- are one new avenue of study that can be applied to highly-complex, cognitive invertebrates (e.g. cephalopods) as well as traditional zoo welfare study subjects (e.g. primates, carnivores, parrots and elephants). Finally, assessment of an animal's behaviour across a 24-hour cycle to determine welfare issues when the zoo is closed, as well as when keepers are present to provide care (Duggan, Burn, & Clauss, 2016), can be undertaken with remote cameras and other such technologies.

Species behaviours have evolved as a response to selection pressures within a habitat (Rose, 2017) and as such fitness can be reduced when such behaviours are not performed in captivity. We understand behavioural effects of fitness well in mammalian species (Silk, 2007) but we know less about such a relationship in other vertebrates, and even less in invertebrates. However, can potentially use similar tools to answer important welfare-based questions across all taxa. individual welfare assessment, based on animal-based indices (Whitham & Wielebnowski, 2013) provides information on coping within the condition provided. As such, we propose the following methodology that can be useful for all species' welfare assessment in the zoo (figure 1).

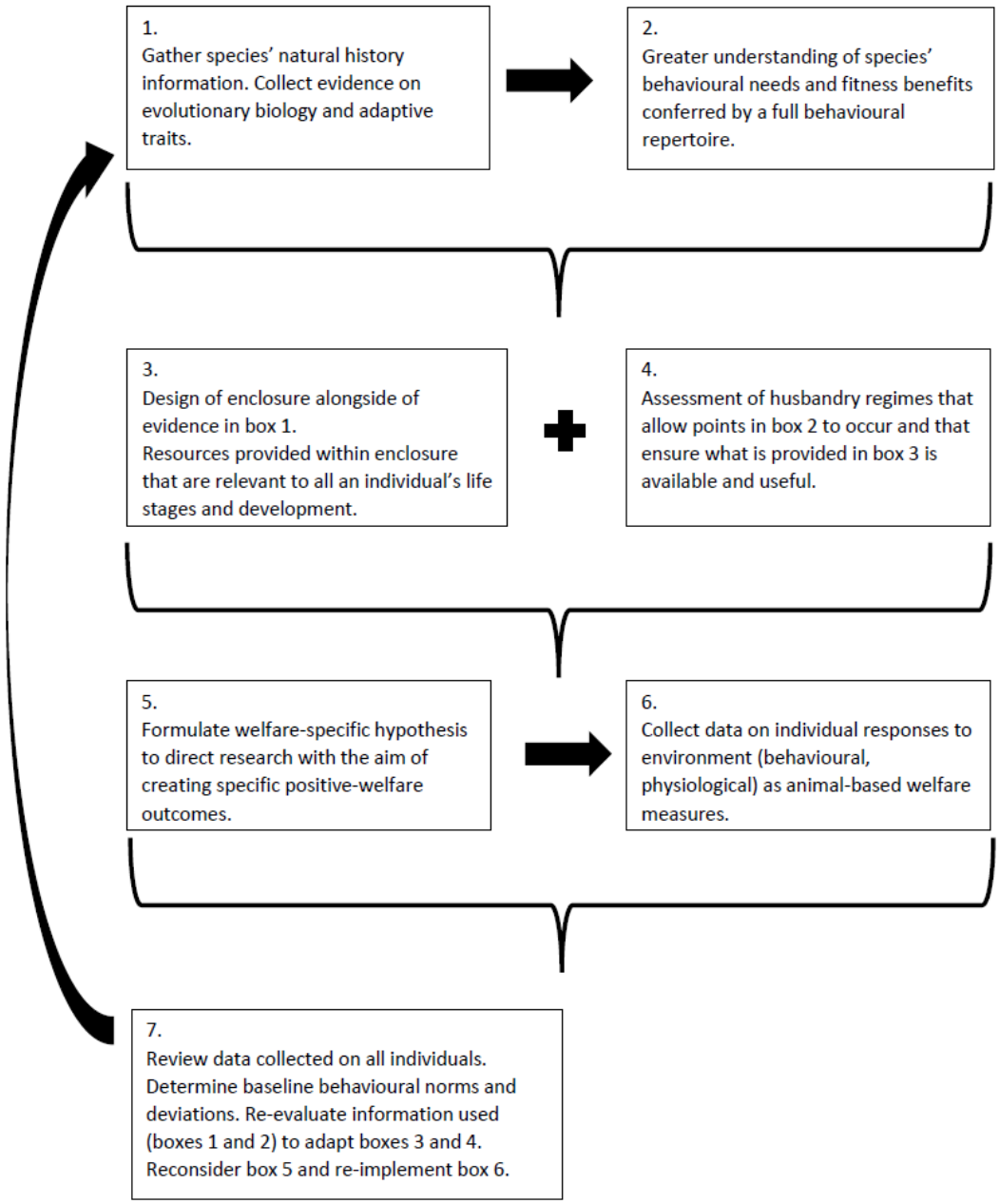

Figure 1: integrating natural history information into zoo animal husbandry and reviewing practice to uphold positive welfare. A method that can be applied across all zoo taxa.

We feel the conclusions made in Rose et al. (2017) are valid to the types of animal discussed, and that they can be extended to other species of animal that were not included. We have covered both terrestrial and aquatic species, and show common trends across these taxa as well as drawing comparisons (in behavioural needs or welfare infringements) where relevant. This paper deliberately makes general statements to help direct welfare measurement in the animal groups we aimed to review. We therefore encourage all other behaviour and welfare scientists to answer the questions

posed in both the taxonomic groups we cover and to extend them to invertebrate groups as they see fit.

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