

## **Food-Based Enrichment Effects on Carnivore Enclosure Use and Behaviors**

There is a lot of good information here, and while not necessarily novel, certainly additive to the existing enrichment literature. The biggest issue is how the data are both analyzed and presented. For instance, it's not clear why the authors chose to present enclosure use in a difficult to assess manner as density per selected area, even after running SPI. Likewise, the analysis of behaviors should be presented visually in graphs, rather than presented in tables that make the information more difficult to comprehend. I will return to these issues at the end of the review.

First, the authors state that zoo enclosures can lack both space and complexity, which they say can create stress and stereotypies. However, it would be better to state that both are correlated with negative welfare indices, such as stereotypies. The difficulty lies in using 'stress' as a causal variable, or suggesting that one causes the other in the absence of such information. The authors can additionally cite Clubb and Mason (2003) for an additional link connecting wide-ranging carnivores with stereotypies in captivity, as well as Carlstead's (1998) Second Nature book chapter on the causes of stereotypies in zoo carnivores. I would also additionally cite Mellen and MacPhee (2001) and Newberry (1995) for how enrichment is used to promote positive welfare (currently, only Mason et al., 2007 is cited in that initial statement). Finally, the preferred formal term is 'environmental enrichment' (it's fine to abbreviate it as 'enrichment' after using the complete term at least once), and while enrichment can be identified via stimuli that are meant to produce enriching effects, enrichment itself is not just the stimulus/event: It is the interaction between the stimulus/event and some positive welfare change, such as improved behavior (Fernandez, 2022).

Otherwise, it might help to look more specifically at the vast literature that involves food-based enrichment for carnivores in zoos. There are a number of studies, particularly involving bears, that look at both changes to behaviors as well as enclosure use. I'll leave it to the authors to dig a bit more through that literature, but suggest looking at Carlstead et al.'s (1991) original study on enrichment in zoo bears, as well as her later work showing changes in enrichment function based on seasonality. Also, see studies on scatter feeds in zoo bears, fixed- and variable- food deliveries, food predictability, etc. Finally, there is work on contrafreeloading in bears, as well as quite a bit of work with canids and felids and these variables too.

While, as I noted above, examinations of food-based enrichment are not necessarily novel, there are two important aspects that help add to the literature that this study details: (1) effects prior to, during, and after the introduction of enrichment (ABA design; most studies only make claims of enrichment vs. non-enrichment comparisons), and (2) visitor perceptions of enrichment activities. The latter is particularly interesting, and there's even a study examining how people respond to natural vs. non-natural enrichment delivered to polar bears (Kutska, 2009). It would be nice to see more emphasis placed on the first point; perhaps cite work related to examining both pre- and post-enrichment effects as well? With regard to the second point, the authors cite some of the work examining what is often called the 'visitor experience', but they're also missing a lot of important work related to this field (for instance, see researchers examining education effects, such as Courtney Collins and Sarah Spooner). A good starting place would be to look at the 2021 animal-visitor interactions (AVIs) special issue of the journal *Animal Behavior and Cognition*.

In the methods, when describing 'scan sampling', this only details a sampling rule (Bateson & Martin, 2021), meaning the number of individuals observed. You should still note the recording rule, or how you sampled behavior (pinpoint vs. interval sampling). If you used an instantaneous sampling method, where you recorded what happened at the exact 4 min mark, note that. If you instead use some type of interval recording method, where you marked all things that happened in

that 4 min period, note that recording rule as well. See both Altmann (1974) and Bateson & Martin (2021) for more detail, and then report it as either pinpoint or interval scan sampling.

The biggest difficulty with the manuscript, as I alluded to at the start of the review, is how the information is presented. The authors used SPI, although they did not mention whether modified SPI (Plowman, 2003) or another enclosure use variability metric, such as entropy (Brereton & Fernandez, 2022) might have been more relevant. Regardless, what would be most appropriate would be to *show* the change, including significant differences, graphically for the enclosure use variability index used. It is incredibly difficult for the reader to try and compare the entire enclosure use sections across the conditions as presented in Figures 1-3, and defeats the purpose of having run a simplified index to assess enclosure use. Show the SPI changes instead.

Similarly, there are no graphs of the behaviors or visibility of the animals across the conditions, instead electing to present the findings of the GLMM in a table. I would strongly suggest presenting these results graphically in some manner, including (again) showing significant effects outlined across something like bar graphs that compare the different conditions. The same could be said for the visitor survey graphs (Figures 4-6), which could instead show how visitor responses changed (or not) in response to enrichment vs. non-enrichment conditions. Even when there is no change, that would at least be more accessible as information to the reader if presented as a graph.

It might also be helpful to run a similar behavior variability index on the data, such as one of the measures of behavioral diversity (Miller et al., 2020). The authors note 'behavioral diversity' in the conclusions, but it wasn't clear that any behavioral diversity index was actually assessed.

Overall, I think there's good information here, and certainly lots of data to present. But the biggest problems could be summarized as three major points: (1) a greater need for more detailed, more recent citations presented, (2) more complete analyses of the results run, such as possibly different indices used, and (3) better presentation of the results. It's this last point that I want to stress, since currently the paper doesn't either show or describe the information in a way that makes it most readable. It shouldn't be too difficult to adjust the information accordingly, but it will require some rethinking of the most optimal way to simplify and present the results.

## References

- Bateson, M. & Martin, P. (2021). *Measuring Behaviour: An Introductory Guide* 4th edition.
- Brereton, J. E., & Fernandez, E. J. (2022). Which index should I use? A comparison of indices for enclosure use studies. *Animal Behavior and Cognition*, 9(1), 119-132.
- Carlstead, K. (1998). Determining the causes of stereotypic behaviors in zoo carnivores: Toward appropriate enrichment strategies. *Second Nature: Environmental Enrichment for Captive Animals*, 172-183.
- Clubb, R., & Mason, G. (2003). Captivity effects on wide-ranging carnivores. *Nature*, 425(6957), 473-474.
- Fernandez, E. J. (2022). Training as enrichment: A critical review. *Animal Welfare*, 31(1), 1-12.
- Kutska, D. (2009). Variation in visitor perceptions of a polar bear enclosure based on the presence of natural vs. un-natural enrichment items. *Zoo Biology*, 28(4), 292-306.
- Mellen, J., & Sevenich MacPhee, M. (2001). Philosophy of environmental enrichment: past, present, and future. *Zoo Biology*, 20(3), 211-226.
- Miller, L. J., Vicino, G. A., Sheftel, J., & Lauderdale, L. K. (2020). Behavioral diversity as a potential indicator of positive animal welfare. *Animals*, 10(7), 1211.
- Newberry, R. C. (1995). Environmental enrichment: Increasing the biological relevance of captive environments. *Applied Animal Behaviour Science*, 44(2-4), 229-243.
- Plowman, A. B. (2003). A note on a modification of the spread of participation index allowing for unequal zones. *Applied Animal Behaviour Science*, 83(4), 331-336.