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Research article

Space use and enrichment in a North American river otter (*Lontra canadensis*) exhibit

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Abstract
Exhibit design and environmental enrichment can influence space use by captive animals. On 2 May 2014, the Tennessee Aquarium opened a new, expanded North American river otter (*Lontra canadensis*) exhibit, "River Otter Falls". The exhibit housed six otters (5 male and 1 female). A group of three otters was rotated in the exhibit every 2–2.5 hours. Using a scan sampling procedure with 30-sec intervals, the location and number of otters in each of nine areas of the exhibit was marked. The number of otters not visible was also counted. The study lasted for 4 months, with 43 sessions each lasting ~45 min. The results showed that otters tended to use all areas of the exhibit rather than confining themselves to one or a few areas (total SPI=0.35) and were visible 98% of the time. *G*-tests showed that otters were using the areas significantly differently from chance with variations in how they were using each individual area of the exhibit. Comparisons of visibility and location after enrichment showed that otters tended to use the exhibit less uniformly during enrichment, but increased time spent in areas of the exhibit with greater visibility and proximity to guests. During enrichment sessions, otters were more visible in the areas of the tank that visitors may see most easily, emphasising the role that enrichment can have on space use of an enclosure and visibility of animals in captivity.

Introduction

Accommodation for animals in captivity in zoos and aquariums can be a balancing act between allowing visitors to see animal activity while also creating an enriching naturalistic environment for animals that provides privacy for the animals. An exhibit designed to be more naturalistic is likely to provide additional space for animals to hide, providing less opportunity for visitors to view animals and maintain visitor interest. But natural designs are positively correlated with animal activity, proximity to guests and visibility (Bitgood et al. 1988). These elements also serve an important purpose for the animals by allowing them to play and forage (Reed-Smith and Larson 2017). For the visitors, higher attendance and interest at exhibits can promote public education about animals and generate revenue from the attendance to enable research and conservation efforts (Fernandez et al. 2009; Kuhar et al. 2010). A well-designed naturalistic exhibit will provide the animal with opportunities for environmental enrichment (Seidensticker and Doherty 1996).

Although a natural exhibit design provides a certain amount of enrichment, environmental enrichment can also be implemented by introducing a variety of novel stimuli or food items to animals in the exhibit. The quality of life is thereby enhanced for animals in captivity (AZA Small Carnivore TAG 2009). Such enrichment combats stereotypical behaviour in captive animals and increases visibility and uniform space use at an exhibit (Kuczaj et al. 2002). Previous research examining otters in captivity has shown effective use of enrichment to stimulate animals (Foster-Turley and Markowitz 1982; Ross 2002) but has not focused on the role of enrichment on exhibit space use.

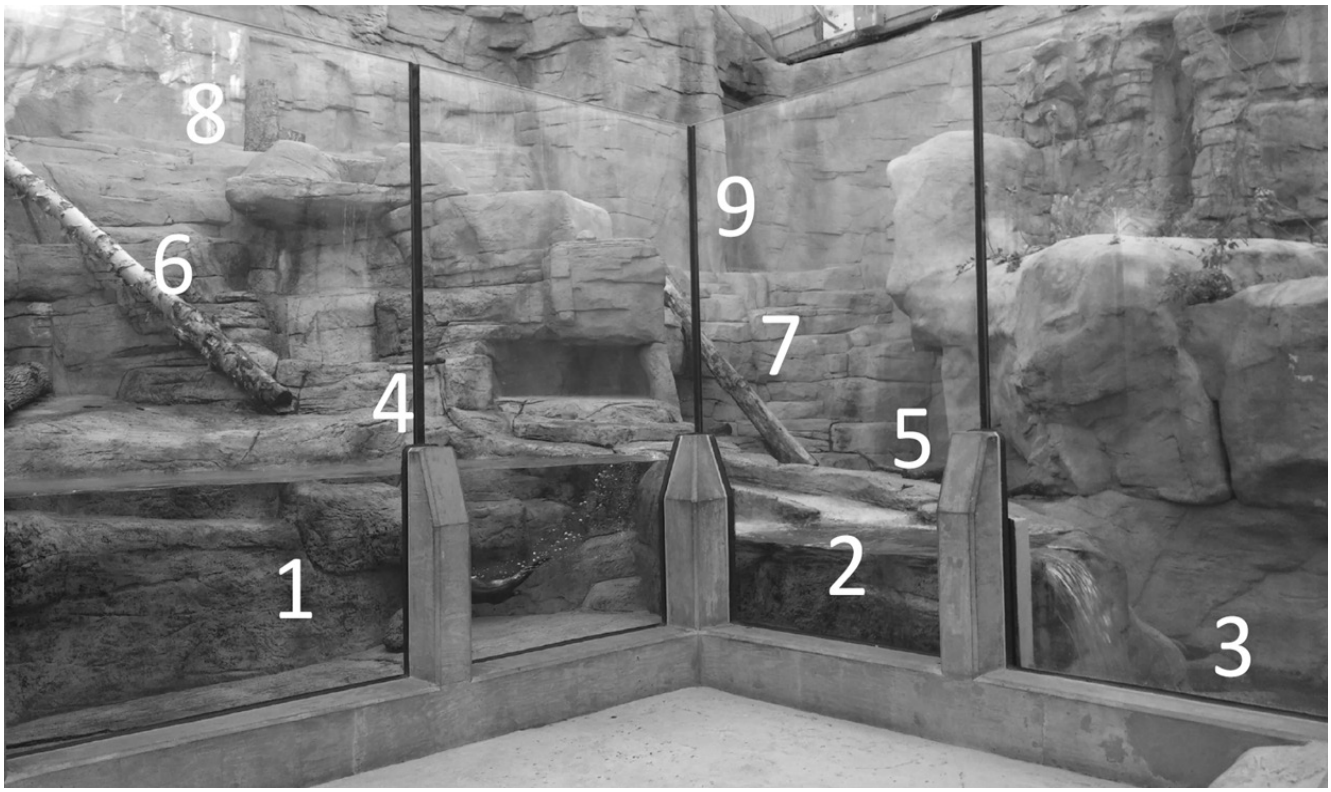

Figure 1. Photo of otter exhibit with areas numbered. Labelled areas 1–9 of "River Otter Falls". 1=Longest pool, 2=Small middle pool, 3=Deep pool, 4=Front ground area, 5=Back ground area, 6=Stairs to upper area, 7=Stairs to door, 8=Upper level, 9=Doorway, 10=Not visible.

A valuable method for ascertaining the effects of exhibit design is post-occupancy evaluation (POE). This systematic technique may be used to determine the effects of the exhibit on the animals as well as on people. A POE is a useful tool to confirm that the design elements of the exhibit are working as intended. However, POE use in animal facilities has been limited (Maple and Finlay 1987; Maple and Perdue 2013).

POEs have been used to examine both how the exhibits affect animal welfare and how they affect visitor reactions to the exhibit. In particular, naturalistic exhibits have been examined to ascertain their effects on visitor interest. The worry about these exhibits is that they will impede the visibility of animals. Alternatively, they appear to increase interest in the animals by presenting them to the visitors in a more natural environment (Shettel-Neuber 1988; Fernandez et al. 2009). These naturalistic environments also help ensure animal well-being (Maple and Perdue 2013).

On 2 May 2014, the Tennessee Aquarium in Chattanooga opened a new exhibit for their otters, "River Otter Falls". This new exhibit is much larger than the previous exhibit and allowed for the exhibition of a greater number of animals. It is a naturalistic exhibit for six North American river otters (*Lontra canadensis*) consisting of simulated rock faces, a waterfall and stream and three pools. The opening of this exhibit provided the opportunity to conduct a POE three months after the otters had taken occupancy. Otter space use in the exhibit was examined, as well as the effects that added enrichment had on the exhibit use and the effects of both on visibility. Understanding the role of enrichment on space use and visibility in this population can contribute to the development of enrichment strategies employed by zoos and aquariums to ensure animals have optimum welfare in a naturalistic environment while also showcasing active animals to guests.

Materials and methods

Subjects and housing

The subjects of this study were six (5 male, 1 female) North American river otters in the "River Otter Falls" exhibit. Only one of these otters (Delmar) had been housed in the previous exhibit. All other otters were new to the aquarium (for details on the individual otters see Supplemental Table 1). Otters were given various objects for enrichment in an off-site holding facility before introduction to the exhibit. Delmar had received food enrichment in the previous exhibit. Enrichment was kept minimal in the first month of occupation of the new exhibit to allow the otters to

Figure 2. Blueprint of otter exhibit with areas demarcated and numbered. Labelled areas 1–9 of "River Otter Falls". 1=Longest pool, 2=Small middle pool, 3=Deep pool, 4=Front ground area, 5=Back ground area, 6=Stairs to upper area, 7=Stairs to door, 8=Upper level, 9=Doorway, 10=Not visible (courtesy of franklin|architects).

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The size of the exhibit is ~88 m^2. Simulating a naturalistic setting to highlight behaviour of otters in the wild, the exhibit consists of a multi-tiered landscape featuring a stream of three pools of varying depths and lengths, waterfalls, cascades, and a variety of substrate. Large glass partitions act as a viewing window to allow visitors to view underwater, an overhead view of the deepest pool, and an eye-level view of the ground levels of the exhibit. Much of the upper portion of the exhibit and some hiding spots on the ground level of the exhibit allow private areas for the otters where they are not visible to guests.

Procedure

Data collection took place over 25 days between 30 July and 21 November 2014. Observations were made using a scan sampling procedure (Altmann 1974) while standing in the visitor viewing area of the exhibit using the ISBO app (Ogura 2013) on an iPad tablet. No changes were made to the animals' normal routine. The exhibit was scanned consecutively for 45–50 minutes at 30-sec intervals per session. Every 2–2.5 hours a group of three otters was rotated into the exhibit from an off-exhibit holding centre. The three otters in each group varied depending on their availability and social preferences. Each rotation constituted a session. Data were collected at sessions throughout the day from ~1100 to 1740. Otters were observed for the first 45-minute period at the beginning of a session and the last 50-minute period at the end of a session. Five minutes were added at the end of sessions to compensate for possible early shifting of the otters. Enrichment activities were provided for the otters at the beginning of sessions and sporadically during the session. When otters received enrichment after the beginning of the session, the time was noted. Enrichment periods were considered to be the 10 scans (5 min) following the start of the enrichment. Natural items, such as ice blocks with frozen food items inside, pumpkins, gelatin, fish, fruit, and other food items, were hidden and dispersed throughout the exhibit before otters were rotated into the exhibit.

For the purposes of data collection, the exhibit was divided into 10 sections based on easily discernible areas (Figures 1 and 2). The water areas were divided by three distinct pool areas each at a different height of the exhibit. The long pool, also the highest pool, provides the largest underwater viewing area making up 12% of the exhibit. This pool flows into the smallest pool (2% of the exhibit) and then to the end of the stream in the deep pool (8% of the exhibit) which allows for overhead viewing of the

Table 1. *G*-scores for total exhibit and post hoc tests for each area

Area	Observed	Expected	G value	P value
Total			6522.41	<0.001
1–3 (pools)	5479	2660.10	3230.86	<0.001
4 (ground level)	768	1828.82	895.81	<0.001
5 (sandy area)	2606	1537.87	725.47	<0.001
6–7 (stairs)	905	872.84	1.26	0.261
8 (upper level)	719	1288.48	329.82	<0.001
9 (door)	610	457.20	48.21	<0.001
10 (NV)	925	3366.69	2757.04	<0.001

Table 2. *G*-scores for pools and post hoc tests for each individual pool. Total pools, α=0.05. Post hoc tests on individual pools used a Bonferroni correction, α=0.02.

Pool	Observed	Expected	*G*-value	P value
Total			106.13	<0.001
1	3163	2996.33	20.43	<0.001
2	308	513.66	104.11	<0.001
3	2008	1969.02	1.17	0.279

otters. Together, the pools account for 22% of the exhibit. Areas 4 (15%) and 5 (13%) make up the ground areas of the exhibit, which include a cave and sandbox. Areas 6 (4%) and 7 (3%) include stairs and logs leading to upper areas of the exhibit which are defined by Area 8, the visible area of the upper terrace (11%) and Area 9, the small area in front of the keeper door (4%). Any sections of the exhibit not visible to visitors make up Area 10 (28%). Since it was not possible to make accurate identifications of the individual otters during the scanning procedure, for each scan, the number of otters in the different exhibit areas were counted.

Statistical analysis

To assess exhibit space use, a modified spread of participation index (SPI) was calculated (Dickens 1955; Plowman 2003). A minimum SPI score of 0 indicates maximum exhibit use with all areas being used equally and a maximum score of 1 indicating use of only one area. The modified formula was used to weight unequal area sizes by percentage of total exhibit space.

To assess if the otters were using the exhibit significantly differently to chance, a *G*-test goodness-of-fit test was conducted, α=0.05. Post hoc *G*-tests were conducted to ascertain if individual areas were being used at greater or less than chance levels. In this analysis, the pool areas (1–3) were grouped as a single area, as were the vertical climbing areas. Further analysis was conducted on the separate pool areas.

Results

Data were collected for a total of 43 sessions. These were divided into 25 beginning sessions and 18 end sessions. Use of each area in percentages for the total time and divided into beginning and end sessions is shown in Figure 3.

Visibility

Based on the NV (Not Visible) category, the percentage of scans in which 0, 1, 2 or 3 otters were visible was calculated. Three otters were visible in 85% of the scans, two otters were visible in 9% of the scans, one otter was visible in 4% of the scans, and no otters were visible in 2% of the scans. At least one otter was visible 98% of the time.

SPI

Modified SPI scores (Plowman 2003) were calculated for the space use of the entire exhibit, the 45 min at the beginning and end of sessions. Areas were weighted based on percentage of exhibit area taken up by each area. For the total exhibit, SPI=0.378; beginning of, SPI=0.431; and end of sessions, SPI=0.356. SPI scores were also calculated for times when enrichment was presented and the following 5 min and also the total data minus those enrichment periods: enrichment, SPI=0.436; enrichment omitted, SPI=0.381.

G-tests

G-test goodness-of-fit tests were conducted (McDonald 2014) to compare the actual space use against space use if otters were using the exhibit equally based on the percentage of exhibit area

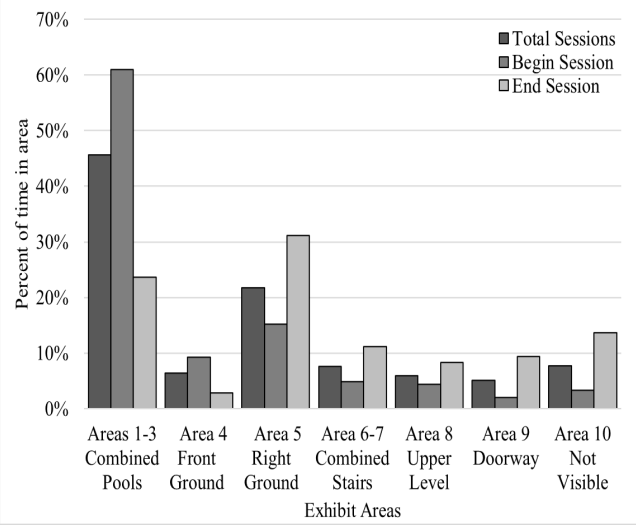

Figure 3. Use of each area in percentages for the total time and divided into beginning and end sessions.

taken up by each observed area (see Table 1). Use of the three pools separately was also compared (see Table 2).

Discussion

According to the SPI scores, it was found that otters tended to use all areas of the exhibit rather than confining themselves to one or a few areas. SPI scores in the beginning sessions were greater than in the end sessions. Enrichment given primarily in the pools and lower land areas at the beginning of sessions may account for this difference. This difference was corroborated by the larger SPI score for the times when there was enrichment as opposed to when there was not. As noted, the otters in the exhibit were rotated every two hours in groups of three. One reason for these rotations is to keep the otters interested in the exhibit. To increase this interest, food enrichment was scattered around the exhibit prior to the otters' entrance primarily in the pools and lower land areas. This schedule may also account for the difference in space use.

Further analysis using *G*-tests confirms that the otters used the exhibit significantly differently from chance. They used the pools and Areas 5 and 9 at greater levels than would be expected. The pools are attractive because otters are semi-aquatic animals (AZA Small Carnivore TAG 2009). Also, food enrichment is provided in the pools. Area 5 contains sand pits in which the otters lie and sleep. Area 9 surrounds two doors, one from which the otters enter and exit and the other which is used by the keepers. The otters tend to stay by these doors in anticipation of exiting, seeing keepers with food, and, possibly, because they can hear the keepers through the doors. Areas 6 and 7 are both steps between the upper and lower areas. These areas were not used more than would be expected by chance. Areas 4, 8 and 10 were used less than would be expected. Area 4 is the land area behind Pool 1 and may be used primarily as a diving area for the pool. Area 8 is the visible lip of the upper area and they would not be visible for most of that area except the lip. Area 10 is all areas of the exhibit in which the otters are not visible, including the upper area behind Area 8, and two indented cave sections off Areas 5 and 7. Interestingly, even though these areas make up 28% of the exhibit, the otters spent much less time not visible than visible. It was found that 98% of the time at least one otter was visible and 85% of the time all three otters were visible. It is important that exhibits be designed with areas in which the animals can stay out of the public eye (Seidensticker and Doherty 1996; AZA Small Carnivore TAG 2009). Due to the naturalistic variety of this exhibit and the enrichment protocol, the otters were much more visible to the public without sacrificing refuge areas. Greater visibility of animals in a naturalistic exhibit can increase visitor attention and longer stays at an exhibit (Davey 2006; Kuhar et al. 2010; Margulis et al. 2003).

Ideally, this study would have included the identification of each otter's space use. Unfortunately, due to the scan sampling procedure and considering the speed and similarity of the animals, counting individuals in the different areas was not possible. Future research may attempt to mark animals for easy identification or use technology-based methods, such as RFID tags and scanners.

In order to keep the otters active and interested throughout the two-hour sessions, it may be necessary to increase enrichment towards the end of sessions. Since these data were collected, the Tennessee Aquarium has instituted this type of enrichment protocol.

Maple and Finlay (1987) argued for POEs to determine the effects of animal exhibits on animal welfare and visitor perceptions of the animals. These evaluations have helped ensure the welfare of a range of species including pandas, primates and red river hogs (Dayrell et al. 2003; Maple and Perdue 2013). Studies such as this may help increase understanding and lead to improvements regarding the effects of exhibits on animals, and can guide enrichment plans. This research can help guide future exhibit design to provide an enriching experience both for animals and visitors. The present research shows that the Tennessee Aquarium's River Otter Falls exhibit is largely successful in both instances and can be a model for otter enclosures in other zoos and aquariums.

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