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Space Use as an Indicator of Enclosure Appropriateness in African Wild Dogs (Lycaon pictus)

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A clear understanding of space use is required to more fully understand biological requirements of nonhuman animals in zoos, aid the design of exhibits, and maximize the animals’ welfare. This study used electivity indexes to assess space use of two packs of African wild dogs (Lycaon pictus) and the appropriateness of two naturalistic, outdoor enclosures at the San Diego Zoo and Bronx Zoo. The results identified enclosure features that were both underutilized and overutilized. They suggest that replacing underutilized areas with features similar to areas that were overutilized may provide more preferred opportunities for the animals. Assessing space use of animals in human care may serve as an indicator of enclosure appropriateness and could have welfare implications. By looking at the possible reasons for area preferences, animal managers can get an idea of where improvements could be made. Designing future exhibits accordingly thus can provide possible welfare benefits for the animals concerned.

Keywords: African wild dog, zoo, enclosure, exhibit design

African wild dogs (Lycaon pictus) are medium-sized (17–32 kg), wide-ranging, social carnivores (Creel & Creel, 2002). They live in a variety of habitats but tend to be more abundant in habitats with dirt substrate dotted with small- to medium-sized shrubs and trees and permanent
water sources (Estes, 1991). The average wild dog pack size is 11 individuals and is usually made up of a dominant pair, their siblings, and offspring (Creel & Creel, 2002). Wild dogs are listed as endangered with a decreasing population trend on the International Union for Conservation of Nature Red List of Threatened Species; therefore, they need to be globally managed in both the wild and in zoos to facilitate their recovery. Because of the complex social structure and wide-ranging behavior (Clubb & Mason, 2007) of wild dogs, managers of zoological facilities face a welfare challenge in ensuring a suitable exhibit for these nonhuman animals.

Measuring the use of space is a common method for determining positive and negative aspects of environments for the nonhuman animals who inhabit them (Ross & Lukas, 2006). Therefore, a clear understanding of space use may be required to more fully understand biological requirements of animals in zoos, to aid in the design of exhibits, and to maximize the animals’ welfare (Estevez & Christman, 2006). Broom (1991) defined welfare as “the state of an individual in relation to its environment” and “its state as regards to its attempts to cope with that environment” (p. 4168). Although there are many different definitions of animal welfare, this definition suggests that the environment can have a strong effect on an individual animal’s well being.

Historically, the welfare of animals in human care often has been examined in relation to the amount of space provided. However, there has been a shift in standards, and exhibits should not only be assessed by the quantity, but also the quality of the space being provided (Estevez & Christman, 2006; Traylor-Holzer & Fritz, 1985). By providing appropriately sized and structured enclosures, animal managers can now display exhibits that feature a wide range of animal species (Kreger & Hutchins, 2010; Little & Sommer, 2002; Mallapur, Qureshi, & Chellam, 2002; Wielebnowski, Fletchall, Carlstead, Busso, & Brown, 2002).

For example, Mallapur et al. (2002) found that creating visual barriers and adding structural elements to the exhibit design were important factors in leopard (Panthera pardus) welfare. Other important aspects of exhibit design may be access to shelter from the elements, a place to hide (Gusset, 2005; Mallapur et al., 2002; Ross & Lukas, 2006; Ross, Schapiro, Hau, & Lukas, 2009), and space that allows for the development and maintenance of natural behaviors (Fraser, Weary, Pajor, & Milligan, 1997). A good understanding of an animal’s use of space permits the design of zoological environments that match the animals’ biological requirements and maximize their welfare (Estevez & Christman, 2006; Kreger & Hutchins, 2010; Spedding, 1993). Electivity indexes are a tool that can be used to access the use of exhibits by animals to determine underutilized and overutilized areas (Lechowicz, 1982; Ross & Lukas, 2006; Ross et al., 2009).

The purpose of this study was to examine the space use of two packs of wild dogs in two separate, outside, naturalistic enclosures, using electivity indexes. A “natural” exhibit, in these cases, refers to the limited use of concrete substrate and the use of trees, logs, grasses, mulch, sand, and water elements. Although replicating a wild environment sounds appealing, the reality of being able to achieve this in a zoo setting is slight. Ultimately, the goal is to ensure that we are providing an adequate environment and proper care for the animals within zoological institutions (Claxton, 2011). The study is not meant to be a comparison between institutions, but it provides two examples of how space use, and more specifically electivity indexes, may serve as an indicator of enclosure appropriateness in wild dogs and eventually be applied to other institutions and species.
### MATERIALS AND METHODS

In this study, space use was assessed using an electivity index $E^*$ (Lechowicz, 1982). While similar indexes were originally used in a study on grazing preference in zooplankton (Vanderploeg & Scavia, 1979), we know of only two studies—one on chimpanzees (*Pan troglodytes*) and gorillas (*Gorilla gorilla*; Ross et al., 2009) and another on geckos (*Phelsuma guentheri*; Wheler & Fa, 1995)—that applied an electivity index primarily to the analysis of enclosure utilization. This type of index thus provides a novel way of measuring spatial preferences that may be important for animal welfare (Ross & Lukas, 2006; Ross et al., 2009).

Where this type of assessment does not directly measure the welfare state, animal managers may use this information in conjunction with other welfare indicators (e.g., stress hormones, positive/negative behavioral indicators of welfare, etc.) to determine how changes in enclosure design affect welfare and can assist in designing future exhibits (Broom, 1986, 1991; Grandin, 2012). Because there is a finite amount of space available in a zoological environment, both overutilized ($1 > E^* > 0$) and underutilized ($-1 < E^* < 0$) areas could have negative welfare consequences.

### Subjects

Two packs of wild dogs were observed at two separate facilities (Table 1). The first pack consisted of one adult male and two adult females held at the San Diego Zoo (SDZ). The second pack consisted of a dominant pair, their five yearlings (three males and two females), four other adult males, and four other adult females held at the Bronx Zoo in New York (BZ). Only five of the animals at BZ were in this study due to practical constraints. Animals were used if the researchers felt they were behaviorally representative of the entire pack: one from a group of four males from previous litters, two females from another splinter group, one female from the newest litter, and the dominant female.

### Exhibits and Animal Care

The outdoor enclosures at both facilities had similar substrates with real and fabricated trees, flat areas of grass and dirt, and shelter from the sun. There were sunny and shady spots in all enclosure areas. The SDZ exhibit (Figure 1) was 1,260 m$^2$ and built into a tiered hillside with...
FIGURE 1  African wild dog exhibit at San Diego Zoo: (a) schematic design (for description of enclosure areas, see Table 2); and (b) photo taken from moving walkway directly below the termite mound looking toward holding area (color figure available online).
TABLE 2
Enclosure Areas at San Diego Zoo

<table>
<thead>
<tr>
<th>Area</th>
<th>Description</th>
<th>Size (m²)</th>
<th>% of Exhibit</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Whole south side of exhibit, including patio feeder: all cement/dirt down to bottom wall</td>
<td>151.8</td>
<td>12.1</td>
</tr>
<tr>
<td>A2</td>
<td>Top tier from rock/cement to waterfall/pool: dirt and grass</td>
<td>190.6</td>
<td>15.2</td>
</tr>
<tr>
<td>A3</td>
<td>Second tier, same line down as A2: dirt and grass patches</td>
<td>130.4</td>
<td>10.4</td>
</tr>
<tr>
<td>A4</td>
<td>Third tier down: more dirt than grass</td>
<td>151.8</td>
<td>12.1</td>
</tr>
<tr>
<td>A5</td>
<td>Bottom tier, same lines as A2, A3, and A4: more grass than dirt</td>
<td>104.1</td>
<td>8.5</td>
</tr>
<tr>
<td>A6</td>
<td>Below waterfall, behind termite mound to back wall: 1.5 m² × 1 m pool, dirt, and tall grass</td>
<td>195.7</td>
<td>15.6</td>
</tr>
<tr>
<td>A7</td>
<td>Termite mound to bottom wall: dirt and tall grass</td>
<td>146.8</td>
<td>11.7</td>
</tr>
<tr>
<td>A8</td>
<td>Whole north side of exhibit from downed logs to wall: quite sloped with tall grass</td>
<td>183.1</td>
<td>14.6</td>
</tr>
</tbody>
</table>

1.2-m walls separating each tier. This exhibit had a 4-m² shelter with cement flooring (adjacent to the holding area), a 1.5-m² × 1-m pool, and a fabricated hollowed-out termite mound to be used as a den. The only way to view this area was from two moving walkways and the platform that connects them. This exhibit was separated into areas (Table 2) to facilitate the determination of space use. This was done by using the natural layout of the land (the tiering) and a downed log that separated three areas. The animals were only taken off the exhibit during servicing, repairs, or veterinary procedures.

The BZ exhibit (Figure 2) is 650 m² and a wide, open space that gently slopes with large trees. It was directly off the main visitor path that connected three main viewing areas—one of which had a large glass window. This exhibit had the added features of a roughly 20-m² shallow pool, sand pit, mulched area, permanent muddy patch, and abundant flat, grassy space with 10 areas in total (Table 3). In this case, substrate and elevation change were used for the area delineations. The animals were on exhibit from 1000 hr to 1700 hr and were housed in an off-exhibit holding area overnight.

TABLE 3
Enclosure Areas at Bronx Zoo

<table>
<thead>
<tr>
<th>Area</th>
<th>Code</th>
<th>Description</th>
<th>Size (m²)</th>
<th>% of Exhibit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female Hill</td>
<td>FH</td>
<td>Small, flat hill near holding covered with dirt and grass</td>
<td>96.4</td>
<td>14.8</td>
</tr>
<tr>
<td>Mud Flats</td>
<td>MF</td>
<td>Long, narrow, wet, low-lying area at front of exhibit</td>
<td>25.6</td>
<td>3.9</td>
</tr>
<tr>
<td>Center Right</td>
<td>CR</td>
<td>Fairly flat with grass and one large tree, dead fall</td>
<td>58.2</td>
<td>8.9</td>
</tr>
<tr>
<td>Pool</td>
<td>PL</td>
<td>Wide and shallow</td>
<td>18.5</td>
<td>2.8</td>
</tr>
<tr>
<td>Center Front</td>
<td>CF</td>
<td>Flat with grass and dirt, large branches, and dead fall</td>
<td>38.6</td>
<td>5.9</td>
</tr>
<tr>
<td>Sand Pit</td>
<td>SP</td>
<td>Small sandy area with large fabricated dead fall (den)</td>
<td>28.6</td>
<td>4.4</td>
</tr>
<tr>
<td>Mulch Pile</td>
<td>MP</td>
<td>Long, narrow, dry mulch at front of exhibit</td>
<td>29.3</td>
<td>4.5</td>
</tr>
<tr>
<td>Grass Flats</td>
<td>GF</td>
<td>Large, flat to slightly sloping grass-only area</td>
<td>202.2</td>
<td>31.1</td>
</tr>
<tr>
<td>Lower Ridge</td>
<td>LR</td>
<td>Fairly steep area with grass and many tall trees</td>
<td>99.5</td>
<td>15.3</td>
</tr>
<tr>
<td>Upper Ridge</td>
<td>UR</td>
<td>Narrow, flat area with grass, dirt, and trees along fence line</td>
<td>53.4</td>
<td>8.2</td>
</tr>
</tbody>
</table>
FIGURE 2  African wild dog exhibit at Bronx Zoo: (a) schematic design (for description of enclosure areas, see Table 3); and (b) photo taken straight out from between small viewing area and glass-front viewing area. AWD = African wild dog (color figure available online).
Data Collection

Data were collected by the same observer (S.C.H.) between 0900 hr and 1830 hr for the SDZ wild dogs, and between 1000 hr and 1700 hr for the BZ wild dogs, provided there was daylight, in the outdoor exhibits at the two facilities. The SDZ wild dogs were observed from May to December 2007 for a total of 137 hr (Table 1). Thirty hours of observations were completed in the summer of 2006 at SDZ to work out time intervals, enclosure area delineations, and animal identifications.

The BZ wild dogs were observed during a 2-week period in April/May 2008 for a total of 44 hr (Table 1). In both cases, data were collected at 2-min intervals from public viewing areas. At the time of alarm (standard stopwatch), instantaneous scan sampling from left to right was used to ensure randomness (Crockett & Ha, 2010; Martin & Bateson, 1993), and the location of each animal in the study was noted. These enclosure areas represented all areas to which the animals had access during observations.

Time of day was also noted and placed into one of four categories: morning (0900–1130 hr for SDZ and 1000–1130 hr for BZ), noon (1131–1400 hr), evening (1401–1600 hr), and dusk (1601–1830 hr for SDZ and 1601–1700 hr for BZ). Due to logistical constraints, such as the hours of zoo operation and lack of daylight needed to make observations, differences in time spent in each category were accounted for in the analysis of spatial preferences (see Results). Animals were observed continuously, when visible. On occasion when they were not seen, less than 1% for the SDZ pack and 1% to 13% for the BZ pack, the time was taken off the total observation time. At BZ, the wild dogs would occasionally retreat to a section by the holding/keeper area (Figure 2), just out of view from the public.

Data Analysis

Electivity indexes measure the actual utilization of an array of environmental elements in relation to their availability in the environment (Lechowicz, 1982) and have been mainly used in ecological contexts (Ross et al., 2009; Vanderploeg & Scavia, 1979). Areas that are used in greater proportion than their availability in the environment are considered preferred or overutilized. Conversely, areas that are proportionately underutilized are considered to be avoided. Nonpreferential use of areas that result in a neutral (zero) electivity index represent equal use of space in relation to availability.

The electivity index of Vanderploeg and Scavia (1979) was applied for the analysis of space use in the present study:

\[
E^* = \frac{W_i - (1/n)}{W_i + (1/n)}
\]

Where \(W_i = (r_i/p_i)/\sum r_i/p_i\), \(r_i\) = observed use (proportion of time) of area \(i\); \(p_i\) = expected use (proportion of time) of area \(i\); and \(n\) = number of types of areas.

By comparing \(E^*\) for specific enclosure areas (Tables 2 and 3) during four specified times of day (see Data Collection), we determined the degree to which the different areas of the enclosure structurally fulfilled the wild dogs’ spatial preferences. Expected space use was calculated as the proportion occupied in any given enclosure area. The different configuration of the two enclosures did not allow for pooling of the data between facilities. The data did
not fulfill the assumptions required for parametric statistics; therefore, nonparametric Mann–Whitney U Tests were used (Siegel, 1957). Due to the small sample size \((n = 3)\), statistics were not used on data pertaining to the SDZ pack.

**RESULTS**

San Diego Zoo

Figure 3a shows the observed and expected space use for the pack at SDZ. Because the areas were approximately the same size and we assumed there would be no spatial preferences, we expected that the wild dogs would spend roughly the same amount of time (8.5%–15.6%) in each of the enclosure areas. However, the data suggest that there was a preference for certain areas, most notably A1 and A3 (23.7% and 26.1%, respectively). Other areas—A2, A6, and A8—appeared to be largely avoided (5.1%, 2.2%, and 1.1%, respectively). The animals’ selection of enclosure areas seemed largely independent of the time of day (Figure 4a).

Bronx Zoo

Figure 3b shows the observed and expected space use for the pack at BZ. Here, the wild dogs showed preference for the female hill \((n = 5, U = 0.0, p = .005)\), which is a central high point of the exhibit. The dominant female spent 64.4% of her time in this area. However, on average, the wild dogs underutilized the mud flats \((n = 5, U = 25.0, p = .005)\), pool \((n = 5, U = 25.0, p = .005)\), and lower ridge \((n = 5, U = 25.0, p = .005)\). The other enclosure areas were used at rates that were proportional to their availability \((p \geq .05)\). Figure 4b shows the electivity indexes for the pack at different times of day. These results suggest that time of day did not have a large influence on the animals’ selection of enclosure areas.

**DISCUSSION**

The results of this study suggest that some areas in the wild dogs’ enclosures were overutilized and others were underutilized. At SDZ, the space use suggests that they preferred the side adjacent to the keeper/holding area (A1) and the one right next to it on the same level (A3). They underutilized the two areas farthest from the holding area and closest to the visitors (A6 and A8) throughout the day. The base of the visitor walkway is fairly near (approximately 10 m away) to A1 and the holding area; therefore, it is unlikely that the animals were hiding from public view. Perhaps they simply preferred the close proximity to the keeper area where the food was usually provided. It is not known if the areas farthest from holding (A6 and A8) were underutilized because of the proximity to the visitors or simply because the animals did not care for other characteristics of the area.

At the BZ exhibit, the female hill and grass flats (Table 3) were points in the exhibit easily viewed by the public and were observed as being popular spots for the whole pack at varying times of day. A preferred or overutilized area may be monopolized by a single individual or a small percentage of the group, especially if the area is small, which reduces the availability
FIGURE 3  Observed (mean ± SE) and expected use of enclosure areas at (a) San Diego Zoo and (b) Bronx Zoo (for description of enclosure areas, see Tables 2 and 3).
of a positive feature to other individuals (Lechowicz, 1982). With a limited space, a neutral area ($E^* = 0$) may be important for supplying additional favored features. The BZ exhibit is large; however, several enclosure areas were underutilized, with spatial preferences varying only slightly during the course of the day. Areas may be underutilized due to the fact that they are present in greater proportions than is necessary for the animals, or because they are
undesirable in some respect (Broom, 1986, 1991; Duncan, 1987; Grandin, 2012; Lechowicz, 1982).

As wild dogs are a far-ranging species, we consider them to need as large a space as possible, even if it is not used all the time. We would therefore not advise that underutilized areas be withdrawn from their use. Although BZ provided a variety of substrates and features, the pack underutilized two of them (mud and mulch). Perhaps this could be explained by a natural preference that wild dogs have for dry, sandy areas interspersed with trees (Estes, 1991) over forested ones that support mulch (wet leaf litter) and mud. Pack dynamics may also be an explanation for underutilization of an area (i.e., dominance of an area by the alpha pair).

The underutilized areas may be undesirable for reasons such as their grade is too steep or their grass is too tall. In these cases, modifications to underutilized areas would accommodate for desirable characteristics, such as additional high points or shorter grass, and could result in a more evenly used space (Baldwin, 1985). By looking at the possible reasons for area preferences, animal managers can get an idea of where improvements could be made. While some managers may exhibit animals where they are easily viewable by the public, judging purely on aesthetics (Melfi, McCormick, & Gibbs, 2004), this may actually contradict what is best for the animals (Chamove, Hosey, & Schaetzel, 1988). Although relatively few studies have been done on the effect of zoo visitors on carnivores, findings suggest that there may be adverse effects on other species (e.g., primates; see Chamove et al., 1988; Hosey, 2000; Hosey & Druck, 1987).

According to Broom (1991), the appearance of fear, pain, frustration, or overstimulation in animals could be indicators of poor welfare. An adequate space could improve welfare by allowing for more options of use, like in the case of two snow leopards (*Panthera uncia*) who showed frustration over not having control over their foraging environment and therefore were offered food in a number of different areas (Burgener, Gusset, & Schmid, 2008). Leopards housed in smaller exhibits with fewer hiding places, visual barriers, and shorter visitor distances tended to spend more time showing stereotypic pacing and thus would benefit from a more appropriately designed, naturalistic, complex exhibit (Mallapur et al., 2002). Future research should examine how, by using the space in underutilized areas to replicate features of overutilized areas, there could be a beneficial change in the animals’ welfare.

**CONCLUSION**

In conclusion, our study of spatial preferences of wild dogs at two zoological facilities identified enclosure features that were overutilized as well as enclosure areas that were avoided (underutilized) and thus could be partially replaced by different or additional options for space use. Assessing the space use of animals in human care may serve as an indicator of enclosure appropriateness. Providing appropriate enclosures for wide-ranging species, such as wild dogs, to explore their natural behavior (e.g., multiple den sites and space to run) is expected to result in improved overall welfare (Clubb & Mason, 2007). The design of an exhibit itself can improve an animal’s quality of life (Ben-Ari, 2001); therefore, designing future exhibits accordingly can provide possible welfare benefits by improving the physical and psychological well-being of any animal concerned.
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