The impact of the open and closed exhibit designs on captive Bennett's wallaby (*Macropus rufogriseus*) behaviour and visitor experience

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ABSTRACT

The impact of the open and closed exhibit designs on captive Bennett's wallaby (*Macropus rufogriseus*) behaviour and visitor experience

Julie Beaudin-Judd

Zoo research on exhibit designs has made notable progress in the past decades. A great challenge zoo exhibit designers are faced with today is finding exhibit designs that optimize both animal welfare and visitor experience. In the present research, the impacts of exhibit design on Bennett's wallaby behaviour and on visitor experience were studied. Data collected from two open design exhibits, allowing physical interaction between visitors and animals, were compared to observations from two closed exhibit designs, where no physical human-animal interaction was possible. Wallaby behavioural data were collected using the focal sampling method for activity budget observations and the scan sampling method for spatial distribution observations. Moreover, visitor experience data were collected using survey-type questionnaires that were randomly distributed to zoo visitors. Our study revealed that, when compared to more traditional closed designs, open exhibit designs increase overall visitor experience and positively benefit visitor perception. Additionally, our results showed that feeding and interactive behaviours were significantly higher in closed exhibit designs but functional use of space was similar in both exhibit design types. Although some behaviours did significantly differ between habitat designs, they did not provide sufficient evidence for major exhibit design impacts on wallaby welfare. However, possible visitor effects on Bennett's wallaby activity budgets and space use was discussed. Our results suggest that the open exhibit design is a good option for optimizing visitor experience without affecting animal welfare, but we recommend continued research to more fully understand the impacts of different exhibit designs on the behaviour and welfare of captive Bennett's wallabies.

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CONTRIBUTION OF AUTHORS

Robert Weladji and Patrick Paré developed the original idea behind this thesis and guided me with experimental design and set up procedures for both chapters. I was responsible for choosing and connecting with all contacts from the three participating zoos in this study. I was also responsible for all data collection and analysis, with the guidance of Robert Weladji for the statistical analyses of my research. As lead author of this thesis, I wrote both chapters of this manuscript with edits performed on final versions by Robert Weladji.

TABLE OF CONTENTS

List of figures…………………………………………………………………viii

List of Tables……………………………………………………………………xii

General Introduction……………………………………………………………1

Chapter 1: ………………………………………………………………………4

The activity budget and spatial distribution of captive Bennett's wallabies in open versus closed exhibit designs ……………………………………………………………4

Abstract………………………………………………………………………5

Introduction……………………………………………………………………6

Methods………………………………………………………………………10

Study species and Study sites………………………………………………10

Activity budget data collection……………………………………………11

Spatial distribution data collection…………………………………………12

Statistical analysis……………………………………………………………12

Activity budget analysis……………………………………………………12

Spatial distribution analysis………………………………………………13

Results…………………………………………………………………………15

Activity budget………………………………………………………………15

Enclosure design comparison………………………………………………15

Additional information from the Zoo de Granby open exhibit design……16

Spatial distribution……………………………………………………………16

Zoo de Granby (open exhibit design) ………………………………………16

Riverview park and zoo (closed exhibit design)……………………………17

Roger Williams Park Zoo (closed exhibit design) …………………………17

Roger Williams Park Zoo (open exhibit design) ……………………………17

Discussion………………………………………………………………………18

Activity Budgets………………………………………………………………18

Spatial Distribution……………………………………………………………22

Concluding remarks……………………………………………………………25

Tables and Figures………………………………………………………………27

Chapter 2: ……………………………………………………………………………..39

The impact of open versus closed exhibit designs on visitor experience and perception……………………………………………………………………………39

Abstract……………………………………………………………………………40

Introduction…………………………………………………………………………41

Methods……………………………………………………………………………43

Study site and subjects……………………………………………………………43

Surveys……………………………………………………………………………43

Statistical Analysis…………………………………………………………………43

Results……………………………………………………………………………44

Discussion…………………………………………………………………………45

Tables and Figures …………………………………………………………………48

General conclusions and recommendations……………………………………52

References……………………………………………………………………53

Appendix A……………………………………………………………………59

Appendix B……………………………………………………………………60

Appendix C……………………………………………………………………61

Appendix D……………………………………………………………………62

Appendix E……………………………………………………………………63

LIST OF FIGURES

Figure 1.1: A top-view image of Zoo de Granby's wallaby exhibit. The enclosure was divided into sections represented by respective letters. The visitor path (Area K) runs throughout the entire exhibit and is delimited by ropes. Area A represents the treed, shaded emu (*Dromaius novaehollandiae*) exhibit. The emus are separated from the visitor paths with a meshed fence made of rope under which the wallabies can easily make their ways through. Areas B and C are located right by the lorikeet holding barn and the exhibit's exit. They provide shade and partial visual barrier from visitors. Areas D, E and F are spans of grass that provide less shade and not much visual barrier from visitors. Two black swans (*Cygnus atratus*) are housed in area G, a pond area delimited with low wooden fences. Unlike areas A-F and J representing temperate regions of Australia with an abundance of vegetation and greenery, areas H and I represent the more arid regions, with red, sandy and rocky terrain. Lastly, area J is the section where the salmon-crested cockatoo (*Cacatua moluccensis*) is located.

Figure 1.2: A top-view image of Riverview park and zoo. Area A represents a retreat barn with two small entries for the wallabies to go inside for complete shade and visual barrier from visitors. Areas B and C are sandy areas located at the farthest points from visitor paths. Area E is an elevated, bushy area, that provides partial visual barrier to individuals in both areas E and C. Area D represents an elevated hill, where individuals can be easily viewed by visitors. Areas F and G are the sections located adjacent to the visitor paths. They are large spans of grassy terrain with a few trees providing areas of shade.

Figure 1.3: Real top-view image of a section of Roger Williams park zoo. Two different populations of Bennett's wallabies are housed in their respective exhibits at this zoological park (represented by red circles in the image). The main entrances to the respective sections of the two exhibits share a common central pathway area and are located at only a few minutes walking distance from each other.

Figure 1.4: A top-view image of the open exhibit located at Roger Williams park zoo. Area A is the visitor entrance. Area B is a low-elevated, trench-like area, providing visual shelter from visitors. Because area A is a bridge, wallabies can hide under it for additional shade and shelter.

Area J represents a sandy visitor path, delimited by low ropes. Areas D, I, H and G are all adjacent to the visitor paths and provide little to no visual barrier from visitors. Area G is adjacent to an emu exhibit, delimited by a metal-mesh fence. Area C is an elevated central area with many tall rocks, bushes and trees for shade and visual barrier. Area E is a grassy span of terrain located farther away from visitor paths. Area F is also adjacent to visitor paths and has a wooden roof structure providing extra shade.

Figure 1.5: A top-view image of the closed exhibit located at Roger Williams park zoo. Area A represents elevated concrete terracing that provides shade and visual barrier from visitors. Area B is an area leading to the interior holding barn, completely out of sight from visitors. Area C is located far from visitor paths, with shade provided by trees and a wooden roof structure. Areas D, E and F are located adjacent to the elevated visitor paths, allowing visitors to spot wallabies easily due to the higher altitude. Areas H and G are large spans of sandy terrain, with lack of visual barrier and shade.

Figure 1.6: Mean activity budgets of all four populations observed during the 2015 field season. All focal samples (N=890) were out of 40 total observation counts. Error bars were extended to ±2 standard errors from the mean values.

Figure 1.7: Mean activity budgets of individuals located in open exhibit designs versus closed exhibit designs. Data collected in 2015 from Zoo de Granby's and Roger Williams's (open) populations were pooled together for the open exhibit design activity budget. Similarly, data from Riverview and Roger William (closed) were pooled together to generate the closed exhibit design activity budget. All focal samples (N=890) were out of 40 total observation counts. Error bars were extended to ±2 standard errors from the mean values.

Figure 1.8: Mean activity budgets of the Zoo de Granby population in the absence of visitors (May 2016) and in the presence of high visitor densities (July-August 2016). All focal samples (N=342) were out of 40 total observation counts. Error bars were extended to ±2 standard errors from the mean values.

Figure 1.9: Mean activity budgets of Zoo de Granby's population during high visitor zoo seasons in 2015 versus 2016. All focal samples (N=541) were out of 40 total observation counts. Error bars were extended to ±2 standard errors from the mean values.

Figure 1.10: Map of the Zoo de Granby exhibit representing the proportions of time allotted to the different exhibit areas in June-July 2015.

Figure 1.11: Map of the Zoo de Granby exhibit representing the proportions of time allotted to the different exhibit areas in June-July 2016.

Figure 1.12: Map of the Zoo de Granby exhibit representing the proportions of time allotted to the different exhibit areas in May 2016.

Figure 1.13: Map of the Riverview park and zoo exhibit representing the proportions of time allotted to the different exhibit areas in 2015

Figure 1.14: Map of the Roger Williams park zoo closed exhibit representing the proportions of time allotted to the different exhibit areas in 2015.

Figure 1.15: Map of the Roger Williams park zoo open exhibit representing the proportions of time allotted to the different exhibit areas in 2015.

Figure 2.1: Proportion of answers (%) given by visitors when asked: "How much did you enjoy the exhibit?" at Zoo de Granby (open exhibit design) versus Riverview park and zoo (closed exhibit design) in 2015 (N=63).

Figure 2.2: Proportion of answers (%) given by visitors when asked: "How did you appreciate the animal visibility at this exhibit?" at Zoo de Granby (open exhibit design) versus Riverview park and zoo (closed exhibit design) in 2015 (N=63).

Figure 2.3: Proportion of answers (%) given by visitors when asked: “How much do you think wallabies benefit from being in a walkthrough exhibit instead of a fenced exhibit?” at Zoo de Granby (open exhibit design) versus Riverview park and zoo (closed exhibit design) in 2015 (N=63).

Figure 2.4: Proportion of answers (%) given by visitors when asked: “How much do you think visitors benefit from being in a walkthrough exhibit instead of a fenced exhibit?” at Zoo de Granby (open exhibit design) versus Riverview park and zoo (closed exhibit design) in 2015 (N=63).

Figure 2.5: Proportion of answers (%) given by visitors when asked: “Are animals stressed by the greater proximity of visitors in open exhibits?” at Zoo de Granby (open exhibit design) versus Riverview park and zoo (closed exhibit design) in 2015 (N=63).

Figure 2.6: Proportion of answers (%) given by visitors when asked: “Do animals positively benefit from the possible interaction with visitors in open exhibits?” at Zoo de Granby (open exhibit design) versus Riverview park and zoo (closed exhibit design) in 2015 (N=63).

Figure 3.1: Images of the four study sites showing their design concept. Zoo de Granby and Roger William Park Zoo’s first exhibit are open designs with roped visitor paths travelling through the wallabies’ enclosure (allowing close proximity and physical interaction with visitors). Riverview Park and Zoo and Roger William Park Zoo’s second exhibit are closed, with fenced delimitations from visitors (less proximity and no physical interaction possible with visitors).

Figure 3.2: Initial survey-type questionnaire distributed to Zoo de Granby visitors in June-July 2015.

Figure 3.3: Initial survey-type questionnaire distributed to Riverview park and zoo visitors in July 2015.

LIST OF TABLES

Table 1.1: Table 2: Ethogram of behaviours recorded during focal sampling periods, inspired by Russel 1968 and Stirrat 2000.

Table 1.2: Proportions (%) of time allotted to the different exhibit areas at Zoo de Granby during three different time periods

Table 1.3: Proportions (%) of time allotted to the different exhibit areas at Riverview Park and Zoo and Roger Williams park and zoo in 2015

Table 2.1: Survey questions retained for analysis and percentage answered at Zoo de Granby (N=32) versus Riverview park and zoo (N=31).

Table 3.1: Characteristics of *Macropus rufogriseus* individuals per population

Table 3.2: Focal sampling check sheets used for behavioural data collection

Table 3.3: Model selection based on AIC to explain the variability of six Bennett's wallaby behaviours (vigilance, resting, locomotion, feeding, grooming and social interaction). Models with ΔAIC ≤2 or the two models with the lowest AIC are presented. Selected models are bolded and interactions are represented by « * » in the table.

GENERAL INTRODUCTION

The reasons why humans keep animals in captivity have been ethically challenged through time (Barber & Mellen, 2013). Whether it is for life companionship, farming, laboratory research, entertainment or conservation purposes, the issue of animal welfare in captivity is a complex and multifaceted one (Barber & Mellen, 2013). Since the welfare of animals is described and interpreted by humans, its measurement as a continuum from poor to good can be subjective and is therefore constantly being refined (Barber & Mellen, 2013; Maple & Purdue, 2013). Approaches to assess and interpret animal welfare have been mainly focused on the physiology and psychological health of the animals and the ability for them to behave as they would according to their natural history (Fraser, 2009). These are commonly measured with the use of welfare indicators such as hormone levels, life expectancy, presence of disease or injury, reproductive success and behaviour (Broom, 1991). A described definition of animal welfare is "the degree to which an animal can cope with challenges in its environment as determined by a combination of measures of health and of psychological well- being" (Barber & Mellen, 2013). The environmental challenges mentioned in the previous definition can vary depending on the captive setting the animals are in. Environmental stressors such as loud noises, unnatural substrates and artificial lighting, and confinement-related stressors like forced human proximity, imposed social group formations and restricted movement and space are all examples of challenges captive zoo animals are confronted with daily (Morgan & Tromborg, 2007). However, many of these stressors can be alleviated with suitable exhibit design and can thus, contribute to increasing zoo animal welfare (Kelling & Gaalema, 2011).

Knowledge on zoo animal welfare has come a long way since ancient Egyptian times, a time known as having the earliest records of animal keeping (Bostock, 1993). It was only a few decades ago that zoological parks began shifting their philosophies to give more importance to the welfare of their animals (Wineman & Choi, 1991; Maple & Purdue, 2013) Before then, the purpose of zoos revolved solely around human entertainment and use (Maple & Purdue, 2013). Animal exhibits were organised in walkways of small barred cages with cement or tile flooring, mainly meant to increase the visibility of the animals and facilitate cage cleaning (Wineman & Choi, 1991; Kelling & Gaalema, 2011). However, these exhibit designs did not always meet the animals' basic health and psychological needs (Kelling & Gaalema, 2011). Abnormal and stress-related behaviours such as coprophagy and stereotypy were frequently observed (Kelling & Gaalema, 2011). As greater amounts of research were being published in the field, concerns for zoo animal welfare increased (Kelling & Gaalema, 2011). In the attempt to benefit animal welfare, zoo exhibit designs consequently shifted away from their original appearances to include improved size, complexity and natural characteristics (Kelling & Gaalema, 2011). Moreover, current zoological park philosophies and missions now put greater emphasis on visitor education, animal conservation and research (Wineman & Choi, 1991). Therefore, present-day research has also been focused on how exhibit designs impact visitor education and willingness to contribute to conservation issues. Jon Coe (1985) analysed zoo exhibit design from a visitor psychology perspective. He claimed that displaying high exhibit aesthetical value and psychologically healthy animals directly affects visitor learning ability, long-term memory and empathy towards animals in need of conservation (Coe, 1985). Therefore, both modern zoo goals and animal welfare greatly benefit from species-specific and more complex exhibit designs that many zoos display today. Additionally, zoos directly depend on visitor experience to generate their revenue (Mitchell & Hosey, 2005). Hence, trying to find designs that optimize zoo goals, animal welfare and visitor experience altogether is now one of the many challenges today's zoo designers are faced with (Sha Chih Mun, et al., 2013).

With the intention of further contributing to visitor experience, empathy and sense of connection to the animals, many zoo exhibits nowadays adhere to the concept of "landscape immersion" (Coe, 1985). The landscape immersion's goal is to provide visitors with the opportunity to feel as if they are part of the displayed animal's natural landscape. Even if visitors are standing outside the enclosure, realistic visual decorations, audio effects and ecologically-related neighbouring exhibits surrounding the viewed enclosure all contribute to the resulting visitor experience (Coe, 1985). Moreover, the concept of landscape immersion is sometimes pushed further to allow zoo visitors to experience an even closer proximity to the animals (Price, et al., 1994; Morgan & Tromborg, 2007). One particular exhibit design that provides visitors with closer proximity by allowing potential physical contact with animals is the open exhibit design, sometimes referred to as the walkthrough or free-range exhibit. These zoo exhibits typically have designated visitor pathways travelling throughout the enclosure, with limited visual and minimal physical barriers delimiting the pathways from the rest of the exhibit. Therefore, animals housed in these habitats have the opportunity to approach visitor pathways if they choose to or they can also favour the alternative of staying farther away from the visitors. In Australia, kangaroos and related marsupial species are commonly housed in open exhibits (Sherwen, et al., 2015). It is on these open designs in particular, that we will focus this study.

Zoo research has played an important role in the rapid evolution of modern zoo philosophies and exhibit designing. Although scientists have come a long way in the past decades, there still remain fairly large gaps to be filled in this area of research (Melfi, 2009). For instance, most of the research has been directed towards the larger, more charismatic species such as primates and large felids (Melfi, 2009). Also, few captive species have the necessary temperament that makes physical interaction with humans possible. Thus, research studying petting-zoo concepts and similar designs more specifically, have mainly been focused on farm animals (Anderson, et al., 2002). Consequently, although many species of marsupials are presently being exhibited in open design concepts; little research has been done to investigate the impact of this design on the welfare of these species (Sherwen, et al., 2015). Similarly, studies investigating the impact of immersive designs on visitor experience are rare (Price, et al., 1994). No studies involving marsupial species have taken the initiative to compare data from open concepts to traditional, fenced exhibit designs, such as will be done in this study.

The aim of this thesis was to contribute to the ongoing zoo research advancement by providing scientists and zoo officials with a better understanding of the impacts of open exhibit designs on Bennett's wallaby welfare and visitor experience. The conclusions of this study may also be applicable to other species exhibited in similar enclosure designs and can therefore contribute to future exhibit development across different zoological institutions. This thesis includes two chapters and will study the impact of open exhibit designs by comparing data from open exhibit designs to the more traditional, closed designs. As previously mentioned, zoo designers have to consider both animal welfare and visitor experience when designing successful zoo exhibits. Chapter one will therefore evaluate Bennett's wallaby behaviour as a means of welfare assessment in both exhibit design concepts. Chapter two will discuss how these designs affect visitor experience.

CHAPTER 1:

The activity budget and spatial distribution of captive Bennett's wallabies in open versus closed exhibit designs

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ABSTRACT

Although many studies investigating the impacts of zoo exhibit designs on captive animals exist, none have been performed on how they influence the behaviour and welfare of captive Bennett's wallabies (*Macropus rufogriseus*). In the present research, the impact of the open exhibit design on the activity budget and spatial distribution of captive Bennett's wallabies was studied. Data collected from two open design exhibits, allowing physical interaction between visitors and animals, were compared to observations from two closed exhibit designs, where no physical human-animal interaction was possible. Wallaby behavioural data were collected in the form of 10-minute focal samples and spatial distribution was recorded on exhibit maps at regular time intervals. Generalized linear mixed models and generalized linear models were used for statistical analysis. Results revealed a significant increase in feeding and interactive behaviours in closed exhibits when compared to open designs. However, no other behaviours of interest such as resting, locomotion and vigilance varied with design. Functional use of space was similar between both designs, though habituation periods may be relevant to consider in future studies. Although some support for visitor effects were present, our study provided no evidence for strong impacts of exhibit design on Bennett's wallaby welfare. More research is needed to fully understand how zoo environments affect Bennett's wallaby behaviour and welfare.

INTRODUCTION

Studying animal welfare requires the use of indicators that can be measured and experimentally tested (Dawkins, 1990; Broom, 1991). Common welfare indicators include hormone levels, disease or injury presence, life expectancy, reproductive success and behaviour (Broom, 1991). Using behaviour, a non-intrusive and non-invasive method of welfare assessment, can be useful to provide information on both animal physical and mental health (Dawkins, 2004). For instance, behaviours are considered abnormal when they differ in pattern or frequency from what would typically be observed in unrestricted contexts or when they are displayed with no particular purpose (Broom, 1991). For example, abnormal behaviours can be detected through stereotypies, atypical frequencies of aggressive, social, vigilant or active behaviours, and changes in spatial distribution (Dawkins, 2004; Mason & Veasey, 2010; Koene, 2013). Therefore, the presence of abnormal behaviours within a captive population is a well-accepted sign of decreased welfare (Broom, 1991). On the other hand, the presence of normal behavioural proportions as well as additional behaviours such as play and social interaction usually indicate higher levels of welfare (Mitchell & Hosey, 2005). Behavioural observations of zoo animal activity budgets and spatial distribution can therefore be valuable welfare indices in zoo research.

The way in which animals budget their daily activities greatly varies from species to species (Hill & Broom, 2009). Animals can use the different ranges of behaviours in their repertoire to cope or react to their surroundings and needs (Hill & Broom, 2009; Koene, 2013). More specifically, an animal's behavioural response is directly related to how it values a given stimulus, experience or resource (Mason & Veasey, 2010). For example, in terms of an animal's activity budget, inappropriate levels of locomotion could be interpreted as chronic avoidance or flight from the presence of a stimulus (Mitchell & Hosey, 2005). On the contrary, an increase in approaching, greeting or interacting behaviours may indicate a positive behavioural response to a stimulus or resource (Mitchell & Hosey, 2005; Mason & Veasey, 2010). In the wild, animals have developed and evolved their activity budgets with unrestricted possibilities to meet their needs and optimize their fitness (Hill & Broom, 2009). In zoos, observed activity budgets are the result of limited opportunities for decision making: social group formation and visitor presence are imposed, space is restricted and food is provided at designated times daily (Morgan & Tromborg, 2007). Thus, one way to interpret observed zoo activity budgets is by comparing them to the activity budget the species is known to display in the wild in order to assess impacts of captivity. Moreover, currently studied activity budgets can be compared to previously recorded ones from different zoo populations with different exhibit designs and environmental stimuli, especially if these populations' welfare conditions were considered good (Hill & Broom, 2009).

Studying zoo animal behaviour by observing how they use available exhibit space is also relevant to understanding the impacts of different enclosure designs (Estevez & Christman, 2006; Ross, et al., 2009). Studies have shown how some captive animals tend to use space selectively according to their preferred areas (Stoinski, et al., 2001; Blowers, et al., 2012; Hunter, et al., 2014). These areas are often highly functional (e.g. presence of food, retreat options) and often include features found in the species' natural environment (e.g. ponds, trees, rocks) (Hebert & Bard, 2000; Stoinski, et al., 2001; Blowers, et al., 2012). Therefore, observing captive animal spatial distribution can provide insight on species-specific biological requirements and preferences that can be applied to future exhibit development (Estevez & Christman, 2006). Features in areas known to be overutilized may be added to underutilized areas to maximize overall space use, enclosure appropriateness and animal welfare (Hunter, et al., 2014). Since zoo exhibit development is a costly process, it is important to observe which areas in the enclosure are preferred by the animals to ensure the available space is used to its full potential in terms of both animal and visitor requirements (Stoinski, et al., 2001).

The effect of visitor presence on captive animals has stirred much interest in zoo research (Davey, 2007). Unlike other captive settings like farms or laboratories, zoos welcome large crowds of visitors on a daily basis. Studies have demonstrated that crowd density, activity level, noise level and proximity are all examples of visitor characteristics that affect zoo animal behaviour (Davey, 2007). In some cases, an increase in visitor density and intensity result in an increase in pacing behaviour, aggressive events and time spent hiding (Sellinger & Ha, 2005). Indeed, a study observing 15 different species of primates concluded that an increase in visitor presence resulted in stressful excitement for the animals because they were significantly more active and aggressive but less affiliative during visitor presence (Chamove, et al., 1988). On the other hand, some researchers have argued that visitor presence may instead represent a beneficial source of enrichment for zoo animals (Claxton, 2011). Some animals will put large amounts of energy expenditure into increasing the probability of visitor interaction, which suggests that human-animal relationships are reinforcing to that particular individual or species (Nimon & Dalziel, 1992). In other studies, primates voluntarily initiated interactions with visitors at many occasions, especially when food was involved (Cook & Hosey, 1995; Hosey, 2000; Choo, et al., 2011). Nevertheless, conclusions about both negative and positive visitor effects on zoo animals are still ambivalent since most of these studies were made using a limited range of study species (Davey, 2007). Moreover, most of them were carried out in traditional, closed exhibits. The physical touch possible in open designs has been found to alter animal behaviour in past studies (Anderson, et al., 2002; Farrand, et al., 2014). In some cases, species exhibited undesirable behaviours that increased with visitor density in open designs (Anderson, et al., 2002). In other species, an increase in visitor density increased interaction sequence rates with the public. (Farrand, et al., 2014). Therefore, whether the human-animal interaction possible in open exhibits is aversive or enriching is still being studied (Anderson, et al., 2002; Farrand, et al., 2014; Sherwen, et al., 2015).

The aim of this study was to compare the behaviour of captive Bennett's wallabies (*Macropus rufogriseus)* in open versus closed exhibits using observed activity budgets and spatial distributions. Multi-enclosure studies are very useful for validating repeatability of results across similar captive contexts as well as for understanding the impacts of different environmental conditions on captive animals (Shepherdson, et al., 2004; Sherwen, et al., 2014). Open and closed exhibit designs differ in the degree to which animal-visitor interaction can occur. In closed exhibits, only auditory and visual interaction can occur due to the physical barriers dividing visitors from animals. Open exhibits additionally provide animals with the opportunity to approach visitor paths for physical contact if they chose to. Varying the level of possible human-animal interaction in zoo exhibits has been found to alter behaviour in the past (Anderson, et al., 2002). We therefore hypothesized that activity budgets from open and closed exhibit populations would differ. More specifically, we predicted that the augmented environmental stimulation present in the open exhibit design would result in an increase in locomotion and decrease in resting behaviours (Sherwen, et al., 2015). Moreover, because they are a well-known prey species in the wild, marsupial species frequently engage in vigilant behaviour in order to constantly monitor their surroundings (Shepherd, 1981; Stirrat, 2000; Pentland, 2014). Marsupials are therefore very likely to be attentive to environmental disturbances, such as close visitor proximity (Shepherd, 1981; Morgan & Tromborg, 2007; Sherwen, et al., 2015). In open designs, both the lack of visual barriers delimiting visitors from animals and the potential for physical touch contribute to increase the level of environmental stimulation that the wallabies experience (Morgan & Tromborg, 2007). We would therefore also expect to observe more vigilance behaviour in the open designs. Furthermore, as seen in previous studies, we expected to observe preferential use of space in both open and closed exhibits (Stoinski, et al., 2001; Blowers, et al., 2012; Hunter, et al., 2014). However, we expected to observe a difference in the functional uses of these preferred areas due to the concurrently predicted variation in locomotion and general activity in open versus closed exhibit designs. More specifically, we expected to observe a more evenly distributed use of space in open exhibit designs.

METHODS

Study species and study sites

The study species used for the present study was the Bennett's Wallaby, an Australian-native marsupial commonly housed in both closed and open zoo exhibit designs. Due to its temperament allowing it to be housed in different exhibit concepts, this species was ideal for the aims of our study.

All data were collected observing adult individuals located at three different zoos; Zoo de Granby, QC, Canada, Riverview Park and Zoo, ON, Canada and Roger Williams Park Zoo, RI, USA. Four different study populations were included in this study: two housed in open-type exhibits and two from closed designs.

The Bennett's wallabies from the Zoo de Granby were housed in a 5425m^2 open walkthrough exhibit, designed with a visitor path delimited by roped barriers traveling throughout the entirety of the habitat (Figure 1.1). The wallabies could therefore interact with visitors by crossing these ropes and paths with ease. The exhibit was specifically designed for the wallabies and was first opened in May 2014 after its construction. A total of 14 adult wallabies and 3 young wallabies (joeys) were housed in this habitat in 2015. In 2016, due to the death of 2 adult individuals and 2 recent births, there were 15 adults and 2 young joeys. All observed individuals were born at the Zoo de Granby with the exception of one individual, who was transferred from a Brookfield Zoo, Chicago shortly after its birth.

The wallaby exhibit at Riverview Park and Zoo was a closed design with a chain-link fence delimiting the visitor paths (Figure 1.2). This 727m^2 exhibit's last enlargement renovation occurred in 1998. Therefore, most individuals were born at Riverview Park and Zoo. The few individuals that were born at different zoos were transferred to Riverview shortly after birth in 2014 or earlier. During our 2015 field season, the zoo possessed a group of 6 adult wallabies and 2 joeys.

Two different populations of captive-born Bennett's wallabies were housed in two separate exhibits at Roger Williams Park Zoo. The main entrances to the respective sections of the two exhibits shared a common central pathway area and were located at a few minutes walking distance from each other (Figure 1.3). The first population was enclosed in a 2044m^2

open walkthrough exhibit (Figure 1.4), similar to the one at Zoo de Granby, with a roped visitor path travelling through the exhibit. In this exhibit also, the Bennett's wallabies could freely cross the visitor paths if they chose to. A total of 5 adult individuals were enclosed in this habitat since the spring of 2014. The second Bennett's wallaby habitat at Roger Williams Park Zoo was a 280m^2 closed design (Figure 1.5). At this exhibit, visitors were separated from the wallabies by a fence and a raised platform. This population of 6 adult Bennett's wallabies and 1 joey had been in this exhibit since the summer of 2014.

Activity budget data collection

Data were collected during the high visitor season at all three zoos from June-August 2015 and during both the visitor absence and high visitor seasons at Zoo de Granby from May-July 2016. Observations began between 9:00-10:00 and usually ended between 15:00-16:00, with the exception of an approximate 30-minute break during lunch hours. All behavioural observations were performed in the same manner for all four different wallaby populations. The focal sampling technique (Martin & Bateson, 2007) was used, whereby single individuals were observed for a period of ten minutes and the dominant behavior, based on an established ethogram (Table 1.1), was recorded every 15 seconds. A tonality was produced at every 15-second mark with a programmed interval timer cellphone application to ensure the recorded behaviours were recorded at precise intervals. The established ethogram inspired by Stirrat (2000) and Russel (1968), consisted of seven behaviours: resting, vigilance, feeding, locomotion, grooming, social interaction and agonistic interaction. Both the interaction behaviours were further subdivided to specify whether the interaction occurred with an individual of the same species, a visitor or another exhibit occupant of a different species. Also, the order in which the animals were observed varied according to a predetermined schedule, enabling all individuals to be studied at different times of day over the total data collection period. In order to provide further insight on the behaviours observed during the focal sessions, additional information such as the date, time, individual ID, visitor density estimation and weather conditions were also recorded. Visitor density was estimated by the observer after every focal sample by counting the number of visitors within eye sight of the observed wallaby. Weather conditions were recorded by observation before every focal sampling session and more precise details on precipitation rates, wind speeds and ambient temperatures were later collected using the historical data available on the Canadian Government archive website (Environment Canada, 2016) and Utah University's weather archives (University of Utah, 2016).

Spatial distribution data collection

Space use data were collected for all 4 populations using the scan-sampling technique (Martin & Bateson, 2007). The position of all visible individuals was recorded every 20 minutes during a day of behavioural focal-sampling. The maps of the exhibits were all divided into quadrants, representing mainly the different functional uses and terrain types of the space available within the quadrants. All quadrants were lettered for identification. The time and date was also recorded for every scan sample.

Statistical Analysis

Activity budget Analysis

All statistical analysis was conducted using R 3.3.1 statistical software (R Core Team, 2016). Two sets of Generalized linear mixed models (GLMM) with a negative binomial family distribution and the log link function were performed for the behavioural analysis. The different individuals observed (Individual ID) in this study were set as a random factor in all models, in order to appropriately control for the repeated measurements of single individuals. Moreover, the logarithm of the total number of observations recorded within each 10-minute period was fixed as an offset in the models to control for the variation in the total possible number of observations within each focal trial.

For the first set of models, frequency of occurrence (counts) was used as response variables. These models assessed how the response variable varied with different predictors: behaviour (resting, vigilance, locomotion, grooming, feeding and social), the interaction between behaviour and exhibit design, the interaction between behaviour and visitor presence/absence, the interaction between behaviour and field season and the interaction between behaviour and population. Different subsets of data had to be used to generate the respective models from the first set, which is why not all predictors could be evaluated within one single model.

The second set of GLMM models assessed how other explanatory variables affected the frequency of each of the six behaviours separately, using different models for each behaviour (resting, vigilance, locomotion, grooming, feeding and social). The response variables of these models were therefore the counts of the different behaviours and the predictors were the temperature, estimated visitor density, interaction between visitor density and exhibit design, time of day and individual sex and age. Since many predictors were included in the second set of models, the most parsimonious models (lowest AIC) were selected using AIC-based backward selection (Burnham & Anderson, 2002). Several competing models were assessed but only those within 2 AIC from the most parsimonious or the nearest model were presented (see Appendix C).

After all models of the behavioural analysis were generated, pairwise comparisons of the involved categorical variables and their interaction were performed using the Tukey-Kramer correction. A 5% level of significance was used for the analysis of behaviour in the present study.

Spatial distribution analysis

Generalized linear models (GLM) were generated for the space use analysis of this study. Different subsets of data were used for the various models, which is why not all variables could be included within one single model. All models were set with quasibinomial distributions and with the proportion of individuals observed per area as the response variable. The proportion of individuals was calculated by dividing the number of individuals observed in a given area by the total amount of individuals observed in all areas of the exhibit during the same scan sample.

The first model aimed to assess the variation in proportions of individuals observed per area and the variation in proportion of individuals per area due to time of day. Time of day was set as a 2-level factor of either morning period or afternoon period. This model was run for all four different populations of this study in order to better understand how they use the space available in their respective exhibits. The second and third models respectively measured the variation in proportion of individuals observed per area due to visitor presence and due to field season at Zoo de Granby. To appropriately evaluate the effect of time of day, visitor presence/absence and field season on space use, we studied the interaction terms of these variables with the different exhibit areas generated by our models.

For all models analysing the spatial distributions of this study, pairwise comparison of the variables and interaction terms included in each model was generated with a Tukey-Kramer correction. A 5% level of significance was used for all tests included in the analysis of spatial distribution in this study.

RESULTS

Activity budget

The rate of occurrence of all six behaviours of the ethogram varied significantly within all four populations (Figure 1.6): Zoo de Granby ($\chi^2_{(5)}$= 1132.90, p< 0.001), Riverview ($\chi^2_{(5)}$= 836.50, p< 0.001), Roger Williams (open)($\chi^2_{(5)}$= 597.99, p< 0.001) and Roger Williams (closed) ($\chi^2_{(5)}$= 536.48, p< 0.001). For all four populations, resting and vigilant behaviours were the most frequent, followed by feeding and grooming behaviours, and finally with locomotion and interaction behaviours. Models including various explanatory variables were also generated forevery behaviour on our ethogram. Vigilance behaviour decreased with the time of day (estimate±SE = -0.38±0.11; $\chi^2_{(1)}$= 13.33, p< 0.001). Resting behaviour was affected by the sex ($\chi^2_{(1)}$= 8.07, p=0.0045) of individuals and increased with age (0.03±0.01; $\chi^2_{(1)}$= 5.73, p=0.017), time of day (0.28±0.02; $\chi^2_{(1)}$= 326.11, p< 0.001), temperature (0.03±0.002; $\chi^2_{(1)}$= 155.56, p< 0.001) and visitor density (0.05±0.002; $\chi^2_{(1)}$= 66.50, p< 0.001). Locomotion decreased with time of day (-0.47±0.16; $\chi^2_{(1)}$= 8.29, p=0.004) and increased with visitor density (0.005±0.02; $\chi^2_{(1)}$= 4.33, p=0.04). Feeding behaviour decreased with time of day (-0.62±0.17; $\chi^2_{(1)}$= 12.80, p< 0.001) and temperature (-0.09±0.03; $\chi^2_{(1)}$= 12.29, p<0.001). Grooming behaviour also decreased with time of day (-0.34±0.12; $\chi^2_{(1)}$= 7.44, p=0.006), age (-0.08±0.04; $\chi^2_{(1)}$= 4.92, p=0.027) and temperature (-0.04±0.02; $\chi^2_{(1)}$= 5.14, p=0.023). Social interaction behaviours were not affected by any of the previously mentioned additional variables.

Enclosure design comparison

Results demonstrated a significant interaction between the observed behaviour occurrences and the enclosure design when comparing activity budgets from open versus closed exhibit populations ($\chi^2_{(5)}$= 58.70, p<0.001). Individuals in closed exhibit designs spent more time engaging in feeding behaviour (estimate ± SE= 0.40±0.12, p=0.04) and social interaction behaviours (1.61±0.23, p<0.001). However, no significant differences between exhibit designs were found for other behaviours of interest such as vigilance, locomotion and resting (Figure 1.7). The same trends for feeding and social interaction behaviours were found when comparing activity budgets from the two populations (one open, one closed) located at Roger Williams park zoo only ($\chi^2_{(5)}$= 54.04, p<0.001). Moreover, since enclosure design and visitor density did not significantly interact, previously mentioned behaviours that significantly varied with visitor density did not do so due to enclosure design. Also, no significant differences were observed when comparing the activity budgets of the two closed exhibit designs together (Figure 1.6). Similar results were observed for the comparison of both open designs with the exception of higher feeding (0.82±0.17, p<0.001) and lower grooming behaviours (-0.70±0.17, p=0.013) observed at Zoo de Granby (Figure 1.6).

Additional information from the Zoo de Granby open exhibit design

The pattern of activity at Zoo de Granby did not vary with visitor presence/absence (P>0.05; Figure 1.8), but did vary with year of study i.e. 2015 vs. 2016 ($\chi^2_{(5)}$=24.08, p< 0.001). This was mainly due to feeding behaviour occurrence being reduced in 2016 as compared to 2015 (-0.59±0.15, p=0.007, Figure 1.9)

Spatial distribution

Zoo de Granby (open exhibit design)

During the high visitor season of 2015, the wallabies housed at the Zoo de Granby did not evenly distribute across their exhibit space and instead, showed preference for particular exhibit areas ($\chi^2_{(10)}$=3264.70, p<0.001). More specifically, individuals spent most of their time in the emu exhibit (area A) and secondly in the adjacent treed areas (areas B, C and D). The sandy areas of the exhibit (Areas G, H, I), the cockatoo area (Area J) as well as the visitor paths (Area K) were used the least (Table 1.2, Figure 1.10). Moreover, the period of day did not significantly alter the use of the different exhibit areas (P>0.05). There was a significant difference in the spatial distribution of the wallabies observed during the high visitor season of 2015 as compared to 2016 ($\chi^2_{(10)}$=384.5, p<0.001). In comparison to 2015, the wallabies spent less time in area A and more time in areas E and F in 2016. Similarly to 2015, the wallabies spent the highest amount of time in the emu exhibit (Area A). However, they now secondly preferred the grassy section of the exhibit's central area (Area E) and the nearby treed area (Area B). Their least preferred areas did not change from 2015, with the sandy portions (Areas G, H, I), the cockatoo area (Area J) and the visitor paths (Area K) being their least favorite (Table 1.2, Figure 1.11). In 2016, there was a significant difference in the preferred exhibit areas between high visitor presence and visitor absence ($\chi^2_{(10)}$=160.12, p<0.001). More specifically, wallabies spent significantly less time in area A and more time in areas C and J in the absence of visitors then they did later in the season with high visitor presence (Table 1.2, Figure 1.12).

Riverview Park and Zoo (closed exhibit design)

Selective use of the different areas of the enclosure was also observed at Riverview park and zoo ($\chi^2_{(6)}$=265.63, $p<0.001$). The area farthest from visitor sight (area C) was the most used and the adjacent areas (areas B and E) were used second highest. The area used the least was the one located immediately next to the visitor paths (areas F and G) and the central, elevated area (Area D) (Table 1.3, Figure 1.13). There was an interaction between the time spent at the different exhibit areas and the time of day ($\chi^2_{(6)}$=47.998, $p<0.001$) for area C. The wallabies increased their time spent in this area even further in the afternoon when compared to the morning (0.74±0.19, p=0.007)

Roger Williams Park Zoo (closed exhibit design)

The wallabies housed in the closed exhibit at Roger Williams park zoo also had area preferences in their exhibits ($\chi^2_{(7)}$=254.49, $p<0.001$). Most of their time was spent in the elevated portion of their habitat that provides shade and visual barrier (Area A). They secondly preferred an area at the farthest end of the exhibit (Area C) and an area adjacent to visitor paths (Area D). The areas used the least were the other two areas located adjacent to the visitor paths (Area E and F) (Table 1.3, Figure 1.14). The time of day did not significantly impact the proportions of time spent in the different exhibit areas.

Roger Williams Park Zoo (open exhibit design)

Selective use of habitat was also observed in the open design located at Roger Williams zoo ($\chi^2_{(9)}$=527.33, $p< 0.001$). The wallabies there spent the highest amounts of time in retreat areas (Areas A, B and C). These areas all provided retreat from visitors either visually or by a difference in terrain elevation. The areas they used the least were visitor paths (Area J) and areas D and I adjacent to the visitor exit (Table 1.3, Figure 1.15). Moreover, the time of day did not significantly impact the proportions of time spent in the different exhibit areas.

DISCUSSION

Multi-enclosure studies are needed to ensure a proper and thorough understanding of how different variables affect zoo animal behaviour and welfare (Shepherdson, et al., 2004). Our multi-enclosure study observed the variation in the activity budgets and spatial distributions of captive Bennett's wallabies with the aim to better understand how captive environments and exhibit designing affects their behaviour and thus, their welfare.

Activity budget

Our hypothesis that the activity budgets observed in open versus closed exhibit designs would significantly differ was accepted. Feeding and social interaction behaviours were significantly higher in closed exhibit designs. However, unlike predicted, the behaviour proportions that were most expected to vary with exhibit design remained similar in both open and closed enclosures. Indeed, resting, vigilance, locomotive and grooming behaviours did not significantly vary with exhibit design. The same results occurred when comparing data strictly from the two populations housed at Roger Williams park zoo (open versus closed). When comparing the two closed designs to each other, no significant differences were found in the proportions of behaviours in their activity budget. When comparing the two open designs of this study, feeding and grooming behaviours significantly varied with population. All behaviours of interest (resting, vigilance and locomotion) did not vary significantly when cross-comparing all four populations.

The total social events account for 0.82% of the activity budget for closed design populations and 0.16% of the activity budget for individuals housed in open designs. Although the difference between the enclosure types was statistically significant, both proportions account for less than 1%, a very low portion of the wallabies' daily activity pattern. This supports the activity budget tendencies of wild macropod species (Stirrat, 2004). In the wild, groups of Bennett's wallabies are relatively unstable and small in size (Johnson, 1985). In fact, they are one of the least social marsupial species, with a tendency to remain solitary, even when part of larger group densities (Johnson, 1985). However, when they do engage in social events, it is usually associated with courtship-related, play fight, aggressive or passive tactile communication behaviours (Russell, 1984; Johnson, 1985). In the present study, the few observed fights were playful in nature (i.e. that did not involve access to a limited resource), which has been said to be beneficial for motor-skill training (Watson & Croft, 1993). Other observed interactive events were most often in the form of passive touch. Therefore, the higher interactive events observed in closed designs were considered positive. Nonetheless, the lower levels of social interaction events observed in open enclosures would not be considered alarming for their welfare since they are typically low in the wild (Stirrat, 2004) as well.

Although relatively solitary, Bennett's wallabies often aggregate into small groups, a tendency interpreted as part of their antipredator strategy (Coulson, 1999). Indeed, wallabies have evolved to adapt their behaviour according to levels of perceived threat risk in their environment (Coulson, 1999; Blumstein, et al., 1999). Another example of their behavioural adaption is through their feeding times (Coulson, 1999; Blumstein, et al., 1999). In our study, feeding behaviour occurrence was significantly higher in closed exhibit designs when compared to open designs. The lack of visual barriers delimiting the animals from the visitors in the open exhibits in this study may have augmented the potential visitor threat risk perceived by the wallabies, causing more frequent interruptions in feeding bouts during visiting hours. Indeed, wild animals frequently have to evaluate the costs and benefits of time spent feeding versus time spent monitoring their environment for potential threats (While & McArthur, 2005; Barnier, et al., 2016). However, vigilance proportions did not significantly vary with exhibit design in our study. Observing lower feeding times coupled with significantly increased vigilance behaviour could have indicated that wallabies in open designs perceived visitors as a greater risk than wallabies housed in closed designs. Since only feeding behaviours varied, our results do not provide sufficient evidence of welfare impacts due to exhibit design specifically. Since our results also demonstrated that feeding behaviour was significantly higher at Granby than at Roger Williams (the two open designs), it is possible that the latter substantially contributed to decreasing the observed frequencies in feeding behaviour in open exhibit designs. Nevertheless, the feeding behaviour proportions observed in all four populations still remained within the ranges of what is typically observed during daylight in the wild (Stirrat, 2004). Moreover, wallaby feeding behaviour decreased with temperature and time of day in our study. This is also supported by what is typically observed in the wild, where marsupials reduce their food intake during the afternoon's higher ambient temperatures to rest (Stirrat, 2004).

Contrary to our predictions, resting behaviours were not significantly lower in open exhibit designs when compared to closed designs. Resting was the most predominant behaviour with an overall mean across all populations of 59.70%. Similar results were found in studies observing closely-related macropods in the wild, where resting behaviour was the most dominant state during the day (Watson & Dawson, 1993; Stirrat, 2004). Evidence has shown that this increase in inactivity in the wild is linked to heat avoidance and thermoregulation strategies as a result of warmer day-time temperatures (Stirrat, 2004). Our results demonstrating an increase in resting behaviour as a function of time of day and ambient temperatures therefore support these previous findings and provide a reasonable explanation for the observed trend. However, resting behaviour also significantly increased with increasing visitor density. This is contrary to Sherwen et al's (2015) recent study that observed a decrease in captive kangaroo resting behaviour with increasing visitor numbers. Whether the decrease in resting state was caused by fear or by curiosity of humans was not conclusive in their study (Sherwen, et al., 2015). Our interpretation of the increase in inactivity with visitor number is also ambivalent. High resting behaviours as a result of visitors may be explained by captive animals choosing to passively endure stressful stimuli rather than respond to them with flight or aggression (McBride, 1984). This has previously occurred in captive settings when animal reactions to stressful stimuli had no effect on its outcome (McBride, 1984). Since forced human proximity can be a significant source of stress for captive animals (Morgan & Tromborg, 2007), observed individuals may have responded to the increase in visitor density with an increase in visitor avoidance, demonstrated with increased resting behaviour. However, resting behaviour proportions observed in this study were very similar to the trends observed in the wild, an environment with no visitors and captivity-related stressors (Stirrat, 2004). Moreover, visitor presence versus absence did not impact the amount of time the wallabies housed at Zoo de Granby spent resting. Also, the perception of closer visitor proximity caused by lack of visual barriers and the possible human-animal physical touch available in open designs did not alter their resting states when compared to closed designs. Therefore, although visitor density may have caused a visitor effect on the resting behaviour of wallabies in this study, more research is needed to clarify whether this effect has direct impacts on the welfare of wallabies in captivity, regardless of design type.

We also predicted to observe an increase in vigilance behaviours in open exhibit designs due to previous studies that have shown that marsupial vigilance varies due to visitor effects such as visitor number, noise and proximity (Larsen, et al., 2014; Sherwen, et al., 2015). Because we predicted these visitor effects to be perceived as amplified in open designs, we expected vigilance to be increased in these designs. Our predictions were not supported since vigilance proportions did not vary with exhibit design. However, vigilance was the second highest behaviour observed for all four studied populations. In the wild, marsupials are preyed on by various predators (Stirrat, 2000; Pentland, 2014). Through time, marsupials have evolved vigilance behaviours to survey their environment from potential threats (Stirrat, 2004; Pentland, 2014). Vigilance has been found to be at its lowest during the day and highest during the evening and at night, where wild marsupials are most prone to predation (Stirrat, 2004). On the contrary, another marsupial species increased its vigilance during the day due to the presence of aerial predators, most active above well-lit scenery (Pentland, 2014). These studies therefore suggest that wild wallabies modify their time spent vigilant with predator pressures. The present study was ongoing during day-time hours and wallabies spent a mean 20.56% of their time in vigilant states. However, no visitor-related variables such as visitor presence versus absence or visitor number influenced this proportion. Therefore, our prediction that visitors cause a significant disturbance to the wallabies' environment, much like predators do in the wild, was not supported for the vigilance behaviours observed by individuals in this study. Vigilance was not increased in the open design, which suggests that wallabies did not see the closer human proximity available in open designs as more threatening than the visitor presence in closed designs. Moreover, vigilance behaviour decreased with time of day. This may correspond with the proportional increase in resting behaviours observed in afternoon periods. In summary, we believe the vigilance levels observed in this study more appropriately reflect the idea that vigilance was used as a scanning habit to gather social and environmental information on their surroundings (Favreau, et al., 2015), irrespective of exhibit design or visitor presence and density.

The predicted increase in visitor effects and environmental stimulation in open designs also lead us to predict higher activity levels, and therefore more locomotive behaviours in comparison to closed designs. This prediction was not supported since no difference in locomotion behaviours occurred with different exhibit design. However, other variables affected locomotion. Locomotion decreased with time of day, which also corresponds with the observed increase in resting behaviours during afternoon periods. Locomotion, with a mean of 1.60% of the total activity budget, also increased with increasing visitor density in all four populations.

This therefore allows us to suggest that increasing visitor density, regardless of the design types, does stimulate wallaby activity. In a study observing primate behavioural reactions to visitors, an increase in activity was interpreted as evidence for irritability and stressful excitement caused by visitors (Chamove, et al., 1988). Moreover, visitors closely observing or taking photographs increased locomotive behaviours in a captive orangutan population, which also suggests that visitor behaviour affects locomotion in zoo animals (Choo, et al., 2011). In another study, an increase in activity with visitor presence was interpreted as positively reinforcing for a captive long-billed corella, since the animal behaved in a manner obviously indicating the desire to interact with the human visitors. (Nimon & Dalziel, 1992). In this study, very few anecdotal observations of human-animal physical touch were observed in the open designs. There was no evidence that the wallabies engaged in behaviour increasing their probability to interact with nearby visitors in both open and closed designs. Therefore, the increase in locomotion with visitor density in the present study is more likely to be a response that is stressful in nature. However, resting, a behaviour that is opposite to locomotion, also increased with visitor density. None of the behaviours included in our ethogram were affected by visitor presence versus absence, another main visitor variable we observed at Zoo de Granby. Therefore, the interpretation of the observed visitor effects in this study in terms of welfare still remains unclear.

Spatial distribution

As expected, all four populations had significant exhibit area preferences. However, contrary to expected, the functional uses of the preferred areas did not differ with exhibit design. In all populations in 2015, the areas located farthest from visitors, often providing partial visual barrier and shade were the most frequently selected areas. Retreat areas are often found in zoo exhibits to provide relief from interaction with the public (Anderson, et al., 2002). Offering zoo animals the opportunity to control their exposure to visitors using retreats has been suggested as being beneficial for animal welfare (Morgan & Tromborg, 2007). In both open and closed designs, these retreats are usually located at a considerable distance from the visitor paths and can also be in the form of visual concealment if the exhibit additionally offers a shelter (Morgan & Tromborg, 2007). The retreat options available for the four populations of this study were therefore most likely frequently used with the purpose of visitor relief, acting as a buffer for undesirable behaviours that might have otherwise occurred (Anderson, et al., 2002). Our results therefore suggest that regardless of enclosure design type, providing retreat areas are most likely important to maintain adequate welfare standards for the Bennett's wallaby species.

Our prediction that open designs would offer increased opportunity for stimulation and concurrently, a more even space use across the exhibit, was not supported. No trend provided evidence that wallabies in the open designs wished to increase physical interaction probabilities with visitors by remaining close or on visitor paths. In fact, the areas closest to and most visible from visitor paths were the least used by all four populations, regardless of design type. This therefore suggests that visitor interaction is not particularly reinforcing for Bennett's wallabies. Sherwen et al (2015) further investigated the question by calculating the mean kangaroo distance from visitor paths as a function of visitor density. They demonstrated that kangaroos did not show an increase in visitor avoidance by modifying their mean distances from visitor paths as visitor numbers increased (Sherwen, et al., 2015). It was therefore concluded that the visitor effects present in open exhibit designs did not present significant adverse effects for the welfare of their occupants (Sherwen, et al., 2015). In the present study, a more general approach was executed and time of day was recorded as an alternative to specific visitor numbers. Only area C, the most used section located at the far end of the Riverview's exhibit, was used even further in afternoon periods when compared to mornings. This may be explained by the increase in temperatures or zoo visitor densities with time of day, which would encourage wallabies to seek an adequate resting area. However, in order to more strongly claim that the wallabies at Riverview were displaying visitor avoidance, the resulting spatial use observations would have had to be coupled with an increase in visitor vigilance with increasing visitor densities (Sherwen, et al., 2015), which was not the case in the present study.

At Zoo de Granby, further observations were recorded to assess variations in space use by comparing data from two consecutive high visitor seasons. Our results showed that Granby wallabies' space use varied from June-July 2015 to June-July 2016. In 2016, there was an important increase in use of area E, a centralized, grassy area where visitors can view animals with ease. Also, they spent less time in the emu exhibit (Area A) when compared to the previous year. This may be explained by a lengthy exhibit habituation process where the wallabies slowly discovered their enclosure and developed different preferred areas through time. Past research studying captive gorilla adaptation to new exhibits revealed a very slow onset of exploratory behaviour after exhibit transfer (Ogden, et al., 1990). These observations were interpreted as possible reactions to the unfamiliarity of their new environment (Ogden, et al., 1990). However, even after one year of observations in the new enclosure, some individuals still hadn't explored 40% of the available exhibit space (Ogden, et al., 1990), which is very similar to the results at Zoo de Granby. It is important to point out that at Zoo de Granby, the least used sandy areas represent approximately half of the exhibit. As seen in Ogden et al's (1990) study, this may be due to the exhibit's novelty. However, it also questions whether wallabies need this terrain type to meet their biological needs. Zoo de Granby's current wallaby exhibit was first opened in 2014, only one year before the first data collection season. It is therefore possible that year 2015 was still too soon after the wallabies' entry into their new exhibit to observe conclusive space use trends. However, the emu exhibit still remained the most used and the sandy sections and visitor paths of the exhibit still remained the least used in 2016, two years after its opening. Therefore, despite showing an increase in preference for area E in 2016, the areas with the most and the least interest remained the same. Further observations would need to be performed over a longer period of time to see if Zoo de Granby's exhibit is used to its full potential.

We also compared data from two different visitor conditions (presence or absence) within the same season at Zoo de Granby. There was also a difference in space use with visitor presence. Interestingly, wallabies spent significantly less time in the emu exhibit during visitor absence than they did later that same year during high visitor presence. It is predicted that the emu exhibit's functional use was as a retreat option for Granby's wallabies. Under no conditions would it be possible for visitors to physically touch the wallabies when in the emu exhibit. In Anderson et al's (2002) research studying farm animals in petting zoos, animals displayed higher amounts of undesirable behaviours at high visitor densities. However, the undesirable behaviours were attenuated when an adequate retreat option was added to the enclosure (Anderson, et al., 2002). Therefore, the high visitor presence later the same year could have further motivated wallabies to spend increased amounts of time in a retreat area (Sellinger & Ha, 2005), which would explain the higher proportion of time spent in the emu exhibit during visitor presence. Under visitor absence conditions, the wallabies perhaps did not find the need to spend as much time in this area.

Concluding remarks

In summary, activity budgets observed in closed versus open exhibit populations significantly differed. Although social and feeding behaviours did vary across exhibit design, no other behaviours of interest such as resting, locomotion and vigilance varied with design. Moreover, space use trends were very similar when comparing both enclosure designs. Therefore, these results did not provide evidence for major differences in the impacts of open versus closed exhibit designs on Bennett's wallaby welfare. However, our results did provide support for a possible visitor effect on Bennett's wallaby activity budgets and spatial distributions; a topic we consider worthwhile studying further in future studies.

Unlike animal research conducted in controlled laboratory environments, studying zoo animals with constantly varying environmental stimuli can be very complex. Like in the present study, different exhibits in different zoos have different animal population compositions, varying weather conditions, different animal care staff members, and different visitor populations and densities. Furthermore, some of these stimuli can additionally vary on a day-to-day basis within the same exhibit in the same zoo. This reality makes it difficult for researchers to completely achieve constant conditions ensuring the accuracy of their results, which is why it is important to account for them when interpreting main results. Moreover, the precise history of studied individuals is often unclear. The number of generations since captivity may influence captive animal reactions to their zoo environments. As animals adapt to captive environments, the nature of their responses to novel environmental stimuli will change with following generations (Price, 1984). Unfortunately, finding precise records on the history of the animals in our study was laborious. However, all individuals in this study were confirmed to be zoo-born, which eliminates any added bias that may have been otherwise observed by wild-caught animals. Fortunately, although zoo researchers have many confounding variables to consider, more and more precautions have been taken to reduce the effects of these variables in recent studies. However, there is still room for improvement and future research should attempt to even further increase control of the confounding variables present in zoo settings.

Hopefully, this comparative study will serve as an opening study, allowing scientists and zoo officials to better begin understanding impacts of zoo exhibit design and visitor effects on Bennett's wallaby behaviour and to continue working towards more in depth research questions on this particular species in captivity. Encouraging future zoo biologists to broaden their choice of study species to ones that have been less studied is key to ensuring that enlightened decisions for future exhibit development are made, not only for marsupial species, but for various other captive species as well.

TABLES AND FIGURES

Table 1.1: Ethogram of behaviours recorded during focal sampling periods, inspired by Russel 1968 and Stirrat 2000.

Behaviour	Description
Resting	Absence of movement or activity. Individuals are sitting or lying down. Facial expression and general attitude shows lack of vigilance, alertness or curiosity.
Vigilance	Individual is in an alert state in order to increase awareness of immediate surroundings. Head positions are always upright and can be either motionless (when observing a specific disturbance) or in rapid movement (when observing surroundings). Vigilance, alertness, curiosity or fear can usually be easily discerned on facial expressions.
Locomotion	Traveling from point A to point B by rapidly hopping with two hind limbs or slowly walking using four limbs and tail for increased stability.
Feeding/Foraging	Actively searching for or consuming food (includes chewing).
Grooming	The use of mouthparts, forelimbs or hind limbs for licking or scratching any body part for comfort or hygiene purposes.
Agonistic Interaction	Engaging in aggressive social behaviour with a conspecific, another exhibit occupant or a visitor. Body positions include skipping, grabbing, sparring, hitting or kicking.
Social Interaction	Engaging in non-aggressive social interaction with a conspecific, another exhibit occupant or a visitor. Includes allogrooming, smelling or touching others.

Table 1.2: Proportions (%) of time allotted to the different exhibit areas at Zoo de Granby during three different time periods

Time	A	B	C	D	E	F	G	H	I	J	K
June-July 2015	74.85	11.17	4.93	5.84	2.52	0.50	0	0	0.20	0	0
May 2016	26.92	12.57	22.04	4.14	17.31	5.62	0.30	2.81	3.25	3.40	1.63
June-July 2016	46.47	13.96	6.52	4.97	20.40	4.89	0.08	1.32	1.09	0.23	0.08

Table 1.3: Proportions (%) of time allotted to the different exhibit areas at Riverview Park and Zoo and Roger Williams park and zoo in 2015

	A	B	C	D	E	F	G	H	I	J
Riverview	6.95	22.43	28.65	6.22	21.56	11.72	2.46	N/A	N/A	N/A
Roger Williams (closed exhibit)	34.77	6.09	18.27	11.59	2.75	4.91	10.41	11.20	N/A	N/A
Roger Williams (open exhibit)	15.07	16.42	16.84	7.90	8.11	10.71	8.63	13.83	2.49	0

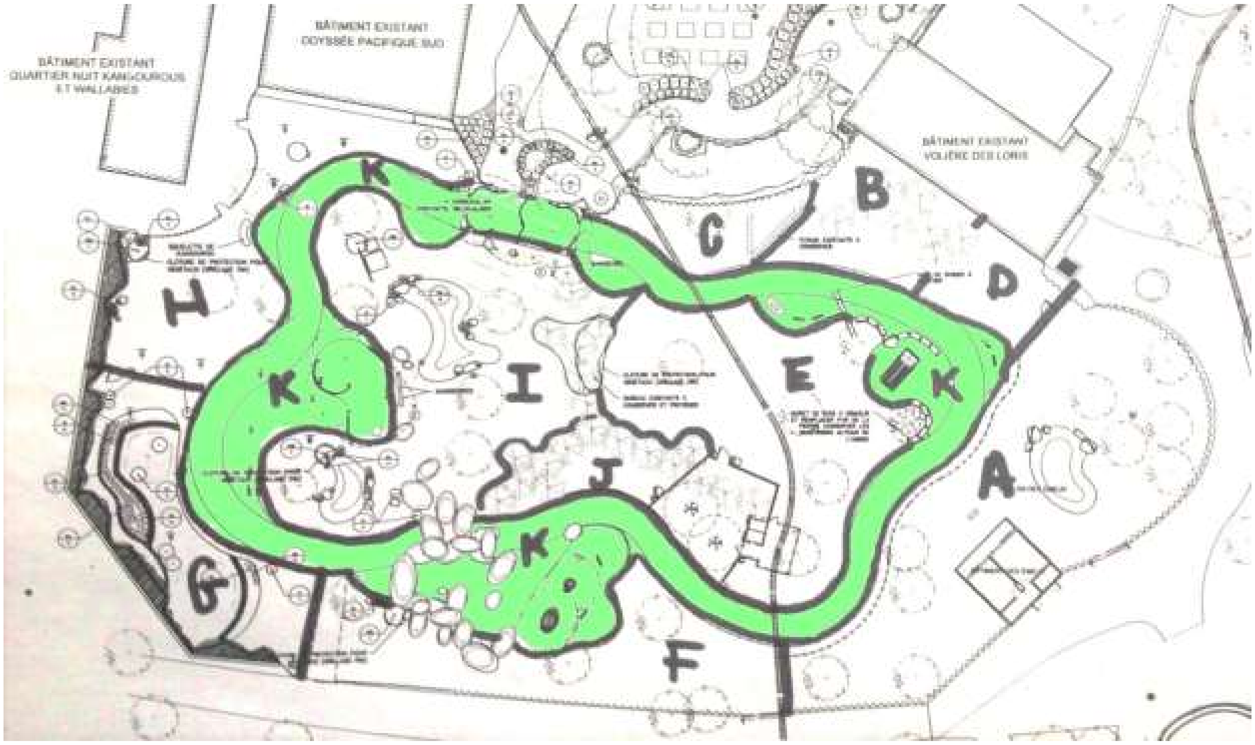

Figure 1.1: A top-view image of Zoo de Granby's wallaby exhibit. The enclosure was divided into sections represented by respective letters. The visitor path (Area K) runs throughout the entire exhibit and is delimited by ropes. Area A represents the treed, shaded emu exhibit (*Dromaius novaehollandiae)*. The emus are separated from the visitor paths with a meshed fence made of rope under which the wallabies can easily make their ways through. Areas B and C are located right by the lorikeet holding barn and the exhibit's exit. They provide shade and partial visual barrier from visitors. Areas D, E and F are spans of grass that provide less shade and not much visual barrier from visitors. Two black swans (*Cygnus atratus*) are housed in area G, a pond area delimited with low wooden fences. Unlike areas A-F and J representing temperate regions of Australia with an abundance of vegetation and greenery, areas H and I represent the more arid regions, with red, sandy and rocky terrain. Lastly, area J is the section where the salmon-crested cockatoo (*Cacatua moluccensis*) is located.

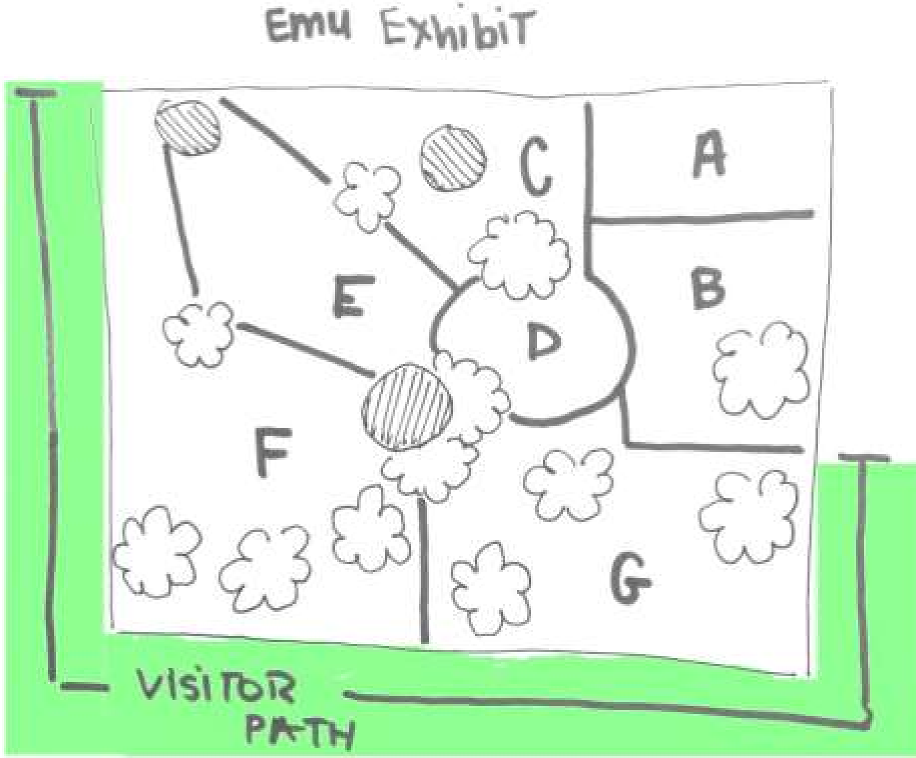

Figure 1.2: A top-view image of Riverview park and zoo. Area A represents a retreat barn with two small entries for the wallabies to go inside for complete shade and visual barrier from visitors. Areas B and C are sandy areas located at the farthest points from visitor paths. Area E is an elevated, bushy area, that provides partial visual barrier to individuals in both areas E and C. Area D represents an elevated hill, where individuals can be easily viewed by visitors. Areas F and G are the sections located adjacent to the visitor paths. They are large spans of grassy terrain with a few trees providing areas of shade.

Figure 1.3: Real top-view image of a section of Roger Williams park zoo. Two different populations of Bennett's wallabies are housed in their respective exhibits at this zoological park (represented by red circles in the image). The main entrances to the respective sections of the two exhibits share a common central pathway area and are located at only a few minutes walking distance from each other. Photo credit: ©Google earth, 2017.

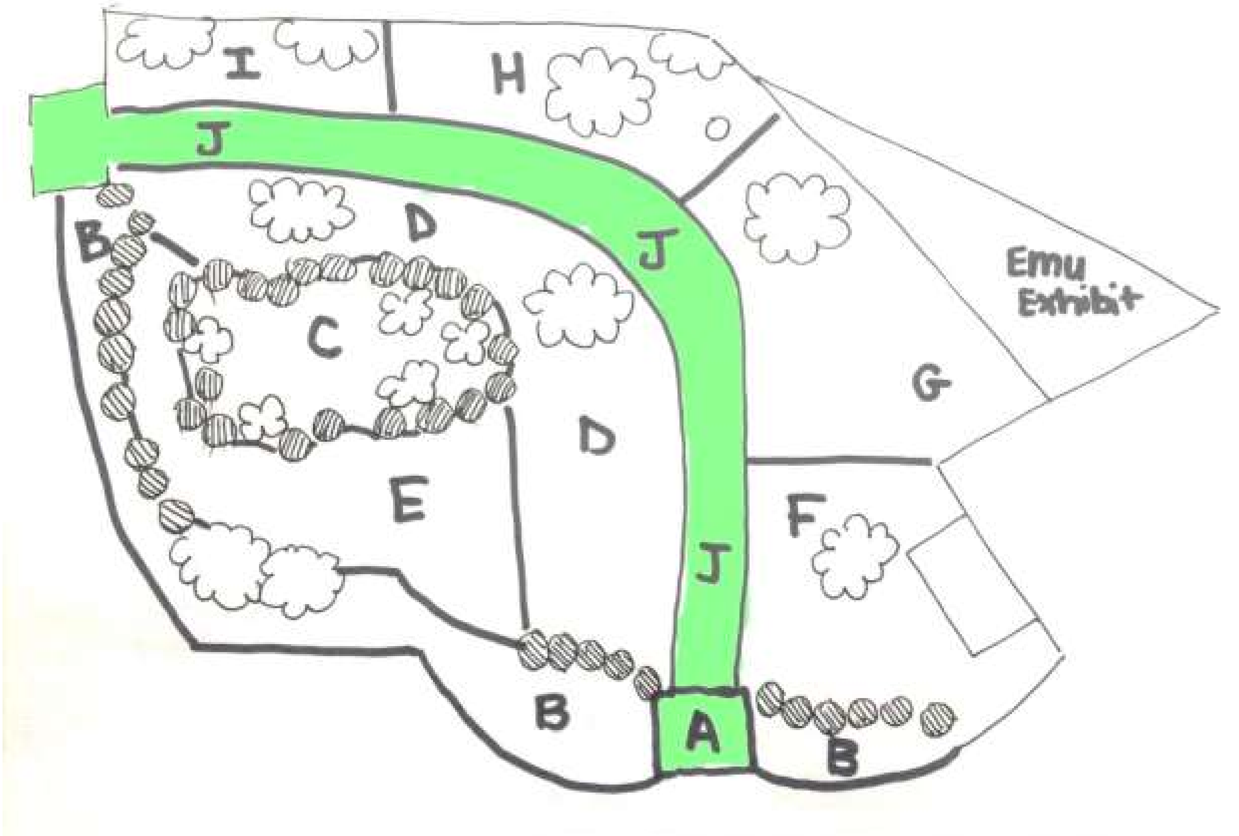

Figure 1.4: A top-view image of the open exhibit located at Roger Williams park zoo. Area A is the visitor entrance. Area B is a low-elevated, trench-like area, providing visual shelter from visitors. Because area A is a bridge, wallabies can hide under it for additional shade and shelter. Area J represents a sandy visitor path, delimited by low ropes. Areas D, I, H and G are all adjacent to the visitor paths and provide little to no visual barrier from visitors. Area G is adjacent to an emu exhibit, delimited by a metal-mesh fence. Area C is an elevated central area with many tall rocks, bushes and trees for shade and visual barrier. Area E is a grassy span of terrain located farther away from visitor paths. Area F is also adjacent to visitor paths and has a wooden roof structure providing extra shade.

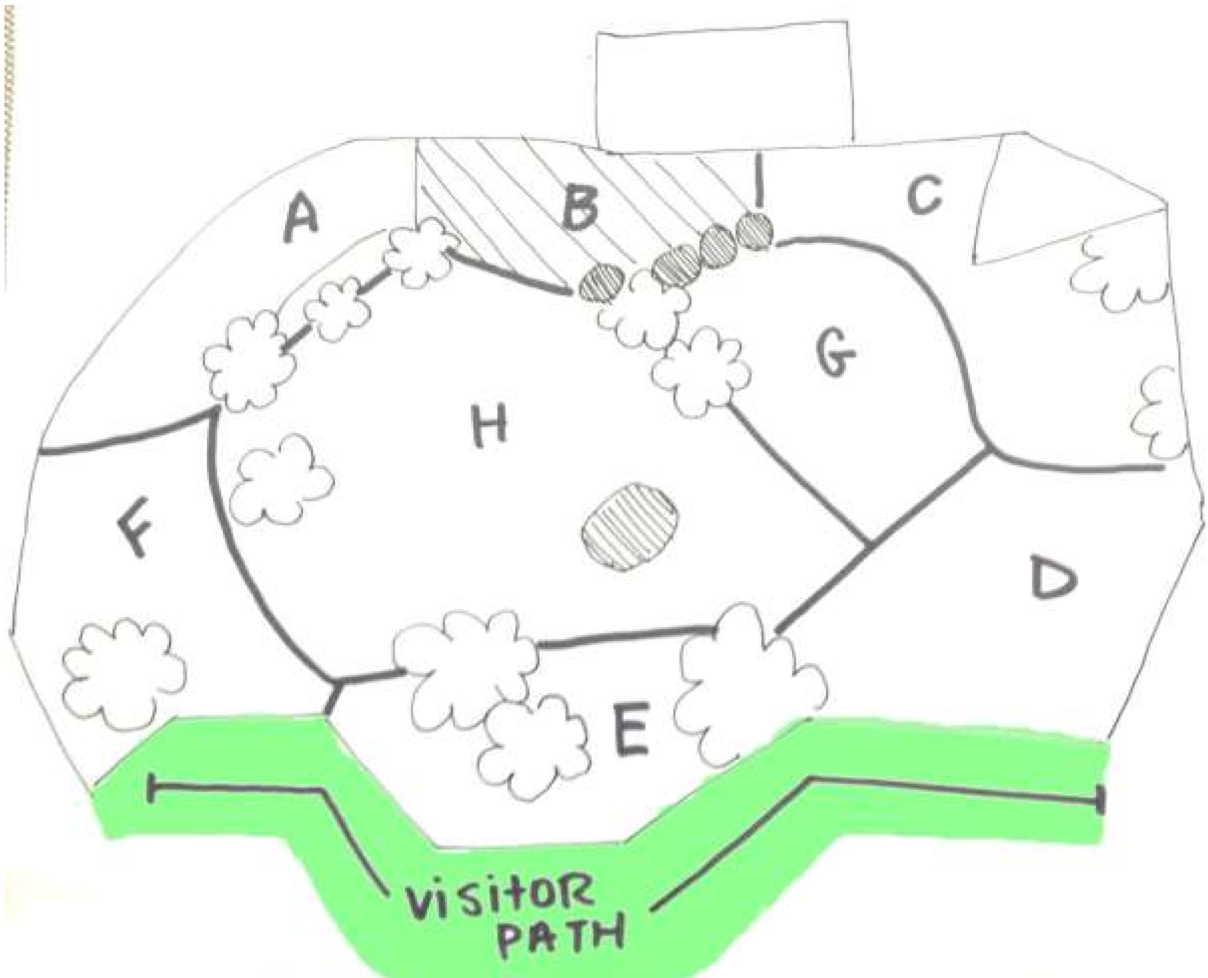

Figure 1.5: A top-view image of the closed exhibit located at Roger Williams park zoo. Area A represents elevated concrete terracing that provides shade and visual barrier from visitors. Area B is an area leading to the interior holding barn, completely out of sight from visitors. Area C is located far from visitor paths, with shade provided by trees and a wooden roof structure. Areas D, E and F are located adjacent to the elevated visitor paths, allowing visitors to spot wallabies easily due to the higher altitude. Areas H and G are large spans of sandy terrain, with lack of visual barrier and shade.

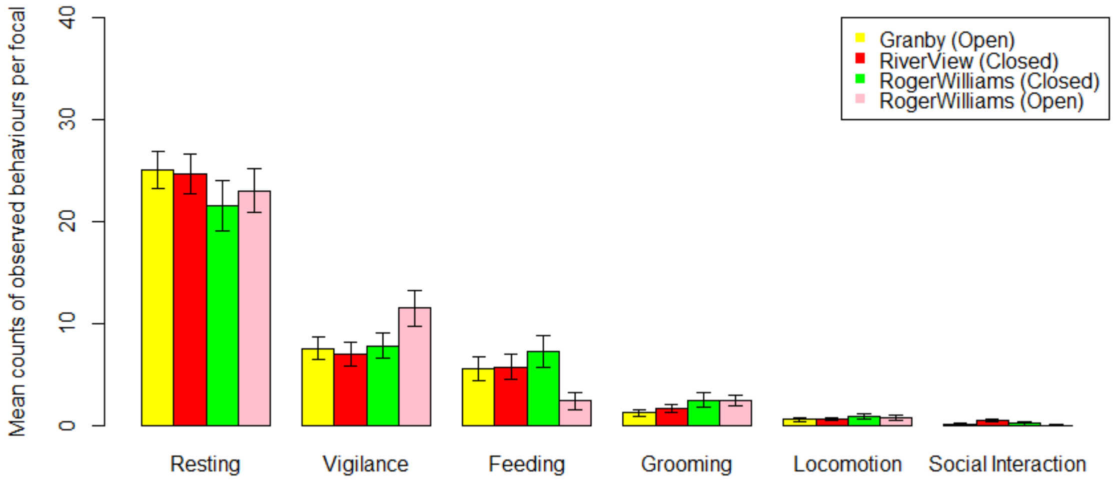

Figure 1.6: Mean activity budgets of all four populations observed during the 2015 field season. All focal samples (N=890) were out of 40 total observation counts. Error bars were extended to ±2 standard errors from the mean values.

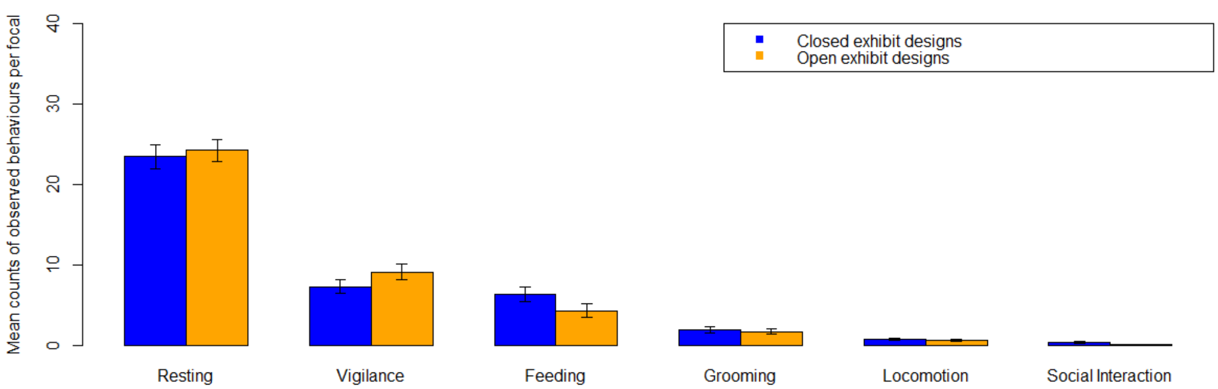

Figure 1.7: Mean activity budgets of individuals located in open exhibit designs versus closed exhibit designs. Data collected in 2015 from Zoo de Granby's and Roger Williams's (open) populations were pooled together for the open exhibit design activity budget. Similarly, data from Riverview and Roger William (closed) were pooled together to generate the closed exhibit design activity budget. All focal samples (N=890) were out of 40 total observation counts. Error bars were extended to ±2 standard errors from the mean values.

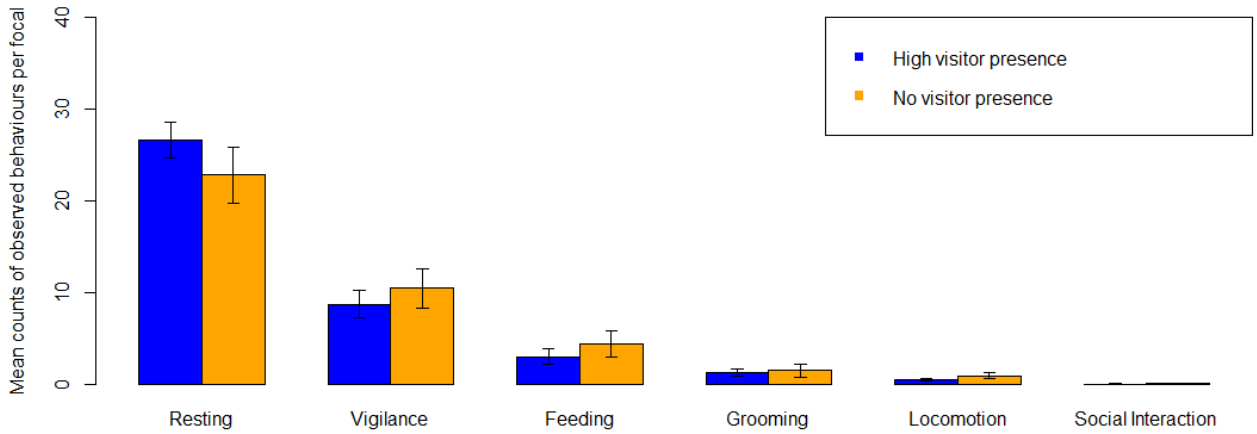

Figure 1.8: Mean activity budgets of the Zoo de Granby population in the absence of visitors (May 2016) and in the presence of high visitor densities (July-August 2016). All focal samples (N=342) were out of 40 total observation counts. Error bars were extended to ±2 standard errors from the mean values.

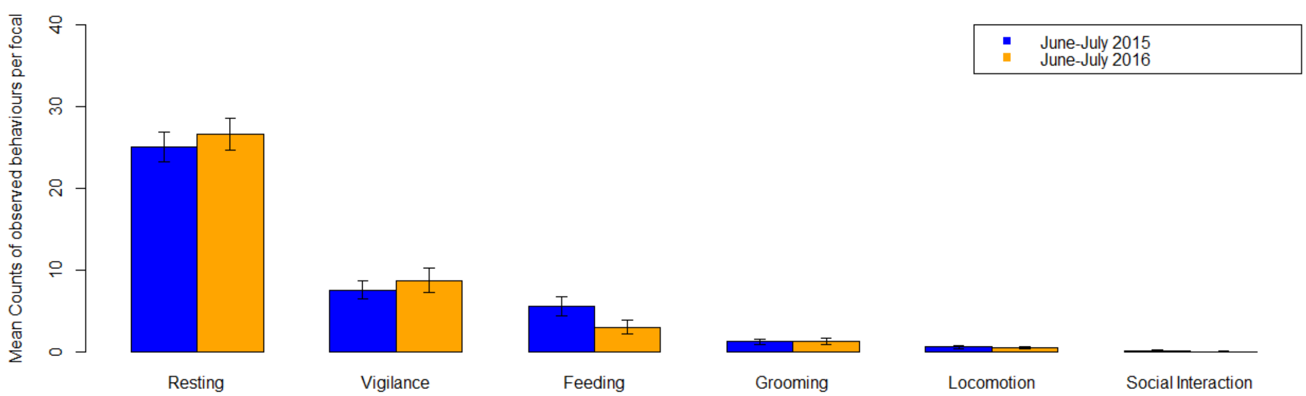

Figure 1.9: Mean activity budgets of Zoo de Granby's population during high visitor zoo seasons in 2015 versus 2016. All focal samples (N=521) were out of 40 total observation counts. Error bars were extended to ±2 standard errors from the mean values.

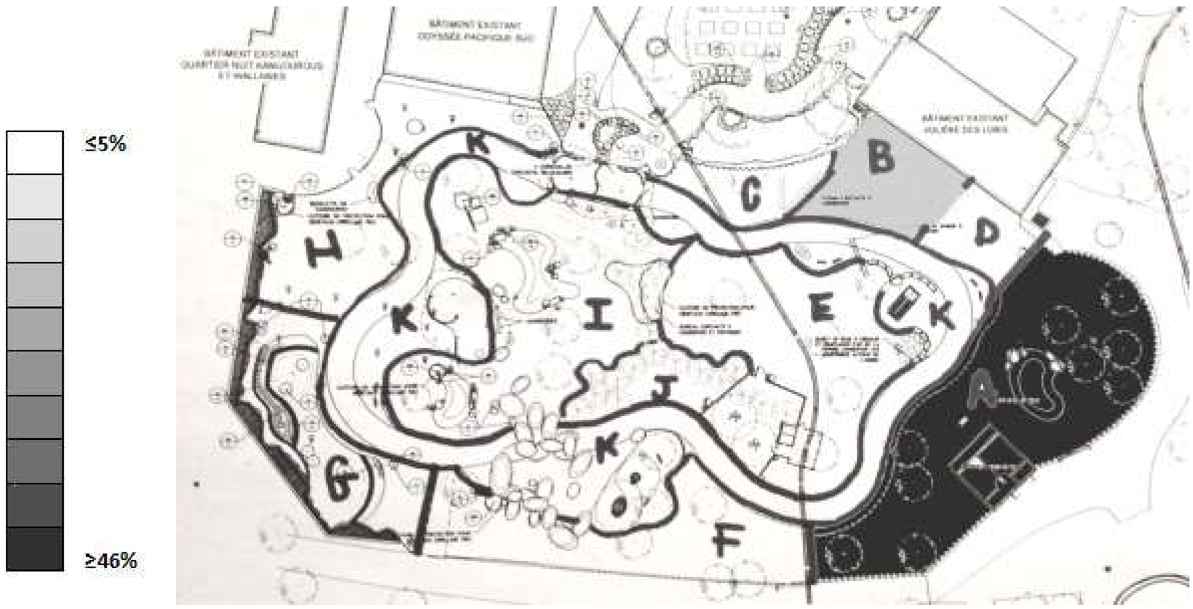

Figure 1.10: Map of the Zoo de Granby exhibit representing the proportions of time allotted to the different exhibit areas in June-July 2015.

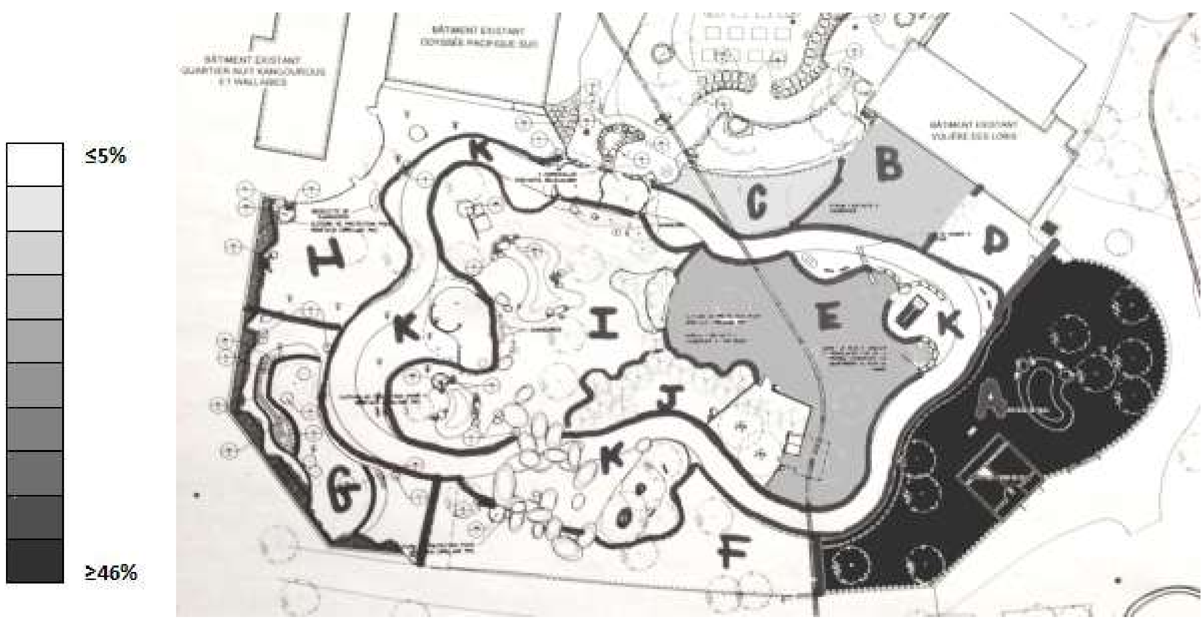

Figure 1.11: Map of the Zoo de Granby exhibit representing the proportions of time allotted to the different exhibit areas in June-July 2016.

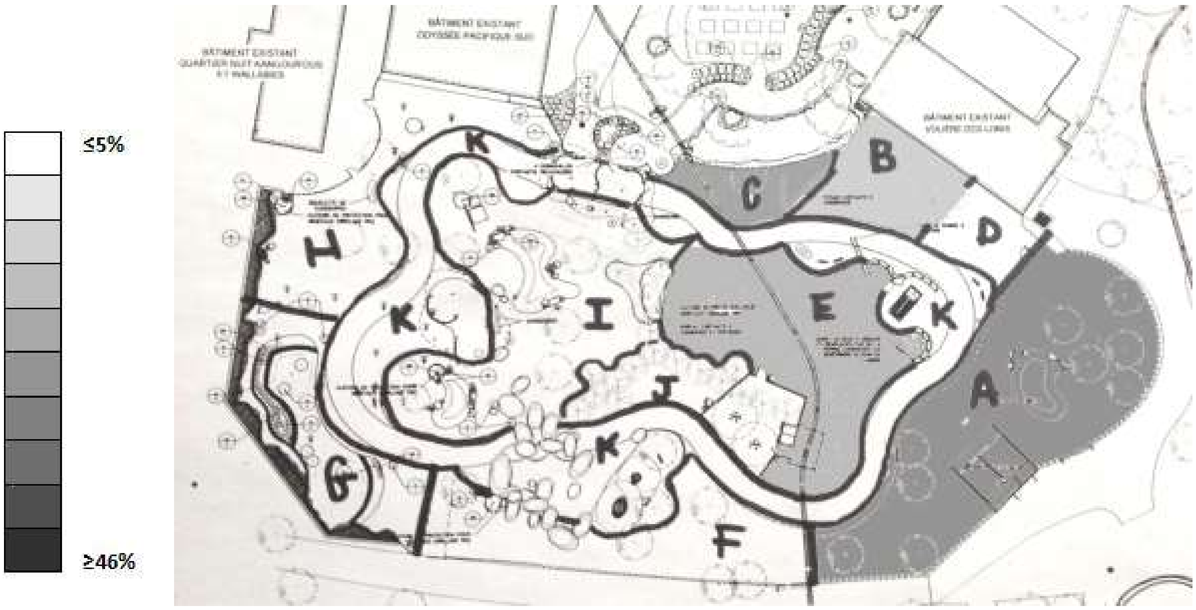

Figure 1.12: Map of the Zoo de Granby exhibit representing the proportions of time allotted to the different exhibit areas in May 2016.

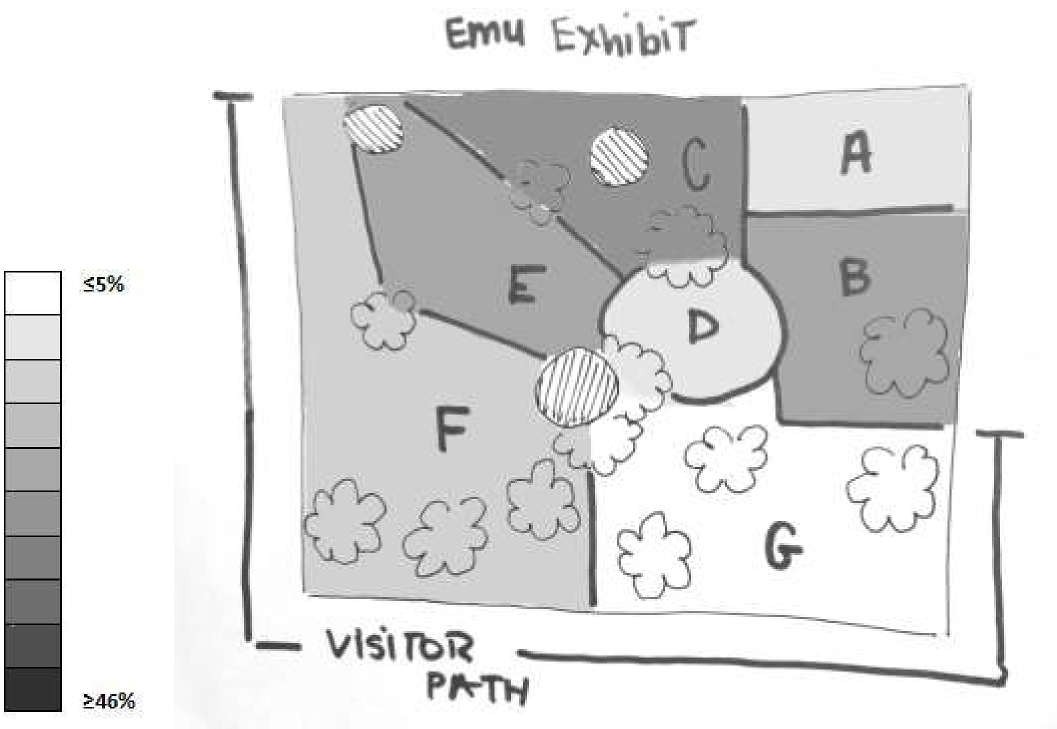

Figure 1.13: Map of the Riverview park and zoo exhibit representing the proportions of time allotted to the different exhibit areas in 2015.

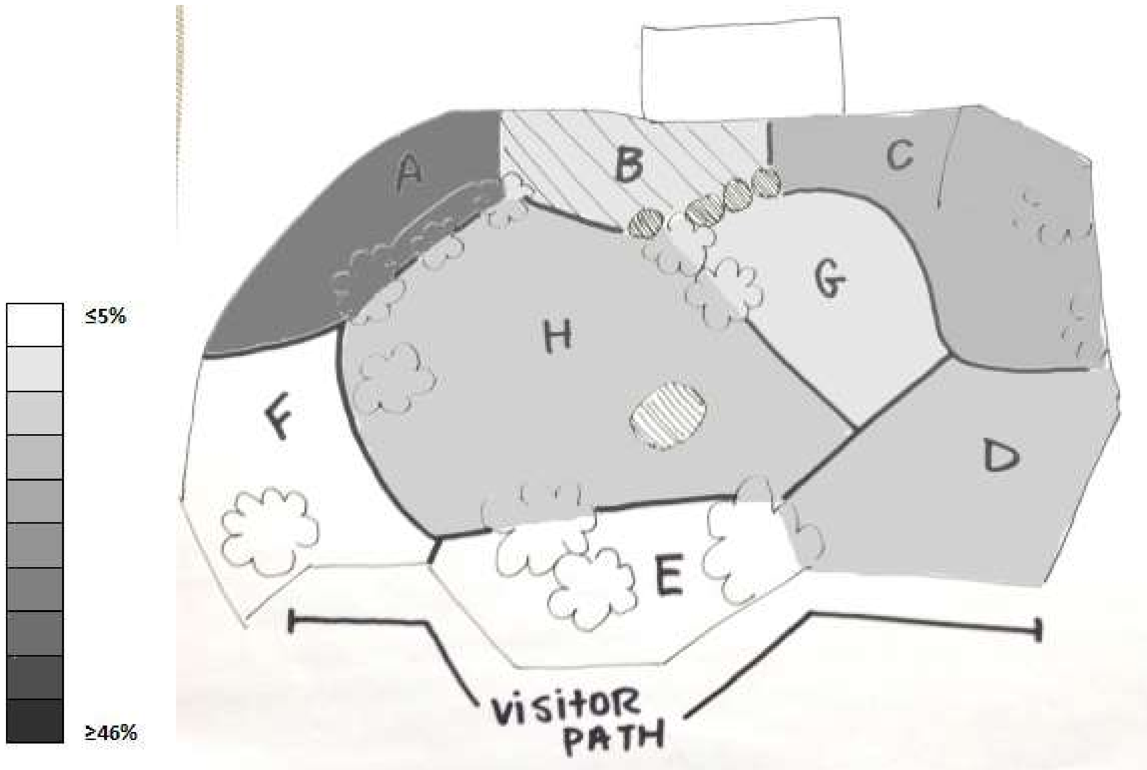

Figure 1.14: Map of the Roger Williams park zoo closed exhibit representing the proportions of time allotted to the different exhibit areas in 2015.

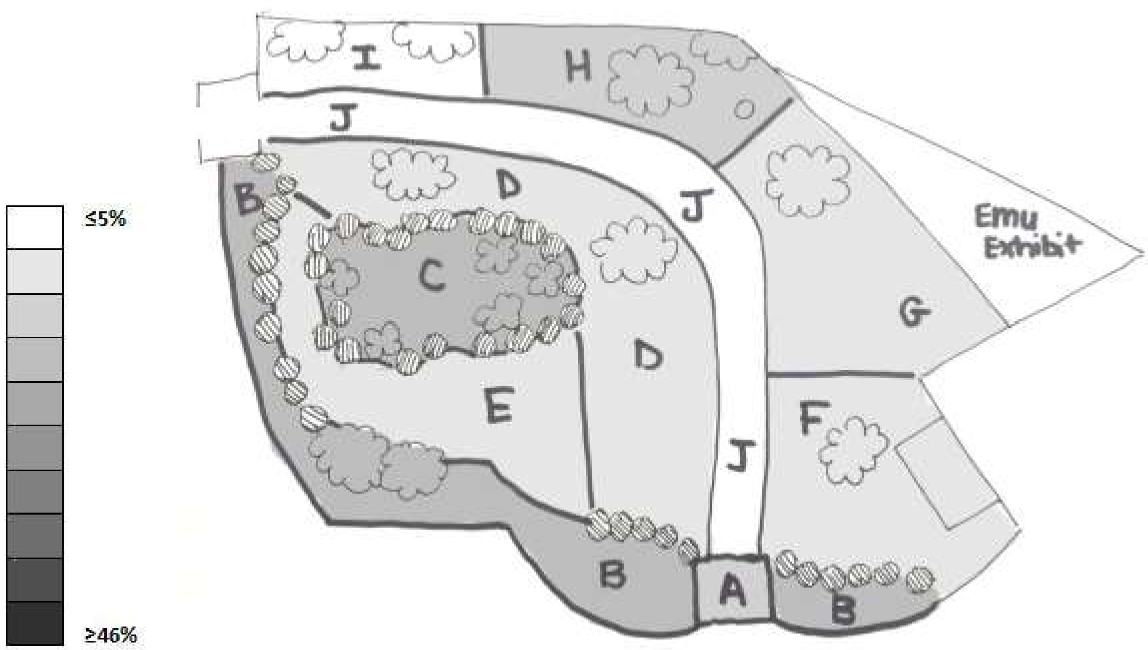

Figure 1.15: Map of the Roger Williams park zoo open exhibit representing the proportions of time allotted to the different exhibit areas in 2015.

CHAPTER 2:
The impact of open versus closed exhibit designs on visitor experience and perception

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ABSTRACT

Zoo visitor experience plays an important role in stimulating visitor empathy and learning process and consequently has a direct impact on their likelihood to contribute to global conservation efforts. We studied the impact of exhibit design on visitor experience and perception. More specifically, their reactions to open exhibits, an immersive design allowing the possibility of physical human-animal touch, were compared to reactions to traditional, closed exhibit designs. We used survey-type questionnaires randomly distributed to visitors exiting an open design (Zoo de Granby) and a closed design (Riverview Park and Zoo) in June-July 2015. We found that visitors preferred the open exhibit's overall experience and animal visibility. Visitors exiting the open design perceived animal welfare as being good in open concepts. However, visitors exiting closed designs had mixed perceptions on animal welfare, stress and the possible human-animal interactions allowed in open designs. With our results suggesting that open designs are beneficial for overall visitor experience and perception of zoo animals, the open exhibit design seems to be a good candidate for achieving modern public education and conservation zoo goals.

INTRODUCTION

With the many growing environmental issues our globe is faced with today, finding different ways to reach and educate the public is becoming vital. With their large daily attendance rates, zoos offer great opportunity for the spread of global empathy for nature and its various animal species (Coe, 1985; Yilmaz, et al., 2010). Therefore, modern zoo goals are increasingly aimed towards public education, animal conservation and research (Wineman & Choi, 1991). The concerned public is one of the largest financial contributors to wildlife conservation efforts (Coe, 1985). Hence, large amounts of efforts are put towards ensuring zoo visitors not only enjoy their zoo experience, but also learn from their positive experiences and remember the conservation messages that were transmitted to them during their visit (Coe, 1985; Wineman & Choi, 1991). In order to do so, zoo exhibits have to be thoughtfully designed to communicate to viewers on both conscious and unconscious levels (Coe, 1985). The presence of strong multi-sensory stimuli, novelty, high aesthetic value and the perception of high animal welfare are examples of exhibit characteristics that are proportionate to increased visitor experience and long-term memory (Coe, 1985). When designing new and innovative exhibits, zoo members therefore keep in mind that the more visitors register positive and memorable images of wildlife during their zoo experience, the higher the chances that they show future interest in wildlife preservation (Coe, 1985).

A candidate exhibit design that has proven to be promising in terms of visitor experience is the open exhibit design (Price, et al., 1994). These designs provide the opportunity for visitors to travel through the exhibit, immersing themselves within the species' habitat and observing the animals with no visual barriers obstructing their view. Studies show that zoo visitor experience and behaviour is directly correlated with animal visibility, animal activity, animal size, animal proximity and exhibit characteristics (Bitgood, et al., 1988). With no fence dividing visitors and animals, open exhibit designs aim to increase visitor experience by increasing animal visibility and proximity. Moreover, visitors travel through the animal's exhibit instead of observing the animals from the outside and may have the opportunity to physically pet the animals. This provides the public with a multi-sensory stimuli experience, increasing the probabilities of leaving a long-term imprint on their memory and increasing appreciation for the housed species

(Coe, 1985). Price et al (1994) demonstrated that when compared to traditional caged designs, open exhibits increase general visitor enjoyment; time spent viewing the exhibit and knowledge of the housed species. Moreover, the public's perception of animal welfare is also improved for free-ranging zoo animals (Price, et al., 1994). This was also more recently supported by a study reporting consistently high visitor enjoyment rates and positive perceptions of the displayed animals in free-range exhibits (Sha Chih Mun, et al., 2013). It has therefore been argued that the higher visitor experience observed at these immersive designs provide the opportunity for more effective public education on conservation issues (Coe, 1985; Price, et al., 1994). Although many studies investigate how exhibit characteristics affect visitor experience and perception in general, few studies investigate open exhibit designs precisely. More research is needed to fully understand its impacts on visitor experience and perception.

The aim of this study was to compare general visitor experience and visitor perception of animal welfare in open and closed zoo exhibit designs in order to gain insight on how enclosure design affects visitors. We tested the hypothesis that visitor experience and visitor perception of the captive animals would differ between the two studied exhibit designs. Due to the increased environmental immersion, animal visibility and proximity, we predicted to observe a higher visitor experience score at open exhibit designs when compared to closed designs. We also expected interviewees from both open and closed designs to perceive animal welfare to be increased in open exhibits, due to the increased stimulation and freedom of choice offered by this particular design.

METHODS

Study site and subjects

The present study took place at the Zoo de Granby and Riverview Park and Zoo during the field season of summer 2015. 63 questionnaires were handed out to passing visitors immediately after they were exiting Bennett's wallaby exhibit areas. The researcher was positioned at the exhibit exits and would ask all passing visitors if they wished to participate in a study. Those who accepted were provided with a brief explanation of the study aims and invited to answer the survey. Subjects were therefore selected at random, with only one visitor at a time answering the questionnaire at any given time to ensure no bias was created by external opinions. Only visitors aged 18 years or more were included as survey participants.

Surveys

The survey-type questionnaires used in this study were inspired by Price et al and Ridgway's studies (Price, et al., 1994; Ridgway, 2000). More specifically, visitors were asked general experience, exhibit design comparison and perception questions. The survey also included a preamble section explaining the anonymity and confidentiality of all answered questions.

Statistical Analysis

Although many questions were included in the initial surveys, only a few questions of interest were retained for analysis in this study (Table 2.1). We were interested in comparing answers from open versus closed exhibit designs. We therefore conducted simple chi-square and Fisher's exact tests to assess whether the categorical variables of the survey answers were significantly dependant on the exhibit design they had visited.

RESULTS

When compared to answers from the closed design, the open exhibit design scored highest when visitors were asked how they enjoyed the exhibit they had just viewed ($p<0.007$; Table 2.1, Figure 2.1). When asked to rate animal visibility in the exhibits, visitor answers varied with the exhibit design type ($p<0.006$), with open exhibit designs also scoring highest (Table 2.1, Figure 2.2).

Visitor perception of animal welfare in open designs also varied according to the exhibit design they had just viewed ($\chi^2_{(4)}= 20.18$, $p<0.001$). More visitors who had just viewed a closed design thought that animal welfare would be decreased in open designs than visitors who had just viewed the open design. In fact, 70% of visitors at the open exhibit thought that wallaby welfare was increased in open designs when compared to traditional closed ones (Table 2.1, Figure 2.3).

On the other hand, design did not significantly alter the perception of visitor experience in open exhibit designs ($p>0.05$). Indeed, over 90% of visitors at both closed and open designs thought that open designs would positively affect general visitor experience. (Table 2.1, Figure 2.4).

Visitor perception of animal stress levels in open designs significantly varied according to exhibit design ($\chi^2_{(3)}= 9.46$, $p= 0.024$). More visitors at closed designs thought that open designs would increase animal stress levels than visitors that had just visited an open design (Table 2.1, Figure 2.5).

Design also altered whether visitors thought the physical human-animal interaction possible in open designs was beneficial for the animals ($\chi^2_{(3)}= 11.02$, $p= 0.012$). More visitors exiting open designs thought that human-animal interaction was good for the housed animals, while many visitors exiting closed designs had a more neutral opinion on the question (Table 2.1, Figure 2.6).

DISCUSSION

As expected, the results presented in this study indicate that an open exhibit design generally provided zoo visitors with a better overall experience when compared to a more traditional, closed exhibit design. This is similar to a previous study that observed increased visitor interest and enjoyment at an open exhibit where visitors travelled through a wooded exhibit with cotton-top tamarins roaming in the tree-tops (Price, et al., 1994). Indeed, they found that visitors enjoyed viewing tamarins in the open design more than the ones in the closed design (Price, et al., 1994). Our results are also consistent with Sha Chih Mun's recent study (2013) that found that over 95% of visitors positively ranked their experience at a free-range exhibit. Our study also reported that animal visibility scores were highest at open designs. It is known that visitors rate animals more positively when they are viewed from more complex and naturalistic exhibits (Finlay, et al., 1988; Fernandez, et al., 2009). It is possible that the open design used in this study had more natural elements to it when compared to the closed exhibit, explaining the better overall experience scores. Furthermore, as reported by Finlay et al (1988), visitors viewing naturalistic closed exhibits with visual barriers (fences, walls or moats) separating them from the animals did not rate animals differently than they did for animals housed in older-generation cages. Indeed, they described these captive populations as restricted, tame and passive instead of the more positive alternative descriptions of graceful, free, active or energetic (Finlay, et al., 1988). On the other hand, in naturalistic exhibits with no visible barriers, animals were rated with significantly more favorable adjectives than in naturalistic exhibits with visible barriers (Finlay, et al., 1988). Therefore, barriers delimiting captive animals from zoo visitors can play an important role in visitor perception and attitudes towards animals (Coe, 1985; Finlay, et al., 1988). Our observed increase in visitor experience therefore coincides with our results demonstrating higher animal visibility ratings in open designs when compared to closed ones. Indeed, open exhibit designs lack fences that could obstruct visitor visibility of the housed wallabies. This could have played a key role in overall visitor experience and perception in this study.

Literature suggests that zoo exhibit designers must give significant priority to the attenuation of perceptual cues that remind visitors that they are observing animals in a zoo (Coe, 1985; Finlay, et al., 1988). Open exhibits, such as the one included in the present study, have the potential to provide exhibit designers with this opportunity by providing visitors with a multisensory feeling of immersion within the habitat. We were therefore interested in investigating how visitors perceived these open designs in terms of visitor experience and animal welfare. At both open and closed design exhibits, survey participants were asked the same questions on their perception of open designs. By doing so, we hoped to see if people would think differently of open designs directly after viewing one versus directly after viewing a very different exhibit concept. Because animals are generally rated less favorably at closed exhibits with visible barriers (Finlay, et al., 1988), we expected visitors to think animal welfare would be increased in open designs, regardless of where they were answering the survey from. However, our results show that depending on whether the visitor was answering a survey at a closed or at an open design, their perception of animal welfare in open designs varied. This may be explained by the surveys being distributed at different zoos, to different clienteles with possibly varying levels of background knowledge on animal welfare in zoos, or with different perception of *ex-situ* conservation. However, our results may also support the idea that exhibit design may be playing an immediate role in visitor experience and visitor perception of their surroundings (Coe, 1985). In this study, the exhibits visitors had just viewed may have contributed to biasing their opinion toward open designs. As expected, many visitors exiting the open design thought animal welfare was increased in open designs when compared to closed ones. However, unlike expected, much less closed exhibit survey participants thought this was the case. Furthermore, many survey participants at closed designs thought animals would be more stressed in open designs than in the closed design they had just viewed. Indeed, 31% of visitors in closed exhibits versus 73% of survey participants answering from the open locations themselves thought physical human touch would be beneficial to the wallabies. Our results are similar to previous findings where visitors who had seen an open design were more likely to think animals were better off in open concepts, than visitors who had seen closed designs (Price, et al., 1994). It is possible that open designs have an instantaneous and effective role on attenuating visitors' preconceived stereotypes and opinions of zoos and visitor proximity, by using thought-out psychological tools during its conception (Coe, 1985). When visitors at closed designs thought about the idea of open designs, they most likely used their own preconceived ideas of how animals would thrive in open designs, which would be why opinions on the matter were shared.

On the other hand, when visitors travelled through the open design, the lack of visible barriers most likely effectively mimicked what they would expect to observe in the wild, and caused visitors to perceive the animals differently, attributing them with more positive descriptions and welfare scores (Finlay, et al., 1988).

Although the perception of survey participants answering from different locations significantly differed in regards to animal welfare in open designs, they did agree on their perception of visitor experience in these designs. More specifically, visitors from both closed and open designs thought that visitor experience would be increased in open exhibit designs when compared to closed ones. These perception results coincide with previous findings as well with our earlier results demonstrating higher overall experience rankings at open designs (Price, et al., 1994; Sha Chih Mun, et al., 2013). With the hopes of leaving visitors more enthralled and excited about their zoo experiences, closer human-animal interaction approaches, such as animal demonstrations, petting zoos, public feedings and animal rides have been implemented in the past (Kreger & Mench, 1995). Although these methods have been successful in regards to visitor experience, they have been largely ethically critiqued (Kreger & Mench, 1995). Open designs, on the other hand, leave animals with freedom of choice over the level of interaction they wish to engage in with visitors, while keeping the desired increase in sense of animal closeness for the visiting public. It is for that reason in particular that survey participants, regardless of whether they are answering from open or closed habitats, like the idea of having a more immersive zoo experience, permitting them to feel closer to the housed animals.

Zoo designers are increasingly moving towards successfully engaging visitors in order to effectively raise awareness to current global conservation issues (Skibins & Powell, 2013). It is of upmost importance to continue pushing the public to develop their appreciation for animal biodiversity and by consequence, contribute to protecting nature as a whole and preventing species from becoming endangered. With our results suggesting that open designs are beneficial for overall visitor experience and perception of zoo animals, the open exhibit design seems to be a good candidate for achieving public education and conservation zoo goals.

TABLES AND FIGURES

Table 2.1: Survey questions retained for analysis and percentage answered at Zoo de Granby (N=32) versus Riverview park and zoo (N=31).

Questions	Answers	Zoo de Granby (%)	Riverview (%)
How much did you enjoy the exhibit?	Disliked	0	0
	Neutral	0	16.13
	Liked	40.63	54.84
	Loved	59.38	29.03
How did you appreciate the animal visibility?	A lot	90.63	58.06
	A little	9.38	32.26
	Not at all	0	9.68
	Not important	0	0
How much do you think wallabies would benefit from being in a walkthrough exhibit instead of a fenced exhibit?	Wellbeing decreases a lot	3.33	3.70
	Wellbeing decreases	0	33.33
	Makes no difference	26.67	33.33
	Wellbeing increases	33.33	29.63
	Wellbeing increases a lot	36.67	0
How much do you think visitors would benefit from being in a walkthrough exhibit instead of a fenced exhibit?	Experience decreases a lot	0	3.23
	Experience decreases	0	0
	Makes no difference	3.13	6.45
	Experience increases	43.75	51.61
	Experience increases a lot	53.13	38.71
Animals are stressed by the greater proximity of visitors in open exhibits	Yes	13.33	41.38
	More or less	60.00	41.38
	No	26.67	10.34
	No difference	0	6.90
Animals positively benefit from the possible interaction with visitors in open exhibits	Yes	73.33	31.03
	More or less	20.00	44.83
	No	6.67	20.69
	No difference	0	3.45

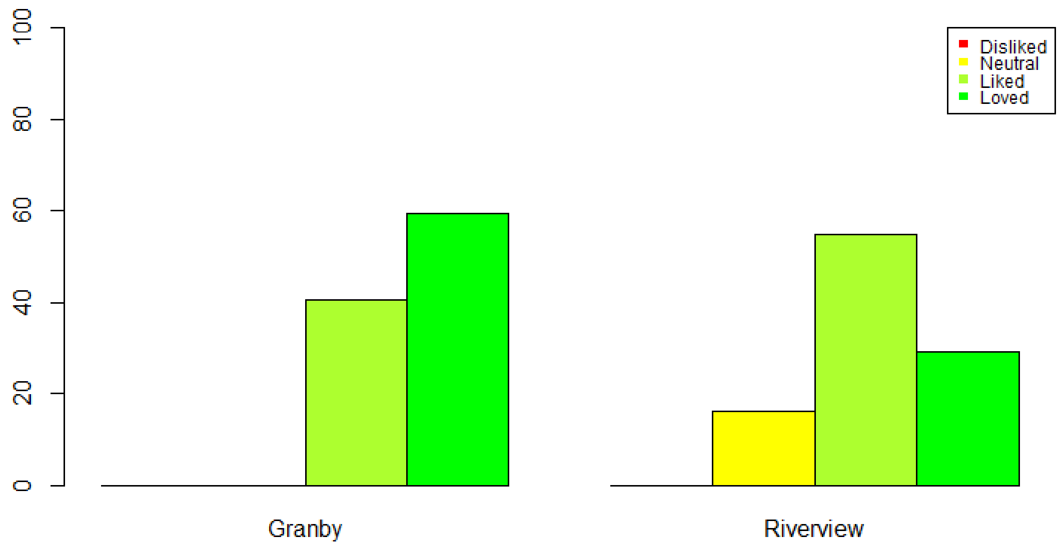

Figure 2.1: Proportion of answers (%) given by visitors when asked: “How much did you enjoy the exhibit?” at Zoo de Granby (open exhibit design) versus Riverview park and zoo (closed exhibit design) in 2015 (N=63).

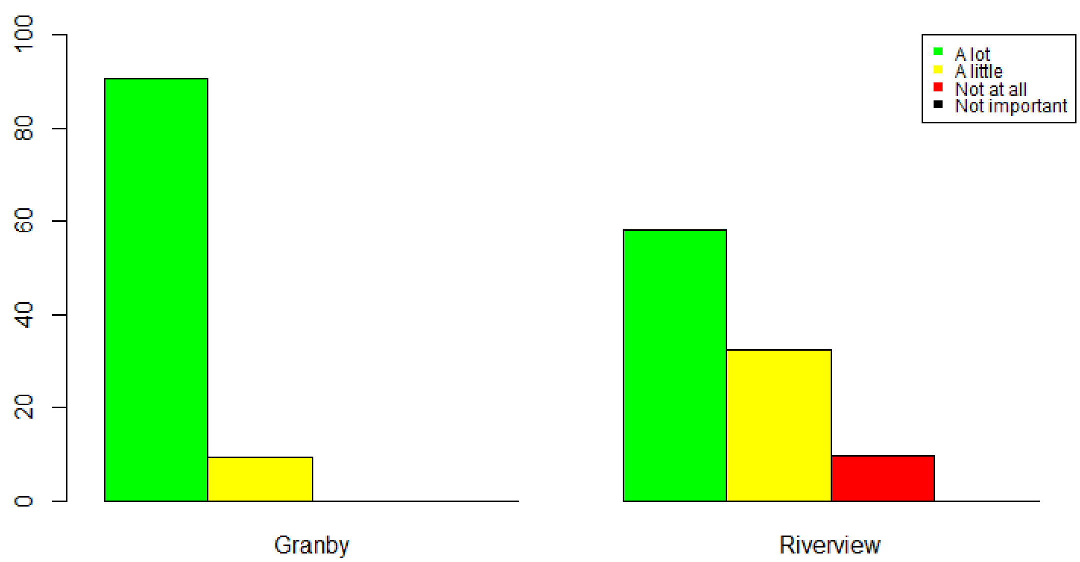

Figure 2.2: Proportion of answers (%) given by visitors when asked: “How did you appreciate the animal visibility at this exhibit?” at Zoo de Granby (open exhibit design) versus Riverview park and zoo (closed exhibit design) in 2015 (N=63).

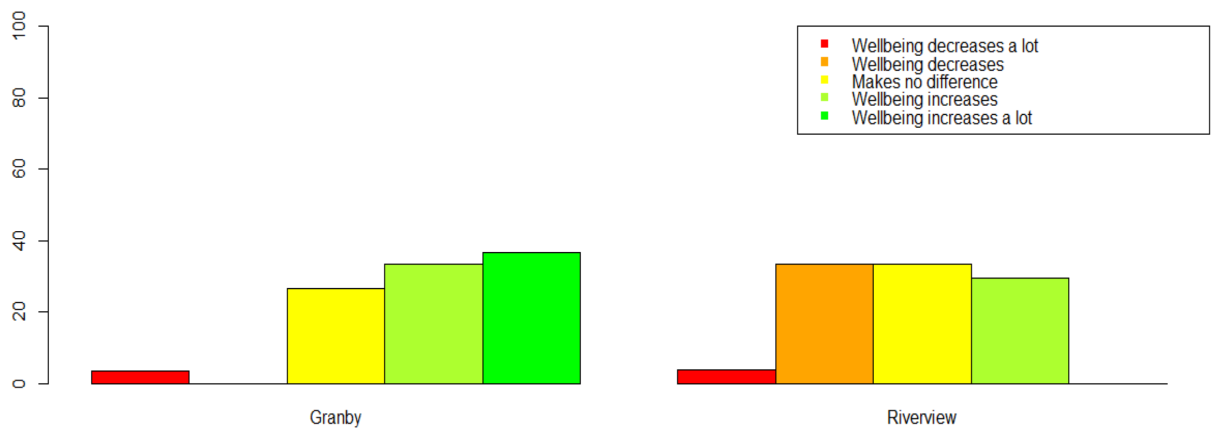

Figure 2.3: Proportion of answers (%) given by visitors when asked: “How much do you think wallabies benefit from being in a walkthrough exhibit instead of a fenced exhibit?” at Zoo de Granby (open exhibit design) versus Riverview park and zoo (closed exhibit design) in 2015 (N=63).

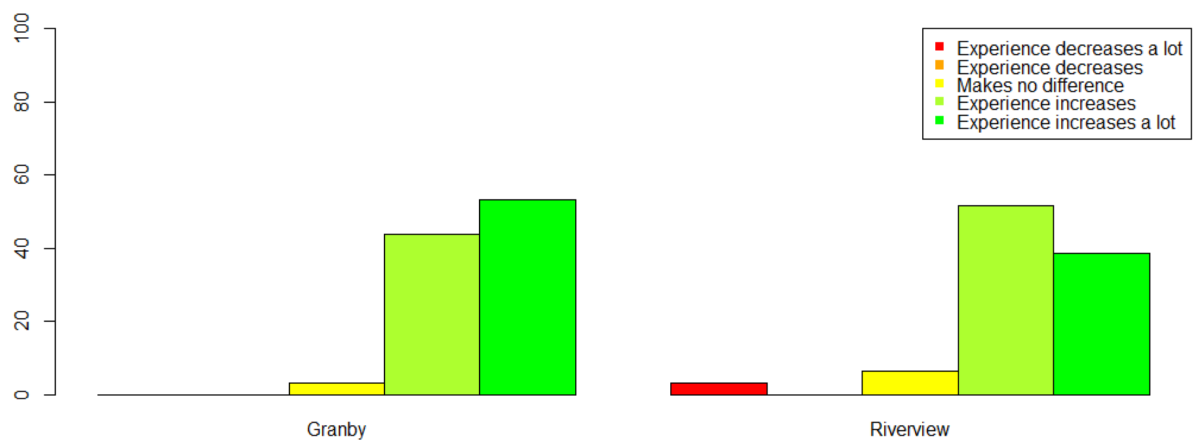

Figure 2.4: Proportion of answers (%) given by visitors when asked: “How much do you think visitors benefit from being in a walkthrough exhibit instead of a fenced exhibit?” at Zoo de Granby (open exhibit design) versus Riverview park and zoo (closed exhibit design) in 2015 (N=63).

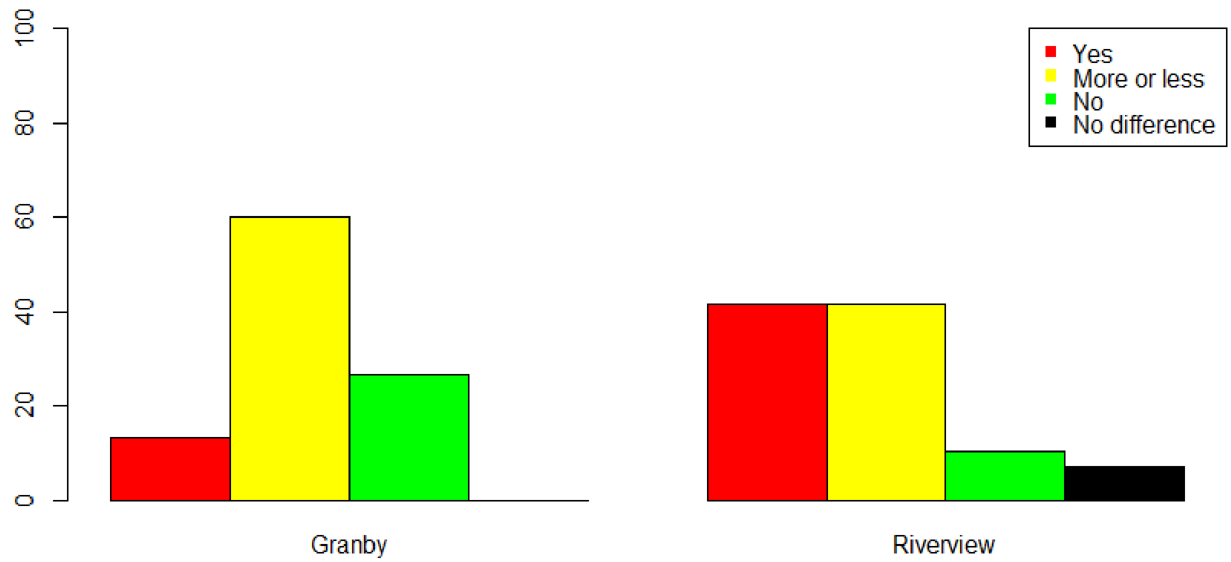

Figure 2.5: Proportion of answers (%) given by visitors when asked: "Are animals stressed by the greater proximity of visitors in open exhibits?" at Zoo de Granby (open exhibit design) versus Riverview park and zoo (closed exhibit design) in 2015 (N=63).

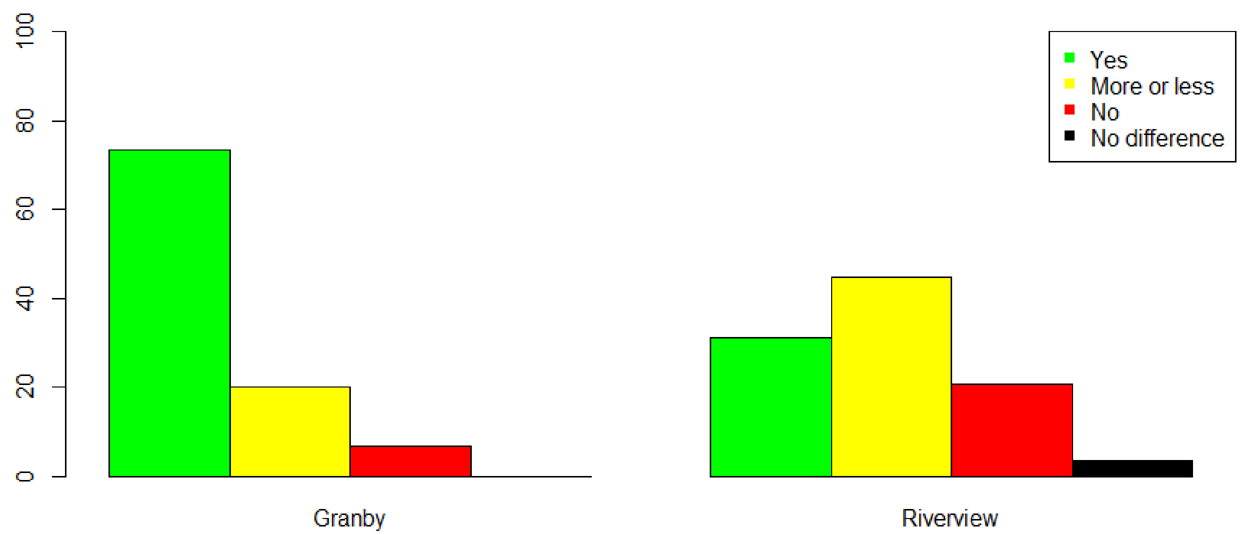

Figure 2.6: Proportion of answers (%) given by visitors when asked: "Do animals positively benefit from the possible interaction with visitors in open exhibits?" at Zoo de Granby (open exhibit design) versus Riverview park and zoo (closed exhibit design) in 2015 (N=63).

GENERAL CONCLUSIONS AND RECOMMENDATIONS

Optimizing visitor experience, while also aiming for high animal welfare standards is one of the greatest challenges zoo exhibit designers are faced with today. Since visitor recreation and animal welfare have often been conflicting in the past (Kelling & Gaalema, 2011; Sha Chih Mun, et al., 2013), zoo research is essential to ensure the best possible exhibits are developed today. Our study revealed that open exhibit designs had high overall visitor experience scores that resulted in positive perceptions of animal welfare, without sufficient evidence for impacts on Bennett's wallaby welfare when compared to closed designs. Thus, at this stage in zoo research, we recommend immersive concepts provided with appropriate retreat zones, such as the open designs included in this study. Indeed, open exhibit designs are good candidates for fulfilling modern exhibit designer goals.

Our study can be considered as a starting point on the topic. More research is needed to ensure the impacts of open exhibit designs are fully understood. In order to do so, research over longer periods of time should be implemented. This would allow researchers to fully understand how time since their arrival in the exhibit affects functional space use as well as activity budgets. Additionally, stricter research protocols should be followed in order to eliminate as many confounding variables existing in zoo environments as possible. Lastly, very few studies on Bennett's wallaby behaviour in captivity exist. More research on the impacts of visitor effects on their behaviour in general are also needed to fully understand how captive zoo environments affect their welfare.

Zoo research has made remarkable progress since just a few decades ago. Exhibit designs have come a long way, becoming increasingly meticulous with details improving visitor experience and animal welfare together. Hopefully our research will serve as a good basis for the generation of many future zoo studies to come.

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APPENDIX A

Table 3.1: Characteristics of *Macropus rufogriseus* individuals per population

Populations	ID	Physical differentiation	Sex	Age (years)
POPULATION 1: Granby Zoo (open exhibit)	M02037	Right ear: red tag	F	10
	M06034	Right ear: 2 yellow tags	F	8
	M06041	Right ear: 1 blue/ 1 red tag	F	7
	M06042	Right ear: 1 blue/ 1 yellow tag + Left ear: 1 blue tag	F	7
	M06043	Left ear: yellow tag	M	7
	M06048	Right ear: 1 green/ 1 blue tag	F	8
	M07037	Left ear: orange tag	M	6
	M08019	Left ear: white tag	M	5
	M09015	Right ear: 1 green tag / 1 red tag	F	4
	M09024	Left ear: green tag	M	4
	M00104	Right ear: purple tag	F	13
	M04008	Left ear: light blue tag	F	9
	M06039	Left ear: knotch	M	7
	M12017	Left ear: 1 yellow/1 red tag	M	1
	M14025	N/D	N/D	1 month
	N/D	N/D	N/D	N/D
	N/D	N/D	N/D	N/D
POPULATION 2: Riverview Park and Zoo (closed exhibit)	1187	Right ear: split	M	8
	1374	Nose: white mark	M	8
	1396	Left ear: 1 knotch	M	3
	1483	Forehead: Dark line	F	3
	1484	Forehead: Dark line	M	1
	1485	Left ear: many knotches	F	2
	1535	N/D	N/D	9 months
	1536	N/D	N/D	9 months
POPULATION 3: Roger Williams Zoo (open exhibit)	Fraiser	Right ear: red tag #54	M	2
	Yuka	Left ear: red tag #66	M	2
	Narrah	Right eye: scar below it	M	3
	Simon	Right ear: yellow tag #53	M	2
	Monster	No tag	M	8
POPULATION 4: Roger Williams Zoo (closed exhibit)	Hobart	No tag	M	5
	Hurley	Left ear: yellow tag #34	F	5
	Cashew	Left ear: Silver clip	F	2
	Joleen	Left ear: red tag #74	F	2
	Maddie	Left ear: red tag #75	F	2
	Blackjack	Right ear: red tag # 70	F	1
	Hop	N/D	N/D	9 months

APPENDIX B

Table 3.2: Focal sampling check sheets used for behavioural data collection

Date : __________
Observer: __________
Wallaby I.D. # : __________
Daily Sampling period #: ________

Start Time: __________
Zoo name and location : ________________
Exhibit design type: ____________
Visitor Density for today: ____________

WEATHER
Cloud cover (1/4): ________
Wind dir. & strength ________
Precip? (rain, snow) ______
Temperature: ____________

							Agonistic Interaction			Social Interaction				
Min. Obs.		**Rest**	**Vigi**	**Locom**	**Feed**	**Groom**	**W**	**O**	**V**	**W**	**O**	**V**	**Other[1]**	**Notes2**
	1													
	2													
	3													
1	4													
	5													
	6													
	7													
2	8													
	9													
	10													
	11													
3	12													
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6	24													
	25													
	26													
	27													
7	28													
	29													
	30													
	31													
8	32													
	33													
	34													
	35													
9	36													
	37													
	38													
	39													
10	40													
SUM :														
End time:													**Notes:**	
Total Time:														

1. Urinating (U), Defecation (D) 2. any additional comments (ex. ID of animal taking part in interactions, more specific details on behaviour)
Rest: Resting Groom: Grooming Vigi: Vigilance O: with other exhibit occupant
Locom: Locomotion Feed: Feeding/Foraging W: with wallaby V: with visitor

APPENDIX C

Table 3.3: Model selection based on AIC to explain the variability of six Bennett's wallaby behaviours (vigilance, resting, locomotion, feeding, grooming and social interaction). Models with ΔAIC ≤2 or the two models with the lowest AIC are presented. Selected models are bolded and interactions are represented by « * » in the table.

Model	Age	Sex	Period	Temperature	Visitor Density	Visitor Density*Design	AIC	ΔAIC
Vigilance								
1	**X**	**X**	**X**	**X**	**X**	**X**	**5205.3**	**0**
2	X	X	X		X		5209.1	3.8
Resting								
1	**X**	**X**	**X**	**X**	**X**	**X**	**13827.8**	**0**
2	X	X	X	X	X		13828.6	0.8
Locomotion								
1			**X**	**X**	**X**	**X**	**1778.9**	**0**
2	X		X	X	X	X	1779.1	0.2
3	X	X	X	X	X	X	1780.7	1.8
Feeding								
1			**X**	**X**	**X**	**X**	**3752.8**	**0**
2		X	X	X	X	X	3754.0	1.2
Grooming								
1	**X**		**X**	**X**	**X**		**2920.1**	**0**
2	X		X	X	X	X	2924.1	4
Social								
1			**X**	**X**	**X**	**X**	**700.0**	**0**
2	X		X	X	X	X	701.8	1.8

APPENDIX D

Figure 3.1 : Images of the four study sites showing their design concept. Zoo de Granby and Roger William Park Zoo's first exhibit are open designs with roped visitor paths travelling through the wallabies enclosure (allowing close proximity and physical interaction with visitors). Riverview Park and Zoo and Roger William Park Zoo's second exhibit are closed, with fenced delimitations from visitors (less proximity and no physical interaction possible with visitors).

APPENDIX E

ZOO GRANBY

Sondage pour Visiteurs – **Traversée Australienne** *(Concept ouvert)*

Chercheuse: Julie Beaudin-Judd – Étudiante à la maîtrise, Département de Biologie, Université Concordia

Ce questionnaire a été conçu pour les chercheurs ainsi que pour les membres du Zoo de Granby dans le but de les aider à mieux comprendre l'impact des différents concepts d'habitat sur le bien-être des animaux en captivité ainsi que sur l'expérience et le divertissement des visiteurs. Les réponses que vous nous fournirez sur le questionnaire suivant resteront confidentielles et seront utilisées exclusivement par les chercheurs de l'étude. Il demeure à votre discrétion de déterminer si vous désirez répondre au questionnaire entièrement ou partiellement. Dans l'éventualité où cette étude serait publiée, l'anonymat et la confidentialité de ce questionnaire s'appliqueront toujours.

N'hésitez pas à communiquer à tout moment avec la chercheuse disponible si vous avez des questions au moment de remplir le questionnaire, ou plus tard à julieju962@hotmail.com

Merci !

I: Information générales sur le visiteur		
Age		
Sexe	M ☐ or F ☐	
Vous visitez le zoo aujourd'hui avec:	☐ Seul(e) ☐ Amis ☐ En couple ☐ En famille (ou famille élargie)	
	☐ Avec enfants (0-14 ans) ☐ Sans enfants	
Etes- vous déjà entré dans un habitat ouvert (contact direct possible) avec animaux **sauvages** dans le passé ?	☐ Oui ☐ Non	
	Si oui, quand?	☐ Il y a moins d'un an ☐ 1-3 ans ☐ 3-5 ans ☐ Plus de 5 ans
	Si oui, à quel endroit ? (le nom du zoo)	

Pour la section suivante, veuillez SVP cocher la meilleure réponse. **Une réponse seulement.**

II: Questions générales sur l'habitat		
Veuillez SVP estimer le nombre de minutes que vous avez passé dans l'habitat des wallabies	☐ Moins de 5 minutes ☐ 5-10 minutes ☐ 10-20 minutes ☐ 20-30 minutes ☐ Plus de 30 minutes	
Comment avez-vous aimé cet habitat?	☐ Je ne l'aime pas ☐ Je suis neutre ☐ Je l'aime ☐ Je l'aime beaucoup	
Comment avez-vous apprécié ces particularités dans l'habitat des wallabies que vous venez de visiter?	➢ votre proximité avec les animaux	Beaucoup ☐ Un peu ☐ Pas du tout ☐ Sans importance ☐
	➢ votre facilité à observer les animaux (visibilité des animaux)	Beaucoup ☐ Un peu ☐ Pas du tout ☐ Sans importance ☐
	➢ les aménagements naturels de l'habitat	Beaucoup ☐ Un peu ☐ Pas du tout ☐ Sans importance ☐
	➢ le sentiment d'être en sécurité lors de votre visite de l'habitat	Beaucoup ☐ Un peu ☐ Pas du tout ☐ Sans importance ☐
	➢ la possibilité de toucher aux animaux	Beaucoup ☐ Un peu ☐ Pas du tout ☐ Sans importance ☐
	➢ votre sentiment de faire partie de leur habitat	Beaucoup ☐ Un peu ☐ Pas du tout ☐ Sans importance ☐
	➢ la possibilité de se faire approcher par un animal sauvage potentiellement dangereux	Beaucoup ☐ Un peu ☐ Pas du tout ☐ Sans importance ☐

III. Comparaison de concepts d'habitats ouverts et fermés	
Quel type de concept d'habitat préférez-vous lorsque vous visitez des zoos ?	☐ Concept ouvert avec sentiers où il est possible d'interagir avec des animaux sauvages ☐ Concept fermé avec clôtures où il est impossible d'interagir avec les animaux sauvages ☐ Concept ouvert où on peut caresser des animaux domestiques (des animaux de ferme)
Placez en **ordre d'importance** les options qui selon vous, justifient le mieux le choix d'opter pour un habitat à concept ouvert pour un gestionnaire de zoo? *(1 étant la meilleure option)*	☐ Le bien-être des animaux ☐ Le potentiel d'éducation du public ☐ L'expérience du visiteur ☐ La sécurité des visiteurs
Selon votre perception, comparativement à un habitat fermé, de quelle façon l'habitat à **concept ouvert** affecte-t-il le **bien-être des wallabies** ?	☐ Leur bien-être diminue grandement ☐ Leur bien-être diminue ☐ Ça ne fait aucune différence ☐ Leur bien-être augmente ☐ Leur bien-être augmente grandement
Selon votre perception, comparativement à un habitat fermé, de quelle façon l'habitat à **concept ouvert** affecte-t-il **l'expérience des visiteurs** du zoo ?	☐ Leur expérience diminue grandement ☐ Leur expérience diminue ☐ Ça ne fait aucune différence ☐ Leur expérience augmente ☐ Leur expérience augmente grandement
Parmi les affirmations suivantes, donnez votre perception à propos d'animaux gardés dans un habitat à **concept ouvert** (vision direct et contacts possibles) comparativement à un habitat fermé (barrière séparant les animaux des visiteurs, aucun contact possible)	➢ Les animaux se sentent plus en sécurité dans un habitat ouvert — Oui ☐ Plus ou moins ☐ Non ☐ Aucune différence ☐ ➢ Les animaux sont stressés par la plus grande proximité des visiteurs dans un habitat ouvert — Oui ☐ Plus ou moins ☐ Non ☐ Aucune différence ☐ ➢ Les animaux ont plus d'espace disponible dans un habitat ouvert — Oui ☐ Plus ou moins ☐ Non ☐ Aucune différence ☐ ➢ L'environnement disponible dans l'habitat ouvert est plus stimulant pour les animaux — Oui ☐ Plus ou moins ☐ Non ☐ Aucune différence ☐ ➢ Les animaux bénéficient positivement de l'interaction possible avec les visiteurs dans un habitat ouvert — Oui ☐ Plus ou moins ☐ Non ☐ Aucune différence ☐ ➢ Les animaux peuvent se cacher plus facilement dans un habitat ouvert — Oui ☐ Plus ou moins ☐ Non ☐ Aucune différence ☐

Veuillez SVP déposer ce questionnaire dans la boite située près de la chercheuse avant de quitter l'habitat.

Merci pour votre temps ! Passez une excellente journée!

Ce questionnaire a été modifié à partir de:

Price, E. C., Ashmore, L. A., & McGivern, A.-M. (1994). Reactions of zoo visitors to free-ranging monkeys. Zoo Biology, 13(4)

Ridgway, S.C. (2000). Visitor behaviour in zoo exhibits with underwater viewing: An evaluation of six exhibits in the western United States (Master's Thesis).

Figure 3.2: Initial survey-type questionnaire distributed to Zoo de Granby visitors in June-July 2015.

Visitor Survey

Researcher: Julie Beaudin-Judd – Master's student, Biology Department, Concordia University

"This survey was designed to help researchers and zoo members to better understand how different exhibit designs impact captive animals as well as visitor experience and enjoyment. Your responses to the following questionnaire will remain anonymous and will only be used by researchers conducting the present study. You are free answer part or all of the questions, or to decline answering them. In the eventuality of this study being published, the anonymity and confidentiality of this survey will remain.

If you have any questions, please do not hesitate to ask the available researcher now or later at "julieju962@hotmail.com".

Thank you!

I: General information on visitor		
Age		
Sex	M ☐ or F ☐	
You are visiting the zoo today with:	☐ Alone ☐ Friends ☐ As a couple ☐ With family	
	☐ With children (0-14 years old) ☐ Without children	
Have you already entered a walkthrough exhibit before today?	☐ No ☐ Yes	
	If yes: Approximately when?	☐ Less than 1 year ago ☐ 1-3 years ☐ 3-5 years ☐ More than 5 years
	If yes: Name and location of zoo?	

For the following section, please put a check next to the best answer. **Check only one option per question.**

II: General questions about exhibit		
Please estimate the amount of time you have spent on this exhibit	☐ Less than 5 minutes ☐ 5-10 minutes ☐ 10-20 minutes ☐ 20-30 minutes ☐ Over 30 minutes	
How much did you enjoy this exhibit?	☐ Didn't enjoy it ☐ Neutral feelings ☐ Enjoyed it ☐ Enjoyed it a lot	
How did you appreciate the following particularities of the wallaby exhibit you have just visited? :	➢ Your proximity with the animals ➢ Animal visibility ➢ The natural characteristics of the exhibit ➢ Feeling safe while visiting the exhibit	A lot ☐ A little ☐ Not at all ☐ Not important ☐ A lot ☐ A little ☐ Not at all ☐ Not important ☐ A lot ☐ A little ☐ Not at all ☐ Not important ☐ A lot ☐ A little ☐ Not at all ☐ Not important ☐

IV. Comparing Open/walkthrough exhibits and closed/fenced exhibits

What exhibit design type do you prefer when visiting Zoos?	☐ Walkthrough-type exhibit (possible interaction with wild animals) ☐ Closed (fenced) exhibit (no possible interaction with wild animals) ☐ Petting zoo-type exhibit (farm animals)
In order of importance (*With 1 being the most important*) For a zoo administrator, which of the following reasons do you think is the most important for letting animals be in a walkthrough exhibit compared to a closed/fenced one?	☐ The welfare of the wallabies ☐ Public education ☐ Visitor experience ☐ Visitor security
How much do you think the **wallabies** benefit from being in a **walkthrough exhibit** instead of a fenced exhibit?	☐ Their wellbeing decreases a lot ☐ Their wellbeing decreases ☐ It makes no difference to them ☐ Their wellbeing increases ☐ Their wellbeing increases a lot
How much do you think the **visitors** benefit from being in a **walkthrough exhibit** instead of a fenced exhibit?	☐ Their experience decreases a lot ☐ Their experience decreases ☐ It makes no difference to them ☐ Their experience increases ☐ Their experience increases a lot

➢ The animals feel safer in an open exhibit	Yes ☐ More or Less ☐ No ☐ No Difference ☐
➢ The animals are stressed by the greater proximity of visitors in open exhibits	Yes ☐ More or Less ☐ No ☐ No Difference ☐
➢ The animals have more available space in open exhibits	Yes ☐ More or Less ☐ No ☐ No Difference ☐
➢ The environment in an open exhibit is more stimulating for animals	Yes ☐ More or Less ☐ No ☐ No Difference ☐
➢ Animals positively benefit from the possible interaction with visitors in open exhibits	Yes ☐ More or Less ☐ No ☐ No Difference ☐
➢ Animals can hide more easily in open exhibits	Yes ☐ More or Less ☐ No ☐ No Difference ☐

"Please return this clipboard to the researcher before leaving the exhibit.

Thank you for your time! Have a great day!"

This survey was modified from:

Price, E. C., Ashmore, L. A., & McGivern, A.-M. (1994). Reactions of zoo visitors to free-ranging monkeys. Zoo Biology, 13(4)

Ridgway, S.C. (2000). Visitor behaviour in zoo exhibits with underwater viewing: An evaluation of six exhibits in the western United States (Master's Thesis).

Figure 3.3: Initial survey-type questionnaire distributed to Riverview park and zoo visitors in July 2015.