Author/s:
Learmonth, MJ;Sherwen, S;Hemsworth, PH

Title:
The effects of zoo visitors on Quokka (Setonix brachyurus) avoidance behavior in a walk-through exhibit

Date:
2018-07-01

Citation:
Learmonth, M. J., Sherwen, S. & Hemsworth, P. H. (2018). The effects of zoo visitors on Quokka (Setonix brachyurus) avoidance behavior in a walk-through exhibit. Zoo Biology, 37 (4), pp.223-228. https://doi.org/10.1002/zoo.21433.

Persistent Link:
https://hdl.handle.net/11343/284165

Research Article

The effects of zoo visitors on Quokka (*Setonix brachyurus*) avoidance behavior in a walk-through exhibit[1]

Mark James Learmonth 0000-0002-2237-0665[1], Sally Sherwen[2] and Paul H. Hemsworth[1]

[1]Animal Welfare Science Centre, The University of Melbourne, Parkville 3010, Australia.

[2]Wildlife Conservation and Science, Melbourne Zoo, Zoos Victoria, Parkville 3052, Australia.

Corresponding author:

Mark James Learmonth

mlearmonth@student.unimelb.edu.au

Tel: +61 419 351 295

Animal Welfare Science Centre

The University of Melbourne | Parkville VIC 3010 | Australia

Running head:

Zoo visitor effects on Quokka behavior

Manuscript word count: 2015 excl. Abstract, References, Tables, and Figures.

[1] This is the author manuscript accepted for publication and has undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi:10.1002/zoo.21433

Abstract

The behavior of zoo animals may be influenced by visitors, with possible implications on animal welfare. We examined the effects of the presence of visitors on the presence and visibility of free-ranging quokkas (*Setonix brachyurus*) in preferred areas of a walk-through enclosure at Melbourne Zoo, Australia. In a controlled experiment, two visitor treatments were randomly imposed: (1) enclosure open to visitors as normal ('Open'); and (2) enclosure closed to visitors ('Closed'). Treatments were imposed for 2-day periods, with five replicates of each treatment (10 2-day periods in total). Instantaneous point sampling of camera footage at 1-min intervals from 0900h to 1600h each day recorded the location and visibility of quokkas. Data were analyzed using a two-factor ANOVA (visitor treatment and study area), with 2-day summary values as the unit of analysis. While the presence of quokkas in the study areas was not affected by treatment, fewer ($p<0.05$) quokkas were visible from the visitor paths and more ($p<0.05$) quokkas were obscured from the visitor paths in the 'Open' treatment than the 'Closed' treatment. Number of quokkas differed between study areas across treatments ($p<0.01$), but there was no interaction ($p>0.05$) between visitor treatment and study area. The reduction in quokka visibility when visitors were present indicates that visitors were at least moderately fear provoking for the quokkas in this experiment, but further research is required to examine the effects of visitor presence and behaviors on the behavior and stress physiology of quokkas in walk-through enclosures, as there may be possible welfare implications.

Keywords: quokka behavior; human-animal interactions; visitor effects; zoo animals; animal welfare

1. Introduction

Identifying and promoting optimal welfare states for zoo-housed animals has become a priority for many zoological institutions and associations worldwide (WAZA, 2015). Public interest in and perception of animal welfare issues have also increased rapidly in the recent past (Whitham & Wielebnowski, 2013), driving increased concern for improving captive animals' conditions. Zoo animal welfare can be influenced (positively or negatively) by a myriad of factors, including husbandry practices (Balcombe, *et al.*, 2004; Melfi, 2009; 2013), enclosure design (Appleby, 1997; Fernandez, *et al.*, 2009; Morgan & Tromborg, 2007), environmental enrichment (Bashaw, *et al.*, 2003; Claxton, 2011; Hosey, 2005) and exposure to visitors (Carder & Semple, 2008; Carlstead, 2009; Davey, 2007; Farrand, *et al.*, 2014). In relation to visitor effects on animals, there is evidence that these can be stressful (Birke, 2002; Davis, *et al.*, 2005; Mason, 2010; Sherwen, *et al.*, 2015a; 2015c), enriching (Claxton, 2011; Hosey, 2013; Jones, *et al.,* 2016; Manna, *et al.*, 2007), or innocuous (Choo, *et al.*, 2011; Hosey & Melfi, 2015; Sherwen, *et al.*, 2014; 2015b). Much of the variation in zoo animal responses to visitors may be the result of species-specific differences, the nature of the visitor interactions, enclosure design or individual animal characteristics (e.g. past experiences and coping style).

Zoos may encourage visitor-animal interaction through the offering of animal presentations, behind the scenes and close-up/close-contact experiences, or through immersive, walk-through enclosures with free-ranging animals (Morgan & Tromborg, 2007; Moss & Esson, 2010; Sherwen, *et al.*, 2015c). These activities are believed to enhance visitor experience and learning outcomes, and ultimately contribute to conservation goals (Clayton, *et al.*, 2008; Skibins & Powell, 2013). Walk-through enclosures often have minimal physical barriers between visitors and animals, and are designed to increase engagement and interest in zoo visitors. Walk-through enclosures are becoming increasingly popular in zoo designs, however, research into the effects on animals and visitors in these environments is lacking (Sherwen, *et al.*, 2015c).

While fear is an adaptive response to aversive stimuli (Gray, 1987; Mellor, 2012), fear is a negative affective experience, and intense and prolonged fear is widely considered an undesirable state of suffering (Dawkins, 2004; Forkman, *et al.*, 2007). Anecdotal observations on quokkas in the free-ranging exhibit at Melbourne Zoo (Zoos Victoria, Australia) suggested that the quokkas avoided many visible areas of their enclosure during zoo operating hours, when zoo visitors were likely to be present. The zookeepers reported that this group of quokkas were all generally timid, shy individuals, but would regularly approach familiar keepers and occasionally some visitors.

To study the effects of visitors on the behavior of the quokkas, we examined whether visitor presence affected the presence and visibility of the quokkas from the visitor walking paths in a walk-through enclosure at Melbourne Zoo.

2. Methodology

2.1 Study animals and enclosure

The study animals were seven adult female quokkas (*Setonix brachyurus*) located in an enclosure at Melbourne Zoo (Zoos Victoria, Australia). All quokkas were captive-born, and ranged from 2 to 9 years old. The enclosure was a walk-through exhibit, with a looping central path for visitors fenced off from several grass and shrubbery areas and an off-display, sandy retreat area which provided the quokkas with nest boxes, food bowls and access for zookeepers. The layout of the enclosure is shown in Figure 1. This research received animal ethics approval from the Zoos Victoria Animal Ethics Committee (ZV15003; Zoos Victoria, Melbourne, Victoria, Australia).

[FIGURE 1 PLACEMENT]

2.2 Experimental procedure

We employed the classic experimental design paradigm to conduct a 'cause and effect' experiment in which two treatments were randomly allocated to the population. We used a completely randomized design (Cochran & Cox, 1957) to allocate five replicates of each of the two treatments. Under this framework, the population of quokkas was considered a single subject and each treatment replicate was the experimental unit, thereby giving a total of 10 experimental units. The two treatments were: (1) the quokka enclosure was open to visitors as normal ('Open'); and (2) the enclosure was closed to visitors by locking the visitor access gates ('Closed'). The treatments were imposed for 2 days for each replicate. Similar study designs on enclosures of zoo animals have been used previously to examine visitor effects (Bloomfield, *et al.*, 2015; Sherwen, *et al*., 2014; 2015a; 2015b; 2015c).

To allow the quokkas to acclimatize to the treatment, a minimum of 5 days separated each replicate irrespective of treatment. On all non-experimental days, the enclosure was open to visitors as per standard zoo conditions. Treatments were only imposed on weekdays to reduce the normal variation in visitor numbers between weekdays and weekends.

2.3 Study areas and observations

Preliminary observations during quiet and busy visitor periods identified five areas most preferred by the quokkas (i.e. most used areas during daytime hours); these areas were labelled "Shrubs"; "Retreat area"; "Open Grass$_1$"; "Open Grass$_2$"; and "OpenGrass$_3$" as shown in Figure 1. Seven cameras in total were installed overhead or at visitor eye level in order to film both the number of the quokkas in these areas, and whether they were obscured from view from the visitor path by physical features in these areas (such as small shrubs and tall-grass). Each open grass area included a clear central space of short grass bordered by tall grasses and shrubs that the quokkas could move into for shelter.

Instantaneous point sampling at 1-min intervals from 0900h to 1600h each day was used to record the number of quokkas in each study area and whether visible or obscured from the view of visitors on the path by the physical features in the study area.

2.5 Statistical analysis

A single summary value, for each measurement, on each of the 10 2-day study periods (replicate) was calculated. Thus, the average number of quokkas in each study area per sample point, and the average number of quokkas either visible or obscured from the visitor path in each study area per sample point were calculated. Furthermore, the average proportion of quokkas visible from the visitor path in each study area per sample point was calculated. Measurements were analyzed using two-factor analysis of variance (IBM SPSS Statistics 21) with the 2-day measurements as the unit of analysis to examine the effects of treatment and study area. The analyses used between-2-day error for assessing the effect of treatment and enclosure area.

Study areas were further classified as "Open" (Open Grass 1, 2 and 3) or "Undercover" (Shrubs and Retreat Area). The open areas were also analyzed excluding the undercover areas, as this was deemed to reflect the most prominent visitor-quokka proximity and visibility points. Analyses are presented for the open study areas only as well as all study areas.

3. Results

There were 5,083 visitors to the enclosure in the Open treatment during the experiment. There were no interactions between main effects ($p>0.05$) on any of the variables studied. There were no treatment effects on the total number of quokkas in each study area. There were significant effects of both treatment and enclosure area on the numbers of quokkas both visible and obscured from the viewing path, and the proportion of quokkas visible from the viewing path (Table 1).

[TABLE 1 PLACEMENT]

Fewer quokkas were in visible positions from the visitor path ($p<0.02$) and more quokkas were in obscured positions from the visitor path ($p<0.02$) when the enclosure was open to visitors than when closed to visitors. Furthermore, the proportion of quokkas that were in visible positions from the viewing path was also lower when the enclosure was open to visitors ($p<0.01$). LSD comparisons showed that the number of quokkas observed differed between the areas (Table 2), with most quokkas in the Open $Grass_2$ area.

[TABLE 2 PLACEMENT]

4. Discussion

The presence of quokkas in the study areas was not affected by treatment. However, in both absolute and percentage terms, fewer quokkas were visible in the study areas from the visitor path when the enclosure was open to the visitors than when closed to visitors. The magnitude of the visitor effect was more pronounced when considering only the three open areas, with a 28% decrease in the proportion of quokkas visible in the open areas when the enclosure was open to visitors, suggesting that the quokkas were avoiding visible areas when visitors were present. Avoidance behaviors have been widely used as an indicator of fear of humans in animals (Forkman, et al., 2007; Gray, 1987; Hemsworth & Coleman, 2011; Sherwen, et al., 2015a,b,c). Fear-provoking stimuli generally include environmental stimuli which are novel and have high intensity, such as loud, large and looming stimuli (Gray 1987), and thus unfamiliar humans whose interactions are close, loud, fast and unexpected may be threatening for many zoo species. Sherwen *et al.* (2015c) recently found that Australian Little Penguins at Melbourne Zoo positioned themselves further from visitor viewing area and spent more time behind enclosure features when visitors were present. In addition to exposure to unfamiliar humans, avoidance responses are evident in zoo animals when exposed to specific fear-provoking visitor behaviors (Hosey, 2000; 2008; 2013; Hosey

& Melfi, 2015; Sherwen, 2015a). The reduced visibility of quokkas when the walk-through enclosure was open to visitors in the present study suggest that visitors were at least moderately fear provoking for this group of quokkas. Whether it was merely the presence of unfamiliar visitors, or patterns of avoidance due to prior exposure to specific fear-provoking visitor behaviors was undetermined. Visitors may display a range of fear-provoking behaviors such as banging on exhibit features, shouting, waving, or throwing objects to elicit some response when animals are not visible or active (Sherwen, *et al.*, 2014; 2015a). Indeed, incidental footage of visitors in the present study revealed children and adults running, shouting, crawling under bushes, traversing or forcibly breaching fence barriers, and approaching and attempting to physically interact with quokkas. Many of these visitor behaviors may be perceived by the quokkas as high intensity fear-provoking stimuli (Gray, 1987) and thus learnt avoidance responses may be a successful strategy to reduce fear and stress. These learnt responses in the quokkas may arise through direct experience or observing their conspecifics, as they have been reported to exhibit partial social learning (Bonney & Wynne, 2004). Avoidance behaviors by the quokka group towards zookeeper presence and interactions were not reported by keepers, suggesting this avoidance response may be to specific visitor behaviors, not merely the presence of humans.

Other reasons for the observed decrease in visibility may include environmental factors, such as temperature or weather, however the treatments were replicated over a 10-week period and thus there should not have been any systematic variation in the temperature and weather variables. Predatory avoidance may elicit the same fear response from quokkas – hiding in tall-grasses or under shrubs – and quokkas may be perceiving humans as predators. However, the avoidance behavior observed may not be predator avoidance due to documented predator-naïvety in the behaviors of wild quokkas (de Tores, *et al.*, 2007).

It is interesting that while quokka visibility decreased when the enclosure was open to visitors, the quokkas' presence in the study areas did not change. This suggests that there were features or conditions in these areas that were attractive, so the preference for these study areas was not affected when visitors were present. Features or conditions that may influence attraction to these areas include desirable environmental conditions (such as access to sunlight and shade), and foraging or feeding opportunities. Furthermore, quokkas may be territorial in their use of these areas, but individual territoriality has not been well documented in the species (de Tores, *et al.*, 2007).

The implications of this fear behavior on quokka welfare is unknown. Previous studies of other species have concluded that avoidance behaviors are indicative of fear responses, and animals displaying these behaviors may be experiencing heightened or prolonged levels of fear and consequently stress, which has obvious implications on welfare (Gray, 1987; Hemsworth & Coleman, 2011; Kuhar, 2008; Mason, 2010; Sherwen, et al., 2015c; Wells, 2005). However, the avoidance shown by the quokkas when visitors were present may have been a successful coping mechanism, sufficient to ameliorate their fear and consequently stress. The focus of this preliminary investigation was to identify visibility of the quokkas during enclosure open and closed treatments, but clearly further research is required to investigate the implications of visitor presence and behavior on the behavior and physiological stress experience (by fecal glucocorticoid metabolite analysis) of the quokkas. More detailed observations of specific visitor and quokka behaviors, and stimulus-response patterns during visitor-quokka interactions, as well as further investigation of visitor factors (e.g. crowd size and time of day), would allow the possible welfare implications to be clearly identified.

5. Conclusions

The finding that fewer quokkas were visible in their preferred areas (the study areas) when visitors were present indicates that visitors were at least moderately fear provoking for this group of quokkas. However, this result may only be applicable to this particular group of quokkas, or these particular conditions. Further research is required to examine the effects of visitor presence and behavior on the avoidance behavior and stress physiology of quokkas in walk-through enclosures because of the possible welfare implications identified in the present study.

Acknowledgements

The authors would like to acknowledge the technical support of Samantha Borg, the advice and support of the zookeepers and staff at Melbourne Zoo, and to Zoos Victoria for facilitating this research. Research was conducted through the Animal Welfare Science Centre, Faculty of Veterinary and Agricultural Sciences, University of Melbourne. This research was supported by funding from an Australian Research Council Linkage Project grant, LP140100373.

References

Appleby, M. (1997). Life in a variable world: Behavior, welfare and environmental design. *Applied Animal Behavior Science, 54*(1), 1-19.

Balcombe, J., Barnard, N. and Sandusky, C. (2004). Laboratory routines cause animal stress. *Contemporary topics in Laboratory Animal Science, 43*(6), 42-51.

Bashaw, M., Bloomsmith, M., Marr, M. & Maple, T. (2003). To hunt or not to hunt? A feeding enrichment experiment with captive large felids. *Zoo biology, 22*(2), 189-198.

Birke, L. (2002). Effects of browse, human visitors and noise on the behavior of captive orang-utans. *Animal Welfare, 11,* 189-202.

Bloomfield, R.C., Gillespie, G.R., Kerswell, K.J., Butler, K.L. & Hemsworth, P.H. (2015). Effect of partial covering of the visitor viewing area window on positioning and orientation of zoo orangutans: a preference test. *Zoo Biology*. (*In press*)

Bonney, K. R., & Wynne, C. D. L. (2004). Studies of learning and problem solving in two species of Australian marsupials. *Neuroscience & Biobehavioral Reviews*, *28*(6), 583-594.

Carder, G. & Semple, S. (2008). Visitor effects on anxiety in two captive groups of western lowland gorillas. *Applied Animal Behavior Science, 115*(3-4), 211-220.

Carlstead, K. (2009). A comparative approach to the study of keeper–animal relationships in the zoo. *Zoo biology, 28*(6), 589-608.

Choo, Y., Todd, P.A., & Li, D., (2011). Visitor effects on zoo orangutans in two novel, naturalistic enclosures. *Applied Animal Behavior Science, 133,* 78–86.

Clayton, S., Fraser, J., & Saunders, C.D. (2008). Zoo experiences: conversations, connections, and concern for animals. *Zoo Biology, 28*, 377–397.

Claxton, A.M. (2011). The potential of the human-animal relationship as an environmental enrichment for the welfare of zoo-housed animals. *Applied Animal Behavior Science, 133,* 1-10.

Cochran, W.G. & Cox, G.M. (1957). *Experimental Designs*. *pp.56-57*. Wiley: New York.

Davey, G. (2007). Visitors' Effects on the Welfare of Animals in the Zoo: A Review. *Journal of Applied Animal Welfare Science, 10*(2), 169-183.

Davis, N., Schaffner, C.M., & Smith, T. (2005). Evidence that zoo visitors influence HPA activity in spider monkeys (Ateles goeffroyii rufiventris). *Applied Animal Behavior Science*, *90*, 133-141.

Dawkins, M.S. (2004). Using behavior to assess animal welfare. *Animal Welfare, 13*, 3-7.

De Tores, P. J., Hayward, M. W., Dillon, M. J., & Brazell, R. I. (2007). Review of the distribution, causes for the decline and recommendations for management of the quokka, Setonix brachyurus (Macropodidae: Marsupialia), an endemic macropodid marsupial from south-west Western Australia. *Conservation Science Western Australia, 6*(1), 13-73.

Farrand, A., Hosey, G. and Buchanan-Smith, H. M. (2014). The visitor effect in petting zoo-housed animals: Aversive or enriching. *Applied Animal Behavior Science, 151,* 117-127.

Fernandez, E., Tamborski, M., Pickens, S. & Timberlake, W. (2009). Animal-visitor interactions in the modern zoo: Conflicts and interventions. *Applied Animal Behavior Science, 120*(1-2), 1-8.

Forkman, B., Boissy, A., Meunier-Salaun, M.-C., Canali, E., & Jones, R.B. (2007). A critical review of fear tests used on cattle, pigs, sheep, poultry and horses. *Physiology & Behavior, 92,* 340-374.

Goulart, V., Azevedo, P., van de Schepop, J., Teixeira, C., Barçante, L., Azevedo, C. & Young, R. (2009). Gaps in the Study of Zoo and Wild Animal Welfare. *Zoo biology, 28*(6), 561-573.

Gray, J. A. (1987). *The Psychology of Fear and Stress, 2nd Edition*. Cambridge University Press: Cambridge, UK.

Hemsworth, P.H., & Coleman, G.J. (2011). *Human-Livestock Interactions: The Stockperson and the Productivity and Welfare of Farmed Animals, 2nd Edition*. CAB International: Oxon, UK.

Hosey, G. (2000). Zoo animals and their human audiences: what is the visitor effect? *Animal Welfare, 9,* 343-357.

Hosey, G. (2005). How does the zoo environment affect the behavior of captive primates? *Applied Animal Behavior Science, 90*(2), 107-129.

Hosey, G. (2008). A preliminary model of human-animal relationships in the zoo. *Applied Animal Behavior Science, 109,* 105-127.

Hosey, G. (2013). Hediger Revisited: How Do Zoo Animals See Us? *Journal of Applied Animal Welfare Science, 16*(4), 338-359.

Hosey, G. & Melfi, V. (2015). Are we ignoring neutral and negative human-animal relationships in zoos? *Zoo Biology, 34,* 1-8.

Jones, H., McGregor, P. K., Farmer, H. L. A., & Baker, K. R. (2016). The influence of visitor behavior on captive Crowned Lemurs (Eulemur coronatus) and implications for welfare. *Zoo Biology, 35(3),* 222-228.

Kuhar, C.W. (2008). Group differences in captive gorillas' reaction to large crowds. *Applied Animal Behavior Science, 110,* 377-385.

Manna, D., Rodeano, M., & Ferrero, E. A. (2007). A lemur mixed exhibit at Parco Zoo Punta Verde, Italy. *International Zoo News, 54(8),* 452-457.

Maple, T. & Perdue, B. M. (2013). *Zoo animal welfare.* New York: Springer.

Margulis, S.W., Hoyos, C., & Anderson, M. (2003). Effect of felid activity on zoo visitor interest. *Zoo Biology, 22,* 587-599.

Mason, G.J. (2010). Species differences in responses to captivity: stress, welfare and the comparative method. *Trends in Ecology & Evolution, 25,* 713-721.

Melfi, V. (2009). There are big gaps in our knowledge, and thus approach, to zoo animal welfare: a case for evidence-based zoo animal management. *Zoo biology, 28*(6), 574-588.

Melfi, V. (2013). Is training zoo animals enriching? *Applied Animal Behavior Science, 147*(3-4), 299-305.

Mellor, D. J. (2012). Animal emotions, behavior and the promotion of positive welfare states. *New Zealand Veterinary Journal, 60,* 1–8.

Morgan, K. & Tromborg, C. (2007). Sources of stress in captivity. *Applied Animal Behavior Science, 102*(3-4), 262-302.

Moss, A. & Esson, M. (2010). Visitor Interest in Zoo Animals and the Implications for Collection Planning and Zoo Education Programmes. *Zoo biology, 29*(6), 715-731.

Packer, W. C. (1969). Observations on the Behavior of the Marsupial Setonix brachyurus (Quoy and Gaimard) in an Enclosure. *Journal of Mammalogy, 50*(1), 8-20.

Sherwen, S.L., Harvey, T.J., Magrath, M.J., Butler, K.M., Fanson, K.V. & Hemsworth, P.H. (2015a). Effects of visual contact with zoo visitors on Black-capped Capuchin welfare. *Applied Animal Behavior Science, 167,* 65-74.

Sherwen, S.L., Hemsworth, P.H., Butler, K.L., Fanson, K.V., & Magrath, M.J.L. (2015b). Impacts of visitor number on kangaroos housed in free-range exhibits. *Zoo Biology, 34(4),* 287-296.

Sherwen, S.L., Magrath, M.J.L., Butler, K.L., & Hemsworth, P.H. (2015c). Little Penguins, Eudyptula minor, show increased avoidance, aggression and vigilance in response to zoo visitors. *Applied Animal Behavior Science, 168,* 71-77.

Sherwen, S.L., Magrath, M.J.L., Butler, K.L., Phillips, C.J.C. & Hemsworth, P.H. (2014). A multi-enclosure study investigating the behavioral response of meerkats to zoo visitors. *Applied Animal Behavior Science, 156*, 70-77.

Skibins J.C. & Powell R.B. (2013). Conservation caring: Measuring the influence of zoo visitors' connection to wildlife on pro-conservation behaviors. *Zoo Biology, 32,* 528–540.

Wells, D. (2005). A note on the influence of visitors on the behavior and welfare of zoo-housed gorillas. *Applied Animal Behavior Science, 93*(1-2), 13-17.

Whitham, J. & Wielebnowski, N. (2013). New directions for zoo animal welfare science. *Applied Animal Behavior Science, 147*(3-4), 247-260.

World Association of Zoos and Aquariums (WAZA) (2015). *Caring for Wildlife: The World Zoo and Aquarium Animal Welfare Strategy. Eds: Mellor, D. J., Hunt, S. & Gusset, M.* Gland: WAZA Executive Office, 87 pp.

FIGURE 1 IMAGE FILE UPLOADED

TABLE 1: Effect of visitor presence on the presence and visibility of the quokkas from the visitor walking paths in five study areas of the exhibit.

VARIABLE	TREATMENT		F-VALUE (DF 1,18)	*P-VALUE*
	Closed to Visitors	Open to Visitors		
ALL AREAS				
Number of quokkas#	0.699	0.749	0.485	*0.495*
Number of quokkas visible#	0.357	0.248	6.861	***0.017***
Number of quokkas obscured#	0.341	0.501	6.632	***0.019***
Proportion of quokkas present that are visible	0.510	0.341	12.271	***0.003***
OPEN AREAS				
Number of quokkas#	0.797	0.876	0.501	*0.488*
Number of quokkas visible#	0.432	0.221	7.821	***0.012***
Number of quokkas obscured#	0.365	0.654	11.695	***0.003***
Proportion of quokkas present that are visible	0.528	0.247	15.453	***0.001***

#average number of quokkas per sample point.

TABLE 2: LSD multiple comparisons for number of quokka observed in areas. Significant P values presented in bold.

Study area	**Mean number of quokkas#**	**LSD p-value for each study area**				
		SHRUBS	RETREAT	OG1	OG2	OG3
SHRUBS	(0.143)	-	**0.001**	0.766	**0.001**	**0.002**
RETREAT	(0.969)	**0.001**	-	**0.001**	**0.001**	**0.007**
OG1	(0.184)	0.766	**0.001**	-	**0.001**	**0.004**
OG2	(1.764)	**0.001**	**0.001**	**0.001**	-	**0.001**
OG3	(0.585)	**0.002**	**0.007**	**0.004**	**0.001**	-

#average number per sample point. OG = Open Grass 1, 2 & 3.

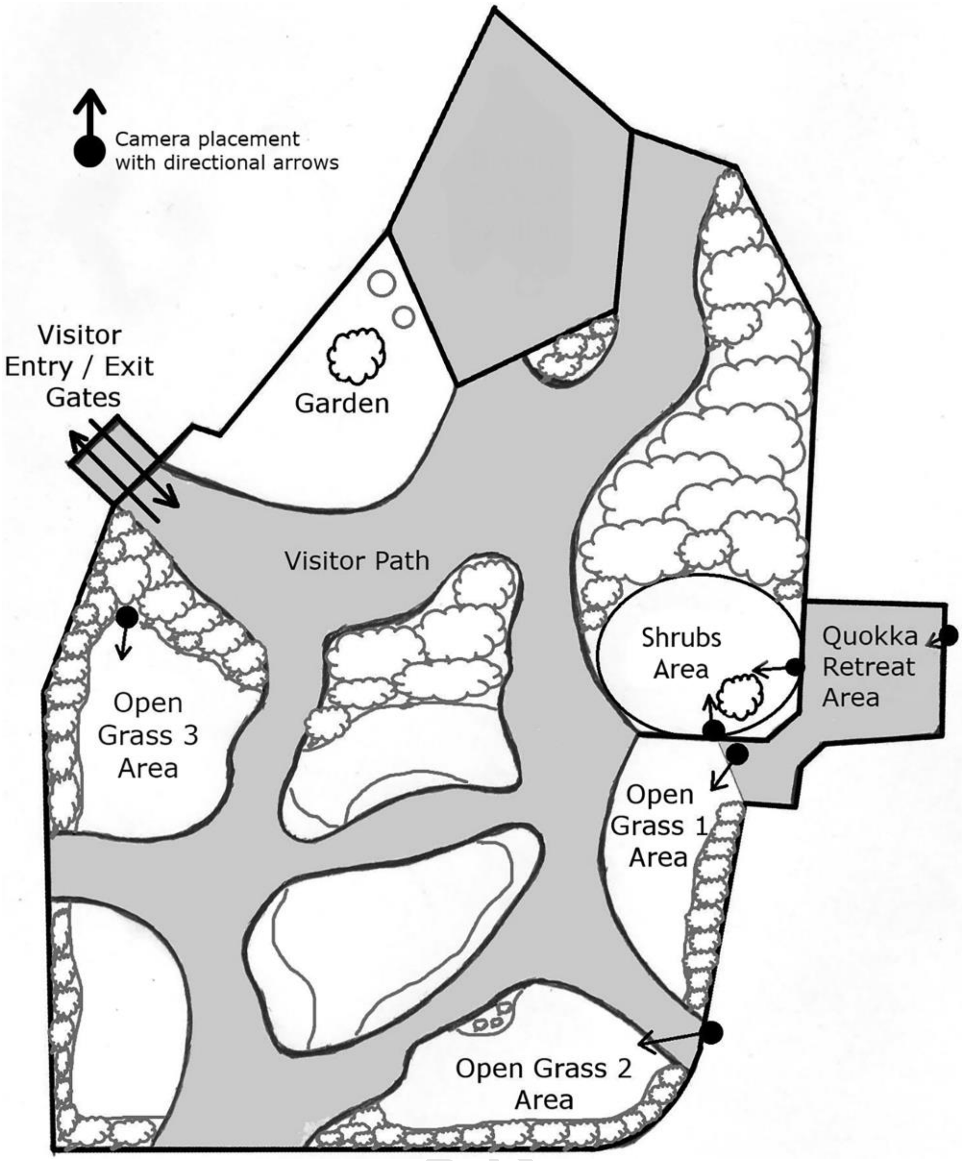
Camera placement
with directional arrows
Visitor
Entry / Exit
Gates
Garden
Visitor Path
Shrubs
Area
Quokka
Retreat
Area
Open
Grass 3
Area
Open
Grass 1
Area
Open Grass 2
Area

Figure 1