



Article

# Zoo Closure Does Not Affect Behavior and Activity Patterns of Palawan Binturong (*Arctictis binturong whitei*)

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**Abstract:** Exploring the interaction between humans and animals has become increasingly important in the evaluation of well-being for species housed in zoos and aquaria. The COVID-19 pandemic saw the global closure of zoos and aquaria to visitors. Chester Zoo, U.K., was no exception, with the charity shutting its doors for the longest period in its 90-year history. Whilst access to site was strictly limited to essential animal care staff, recent investment in networked infrared CCTV camera systems allowed some species to be monitored remotely during this extraordinary period of zoo closure. Here, we used this equipment to investigate whether zoo closure influenced activity patterns and behavior of two adult Palawan binturong, *Arctictis binturong whitei*. The cameras facilitated behavioral monitoring over 24 h enabling the collection of a full activity budget, which revealed a natural crepuscular activity pattern. Overall, visitor presence was found to have a neutral effect on this species, with no significant difference observed in time spent engaging in den use, vigilance or travel behaviors during zoo open and zoo closed conditions. A neutral visitor effect was found when evaluating behavior over a 24 h period and during hours which the zoo would normally be open to visitors (10:00–16:30). This research presents new information on this elusive and understudied species in captivity, and promotes investment in monitoring equipment which enables more comprehensive behavioral sampling than traditional visitor-effect methods.

**Keywords:** COVID-19; understudied; visitor effect; visitor-animal interactions; welfare; 24 h monitoring



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## 1. Introduction

Understanding the association between animals and humans has become increasingly important in the evaluation of animal well-being in zoos and aquaria. The newly updated Five Domains model for animal welfare assessment highlights the significance of this relationship, by integrating ‘animal-visitor’ interactions into their assessment approach. In this amendment, Mellor et al. [1] highlights the significance of human-animal relationships, stating that human behavior can elicit both positive, neutral and negative behavioral responses in animals [1,2].

A large body of research has accumulated over recent decades on the impact of visitor presence on zoo animal welfare [3–5]. As with many zoo studies, there is a taxonomic bias, with the largest number of visitor-effect studies focusing on non-human primates [6,7]. Although this bias is being slowly addressed, very few studies to date have focused on the impact visitors may have on crepuscular or nocturnal species [8]. This may be due to the assumption that these species might be less impacted by visitors as they spend most time active when visitors are not present [9]. However, this assumption should be treated with caution, as visitor presence might disturb vital inactive behaviors, such as rest and sleep which can have a detrimental impact animal wellbeing [10,11]. Furthermore, documenting the impact of visitors on nocturnal or crepuscular species presents a challenge

as institutions do not always have the ability to observe them during their natural period of activity. As animal care staff are largely present during daylight hours, monitoring opportunities are often limited to periods in which species, such as binturong, are largely inactive, causing the potential for welfare or behavioral issues to be unobserved [12]. Investment in infrared camera equipment with remote access options can help address these monitoring issues [13].

In 2020, the outbreak of COVID-19 forced zoos around the globe to close their doors to visitors for an extended period. Despite these circumstances, the abrupt and prolonged closure of zoos and aquaria worldwide provided a unique opportunity to investigate the effect that visitors may have on zoo-housed species [14–16]. For example, during this period, visibility of amphibian species was suggested to be influenced [17] whilst differences in behavior were attributed to seasonal rather than visitor effects for two species of flamingo (*Phoenicopterus roseus* and *Phoenicopterus chilensis*) [18]. Enclosure use alongside behavior was also explored in published literature in relation to visitor presence, with meerkats (*Suricata suricatta*) using more of their exhibit areas during periods of zoo closure, whilst space use for African penguins (*Spheniscus demersus*) was unaffected [19]. Additionally, space utilization combined with fecal glucocorticoid concentrations revealed an intra-individual difference in response to zoo closure for banteng (*Bos javanicus*), with a temporary elevation in glucocorticoid concentrations for two of the five animals studied and an increase in time spent close to visitor areas when zoo-visitors returned after closure [16]. Studies also varied in length, with some outlining a shorter pre to post closure comparison [20] whilst others looked more longitudinally, assessing seasonal differences in behavior alongside changes in visitor density [21].

This study documents activity patterns and behavior of two binturong during the closure of Chester Zoo, UK in response to the COVID-19 pandemic. The Palawan binturong (*Arctictis binturong whitei*) is a threatened frugivorous carnivore species, native to the forests of South-East Asia [22]. Fondly referred to as the ‘bear cat’, binturong are held in zoos due to their distinctive morphology and threatened conservation status. However, their naturally crepuscular activity pattern [23] means they are often resting during visitor opening hours. Using networked infrared CCTV cameras, we adopted a 24 h approach in monitoring of this under-studied species allowing for a more detailed insight into activity patterns and behavior in response to the absence of zoo visitors. Based on species natural history and previous published work [20,24,25], we make the following predictions: that binturong activity over 24 h will follow a crepuscular pattern (P1) and that these activity patterns are mostly likely to be affected by the change in visitor presence during zoo opening (P2). Additionally, we predict that engagement in specific behavioral categories may be influenced by the change in visitor presence, with vigilance behavior increasing during the zoo open condition (P3) and den use behavior decreasing throughout the zoo closed condition (P4).

## 2. Materials and Methods

### 2.1. Study Subjects and Housing

Study subjects were 1.1 (1 male, 1 female) Palawan binturong housed at Chester Zoo, U.K. (Figure 1). Both individuals were 11 years old at the time of study and formed part of a mixed species exhibit with 1.2 Malayan sun bears (*Helarctos malayanus*) in Chester Zoo’s ‘Islands’ area. The enclosure comprised of one indoor on-show exhibit (96 m<sup>2</sup>), with off-show den areas (7 m<sup>2</sup>) accessed through custom-built metal tunnels for this species, and two open-air outdoor on-show exhibits (totaling 2290 m<sup>2</sup>). Despite being a mixed species exhibit, several species-appropriate furnishings for the binturong were included within the environment such as overhead ropes, wooden posts and platforms to provide arboreal transit routes and resting sites. Subjects had 24 h access to the whole enclosure throughout data collection, except during times of keeper maintenance, which lasted for no more than 30 min, usually between the hours of 11:00–13:00.



**Figure 1.** Palawan binturong (*Arctictis binturong whitei*) housed at Chester Zoo.

## 2.2. Data Collection

Behavioral data were collected using continuous focal sampling via networked CCTV cameras (Axis IP Camera, North West Security Group) for 60 min observation periods [26], using a pre-determined ethogram (Table 1). Some observations ended earlier than the 60 min period due to observer availability through reduced staffing. Cameras had infra-red capability, with the footage being automatically saved and uploaded onto a server, allowing footage to be accessed and replayed remotely for up to one month after capture (Milestone XProtect video management software). Due to the nature of the exhibit, approximately 30% of the environment was not covered by CCTV cameras. Data collection aimed to cover the whole 24 h period equally, in order to obtain a comprehensive overview of behavior. Data collection during the ‘Zoo open’ phase were collected due to routine behavioral monitoring for this species as requested by staff within the animal collections directorate. Chester Zoo closed to the public on 21 March 2020, in response to the COVID-19 outbreak, and behavior observations on the binturong resumed 22 days later.

Data were collected during two conditions:

1. Zoo open: Before zoo closure to the public due to the COVID-19 pandemic (5 March 2020–19 March 2020).
2. Zoo closed: During zoo closure to the public due to the COVID-19 pandemic (13 April 2020–5 May 2020).

Total combined observation time for both individuals was 184.6 h ( $n = 5$  days) in the ‘Zoo open’ condition and 163.2 h ( $n = 6$  days) in the ‘Zoo closed condition’. During the ‘Zoo open’ condition, visitors had access to site from 10:00–16:30. Data were collected digitally, with information inputted directly into a Microsoft Excel spreadsheet by the observers (KF and ML). Study subjects remained in a consistent social grouping, with no management or husbandry routine changes throughout the data collection window. As all observations were conducted remotely using CCTV cameras, there was no observer influence.

**Table 1.** Species-specific ethogram for binturong (*Arctictis binturong whitei*), with descriptions of each behavior outlined. Active behavior category highlights behaviors included when evaluating activity levels. Behavior category highlights how individual behaviors were grouped for behavior analysis.

Active Behaviors	Behavior Category	Behavior	Description
N/A	Den use	Den utilization	Specimen (sp.) is spending time in the den area of the exhibit out of view to the observer.
Active	Other	Feeding	Sp. is chewing and consuming food or water.
Active	Other	Grooming	Sp. is scratching, licking or rubbing themselves against objects within the enclosure.
Inactive	Other	Rest awake	Sp. eyes are open but sp. motionless and displaying no alert or active vigilance behaviors.
Inactive	Other	Rest	Sp. has eyes closed, body relaxed and no movement is observed.
Active	Other	Social interaction	Sp. is engaging in any form of interaction with conspecific. Note whether the interaction was affiliative or aggressive.
Active	Other	Sniffing	Sp. is pressing nose to specific area, inhalation of air can be seen from nostrils.
Active	Other	Sun bear interaction	Sp. engaging in any form of interaction with sun bear.
Active	Travel	Travel	Sp. is moving from one area of environment to another. Includes climbing on and traversing across ropes, branches or moving quadrupedally along the floor or flat surfaces.
Active	Vigilance	Vigilance	Sp. is responsive to stimuli, looking around observing environment or eyeline actively focused in a specific direction.
N/A	N/A	Not visible	Sp. is not visible to the observer in areas of the exhibit other than the den.

For visualization of activity levels across a 24 h period, individual behaviors were grouped into ‘Active’ or ‘Inactive’ categories (Table 1). For the analysis of specific behaviors in response to zoo closure, individual behaviors were re-grouped into main behavior categories (Table 1). In order to gain a holistic insight into how visitors may influence species engagement in defined behavioral categories, data were split into two distinct time periods ‘24 hour’ which contained all time periods observed 00:00:00–23:59:59 and ‘Zoo visitor opening hours’ which contained time periods 10:00:00–16:30:00. Due to low engagement in the ‘Other’ behavioral category (<1% of total activity budget), these behaviors were removed from statistical analysis.

### 2.3. Statistical Analysis

Statistical analyses were conducted in R (Version 3.6.2) [27]. Proportion of time spent engaging in each behavior category were calculated per hour and averaged during each day (‘Day’ was defined as 00:00:00–23:59:59) of data collection. Day was then treated as the experimental unit. Due to blind spots in the CCTV camera coverage, data were only analyzed from periods of time which were either visible to the observer or their location was undisputed, e.g., time utilizing den areas. Behavior data were found to be non-normally distributed (Shapiro Wilks test for normality,  $w = 0.516$ ,  $p < 0.005$ ) and transformations failed to normalize the data, as a result non-parametric tests were used. Paired Wilcoxon signed rank tests were used to compare the mean proportions of time spent engaging in each behavior category between the ‘Zoo open’ and ‘Zoo closed’ conditions. No significant difference in time spent in each behavior category between the study subjects was found (Wilcoxon signed rank test:  $W = 50$ ,  $p = 0.913$ ), therefore data from each individual were combined and analyzed as one data set throughout. Activity patterns are displayed using descriptive statistics using means  $\pm 1$  standard error.

### 3. Results

#### 3.1. Visible Activity Patterns of Zoo-Housed Binturong

Across the 24 h period, peaks in activity patterns were observed between 05:01–06:00 (19.55% ± 8.98) and between 20:01–00:00 (20:01–21:00: 17.91% ± 10.65, 21:01–22:00: 18.53% ± 7.14, 22:01–23:00: 13.91% ± 8.59 and 23:01–00:00: 26.79% ± 12.45, Figure 2a). This revealed a crepuscular nature to activity, as predicted in P1. Throughout the ‘Zoo open’ condition, no activity was observed between the hours of 07:01–11:00 and 12:01–17:00 (Figure 2b). Throughout the ‘Zoo closed’ condition, no activity was observed between the hours of 07:01–10:00 and 00:00–03:00 (Figure 2b). When comparing the activity of the study subjects during the ‘Zoo open’ and ‘Zoo closed’ periods of data collection, there was greater variation in activity levels between the two conditions, particularly between the hours of 10:00–17:00, a time when zoo visitors had access to site in the ‘Zoo open’ condition (Figure 2b). However, when analyzed this trend was found to be non-significant ( $V = 17$ ,  $p = 0.22$ ). This finding is contrary to what was predicted in P2, that activity patterns are mostly likely to be affected by the change in visitor presence during the hours of normal zoo opening times.

#### 3.2. Activity Budget of Zoo Housed Binturong in Relation to COVID-19 Zoo Closure

When considering behavior over a 24 h period during the ‘Zoo open’ compared to ‘Zoo closed’ conditions, there were no significant differences in proportion of behavior observed (Wilcoxon signed rank test: Den Use,  $V = 8.00$ ,  $p = 1$ , Travel,  $V = 6.00$ ,  $p = 0.81$ , Vigilance,  $V = 8.00$ ,  $p = 1.00$ , Figure 3). When considering behavior during zoo visitor opening hours only, there were no significant differences in proportion of behavior observed (Wilcoxon signed rank test: Den Use,  $V = 13.00$ ,  $p = 0.19$ , Travel,  $V = 3.00$ ,  $p = 0.31$ , Vigilance,  $V = 2.00$ ,  $p = 0.19$ , Figure 3). These findings were contrary to our prediction that engagement in specific behavioral categories may be influenced by the change in visitor presence (P3). As stated in the ethogram (Table 1), various behaviors were grouped in the ‘Other’ category.

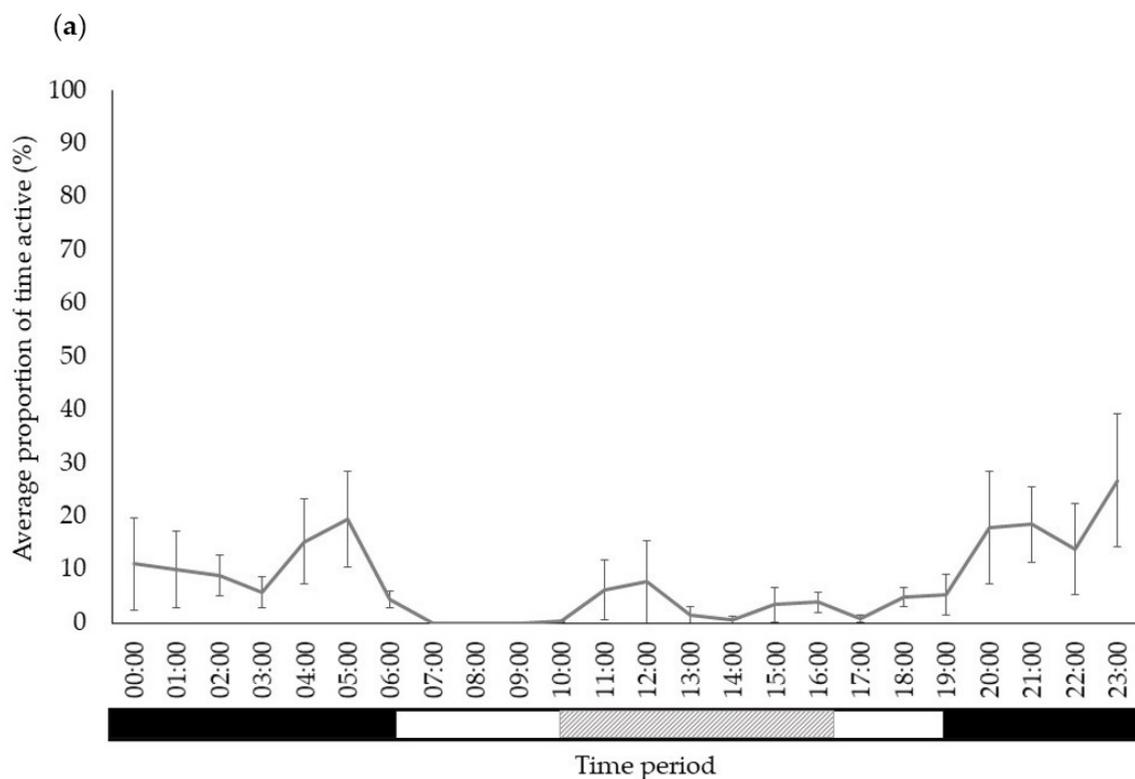
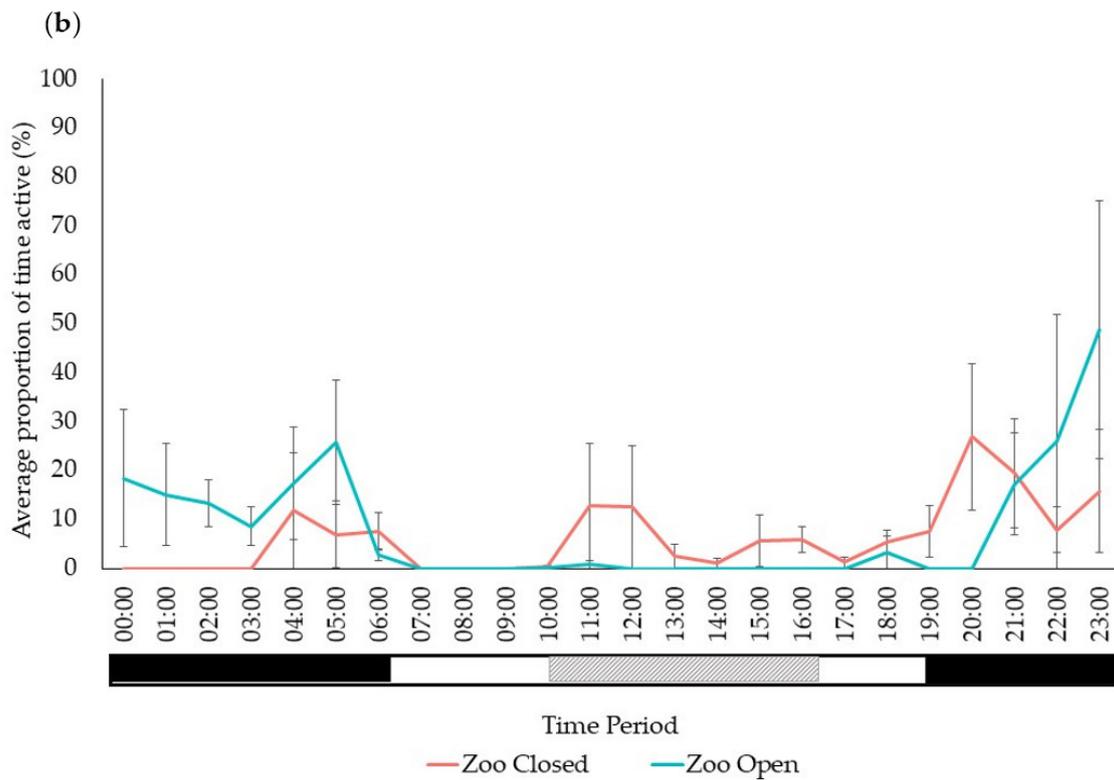
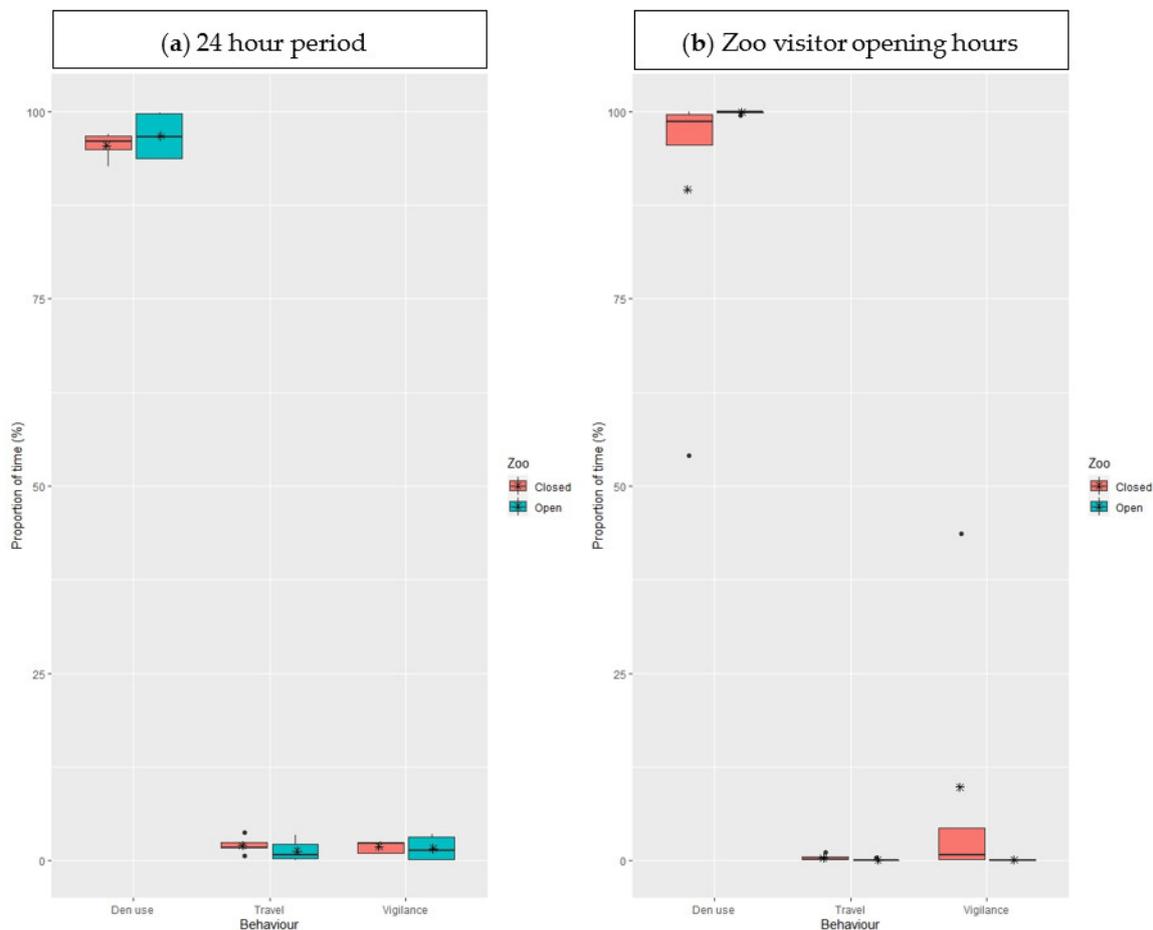


Figure 2. Cont.



**Figure 2.** (a) Mean ( $\pm 1$  SE) proportion of time spent active when visible across a 24 h period for two Palawan binturong (*Arctictis binturong whitei*) throughout the whole data collection period and (b) Mean ( $\pm 1$  SE) proportion of time spent active across a 24 h period for two binturong split into periods of time in which Chester Zoo was open and closed to members of the public due to the COVID-19 pandemic. The box along the x axis represents the photoperiod: periods of darkness (black) and periods of daylight (white) using dawn and dusk times [www.weatheronline.com (accessed on 14 March 2020)]. The grey hashed lines represent zoo visiting hours for members of the public during the ‘Zoo open’ condition.

As engagement in the ‘Other’ behavioral category was so low across both conditions (<1% of visible activity budget), these behaviors were not subject to statistical testing. However, raw values (mean  $\pm$  standard error) outlining proportion of time spent in each behavior are presented as follows. Over 24 h—Zoo open condition; Social interaction (0.04%  $\pm$  0.026), Sniffing (0.12%  $\pm$  0.066), Sun bear interaction (0.01%  $\pm$  0.007), Resting awake (0.24%  $\pm$  0.237) Over 24 h—Zoo closed condition; Feeding (0.12%  $\pm$  0.059), Grooming (0.01%  $\pm$  0.005), Social interaction (0.05%  $\pm$  0.033) and Sniffing (0.52%  $\pm$  0.18). During zoo visitor hours, there was no engagement in any behaviors from the ‘Other’ category in the Zoo open condition. During the Zoo closed condition during zoo visitor hours, engagement in two behaviors from the ‘Other’ category were observed; Feeding (0.01%  $\pm$  0.01) and Sniffing (0.04%  $\pm$  0.014).



**Figure 3.** Proportion of time (%) two zoo-housed Palawan binturong (*Arctictis binturong whitei*) engaged in three behavioral categories throughout ‘Zoo open’ and ‘Zoo closed’ data collection periods over (a) 24 h period and (b) during zoo visitor opening hours (10:00–16:30). Time budgets displayed using boxplots outlining the first quartile, median, third quartile and range of the data. Black circles indicate outliers. Black star denotes the mean value of time spent engaging in each behavior category.

#### 4. Discussion

In this study we found that Palawan binturong at Chester Zoo exhibit a crepuscular activity pattern (as predicted in P1), which remained consistent when the zoo was both open and closed to visitors (differing from our second prediction, P2). The binturong spent most of their time exhibiting three main behaviors, ‘Den Utilization’, ‘Travel’ and ‘Vigilance’. Contrary to our predictions P3 and P4, the proportion of time spent exhibiting these behaviors did not significantly change between ‘zoo open’ and ‘zoo closed’ conditions.

Whilst studies often report the influence that zoo visitors have on animal behavior [28], some work has highlighted that visitor presence has little to no impact on the activity budget of zoo-housed species [8,19,29]. O’Donovan [30] reported that both visitor number and noise level did not influence the activity budget of cheetahs (*Acinonyx jubatus*) and Wascher et al. [29] outlined that no negative welfare impacts of visitors were found in relation to visitor presence in captive corvids. When assessed longitudinally, neither season nor visitor density had an influence on the behavior and welfare of five species of zoo-housed bear [21]. A neutral response to change in visitor numbers could be attributed to a degree of habituation to the presence of zoo visitors in a captive environment [31]. Patel et al. [32] highlight that the likelihood of habituation to visitors is greater if repeated visitor exposure has neither rewarding nor punishing elements and is therefore of no consequence to the species. Sherwen and Hemsworth [2] also outline that the degree to

which individuals are likely to habituate to visitor presence can be attributed to multiple factors, such as species-specific biology, enclosure design and individual differences in behavior. Furthermore, Sherwen and Hemsworth [2] suggest that a neutral response to visitors may be far more widespread than the current literature implies, due to a potential current publication bias. This bias may have been created as a consequence of a previous strong focus on highlighting factors which influence the welfare state of zoo-housed animals, rather than those that do not. When considering literature focusing on zoo-closure due to COVID-19, behavioral response was found to vary by species, with some being largely unaffected whilst other species were observed to alter their engagement in specific behavioral categories and enclosure utilization [17,19,20,33].

Similar to the findings in our study, activity levels of several large felid species at Brookfield Zoo were not found to be influenced by visitor presence. Margulis et al. [34] suggested that as the species observed were naturally inactive throughout most of the day, they were less likely to be affected by visitors, which could also be the case for Palawan binturong. Work by Queiroz and Young [9] supports this theory as they concluded diurnal species showed more behavioral changes in relation to visitor presence than nocturnal in a study of 17 mammal species. A suggested reason for this difference was that the diurnal animals were being observed during their normal activity cycle whilst nocturnal animals were largely inactive during the data collection window [9].

However, the human-animal relationship is complex [1]. Many variables could also influence animal behavior in zoos such as weather conditions, keeper visibility, time of day and husbandry routines [35]. Goodenough et al. [36] explored this relationship in a group of captive ring-tailed lemurs (*Lemur catta*) in a walkthrough exhibit, where potential for visitor effect was suggested to be high. Results revealed that time and weather exerted the strongest effect on behavior, affecting resting, feeding/foraging and locomotion. Similarly, Rose et al. [37] highlighted how any visitor effect is heavily influenced by environmental variables such as temperature and humidity in a pair of captive hornbills. Thus, future directions for work on our study species, the binturong, would be to collect further data allowing for a comprehensive evaluation of how environmental and other variables could influence the neutral visitor effect that we reported.

Little is known in relation to the natural behavioral patterns of Palawan binturong. Research has proved challenging on this elusive species, with individuals known to occupy densely planted, high canopy areas, making them difficult to detect and track in situ [38]. Camera trap images have been used to gather information on individual behaviors [22], revealing their activity pattern to vary from arrhythmic to crepuscular [18]. In light of this information we made the first prediction for this study (P1). P1 was found to be correct as the Palawan binturong at Chester Zoo were found to exhibit a crepuscular activity pattern, with the highest levels of activity observed between 04:01–05:00, 21:01–22:00 and 23:01–00:00. It should be noted however, that patterns of activity were reported to be highly seasonal for wild binturong, with individual travel behavior closely correlated with the timing of fruiting trees [39]. As such, further work may be beneficial during a range of seasons in order to ascertain whether the activity pattern recorded in this study is consistent across the calendar year.

Our finding that visitor presence does not cause behavioral changes in Palawan binturong addresses the gap in literature regarding visitor impacts on non-diurnal zoo-housed species. The neutral reported response to visitors by this species contradicts our predictions P2 to P4, but does help to prevent potential publication bias in this field. When accounting for species natural biology, the lack of response to visitor presence or absence, both during visitor opening hours and across a 24 h period, highlights that individuals are continuing to replicate their natural activity patterns. High utilization of the den area also shows that the enclosure design is facilitating individuals to have an element of choice in where they spend their time and provides them with an option to be out of view from visitors. Access to off-show areas was thought to mediate the visitor effect in a group of

brown bears, with no visitor influence on behavior found in individuals which had access to an indoor holding space [14].

However, the identification of non-significant trends in activity during time periods where visitors would usually be present should not be overlooked. Other factors such as interaction with other species housed in the same facility (in this case the Malayan sun bear), change in social dynamic of the study subjects or indirect consequence of visitor absence, such as a change in other staff not involved in animal care (guest experience coordinators, etc.) could all warrant further investigation. Furthermore, due to limited researcher capacity through reduced staffing only a short time window during zoo closure conditions was able to be captured. Data collection to investigate both the immediate and longer term responses to zoo closure would have been beneficial in gaining a more comprehensive insight into the visitor effect over a longer timeframe.

It is only by accounting for the full 24 h period that we can conclude that behavior and activity patterns of binturong housed at Chester Zoo were not affected by the COVID-19 closure. Whilst we observed greater variation in activity levels over zoo visitor opening hours, overall activity levels and the three main behaviors tested did not significantly change between the 'Zoo open' and 'Zoo closed' conditions. We therefore encourage the investment in appropriate monitoring equipment for species, particularly those who are biologically less active during zoo opening hours, in order to facilitate a more holistic overview of well-being.

## 5. Conclusions

Our findings followed our first prediction (P1) that 24 h activity patterns for Palawan binturong are crepuscular in nature. However, contrary to our second prediction (P2) we found that activity patterns did not change during zoo closure; this was the case over the full 24-h period and when just focusing on visitor opening hours. When considering our final two predictions, P3 and P4, we found them to be incorrect, as, engagement in vigilance and den use behavior of binturong was not affected by visitor presence in this study. We hope that the dissemination of this work will add to the knowledge base on this understudied and elusive species, whilst adding to the body of work surrounding the visitor effect on zoo-housed species in relation to COVID-19 closure, particularly highlighting information on the neutral visitor effect.

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## References

1. Mellor, D.J.; Beausoleil, N.J.; Littlewood, K.E.; McLean, A.N.; McGreevy, P.D.; Jones, B.; Wilkins, C. The 2020 Five Domains Model: Including Human–Animal Interactions in Assessments of Animal Welfare. *Animals* **2020**, *10*, 1870. [CrossRef] [PubMed]
2. Sherwen, S.L.; Hemsworth, P.H. The Visitor Effect on Zoo Animals: Implications and Opportunities for Zoo Animal Welfare. *Animals* **2019**, *9*, 366. [CrossRef]
3. Hosey, G.R. Zoo Animals and Their Human Audiences: What is the Visitor Effect? *Anim. Welf.* **2000**, *9*, 343–357.
4. Davey, G. Visitor behavior in zoos: A review. *Anthrozoös* **2015**, *19*, 143–157. [CrossRef]
5. Fernandez, E.J.; Tamborski, M.A.; Pickens, S.R.; Timberlake, W. Animal-visitor interactions in the modern zoo: Conflicts and interventions. *App. Anim. Behav. Sci.* **2009**, *120*, 1–8. [CrossRef]
6. Wells, D.L. A Note on the Influence of Visitors on the Behavior and Welfare of Zoo-housed Gorillas. *App. Anim. Behav. Sci.* **2005**, *93*, 13–17. [CrossRef]
7. Dancer, A.M.M.; Burn, C.C. Visitor Effects on Zoo-housed Sulawesi Crested Macaque (*Macaca nigra*) behavior: Can signs with ‘watching eyes’ requesting quietness help? *App. Anim. Behav. Sci.* **2019**, *211*, 88–94. [CrossRef]
8. Chiapero, F.; Ferrari, H.R.; Prieto, M.V.; Capocasa, M.C.G.; Busso, J.M. Multivariate Analyses of the Activity Pattern and Behavior of the Lesser Anteater on Open and Closed Days at Córdoba Zoo, Argentina. *J. Appl. Anim. Welf. Sci.* **2021**, *24*, 83–97. [CrossRef] [PubMed]
9. Queiroz, M.B.; Young, R.J. The Different Physical and Behavioral Characteristics of Zoo Mammals That Influence Their Response to Visitors. *Animals* **2018**, *8*, 139. [CrossRef]
10. Monticelli, P.F.; Morato, A.C.M.; Paula, B.C. We, the Disturbing Animal: Effects of Anthropogenic Noise in a Brazilian Zoo. *Tesis Psicol.* **2022**, *17*, 1–33. [CrossRef]
11. Fanning, L.; Larsen, H.; Taylor, P.S. A Preliminary Study Investigating the Impact of Musical Concerts on the Behavior of Captive Fiordland Penguins (*Eudyptes pachyrhynchus*) and Collared Peccaries (*Pecari tajacu*). *Animals* **2020**, *10*, 2035. [CrossRef] [PubMed]
12. Brando, S.; Buchanan-Smith, H.M. The 24/7 Approach to Promoting Optimal Welfare for Captive Wild Animals. *Behav. Processes* **2018**, *156*, 83–95. [CrossRef] [PubMed]
13. Diana, A.; Salas, M.; Pereboom, Z.; Mendl, M.; Norton, T. A Systematic Review of the Use of Technology to Monitor Welfare in Zoo Animals: Is There Space for Improvement? *Animals* **2021**, *11*, 3048. [CrossRef] [PubMed]
14. Podturkin, A.A. Behavioral Changes of Brown Bears (*Ursus arctos*) during COVID-19 Zoo Closures and Further Reopening to the Public. *J. Zool. Bot. Gard.* **2022**, *3*, 256–270. [CrossRef]
15. Masman, M.; Scarpace, C.; Liriano, A.; Margulis, S.W. Does the Absence of Zoo Visitors during the COVID-19 Pandemic Impact Gorilla Behavior? *J. Zool. Bot. Gard.* **2022**, *3*, 349–356. [CrossRef]
16. Edes, A.N.; Liu, N.C.; Baskir, E.; Bauman, K.L.; Kozłowski, C.P.; Clawitter, H.L.; Powell, D.M. Comparing Space Use and Fecal Glucocorticoid Concentrations during and after the COVID-19 Closure to Investigate Visitor Effects in Multiple Species. *J. Zool. Bot. Gard.* **2022**, *3*, 328–348. [CrossRef]
17. Boulwood, J.; O’Brien, M.; Rose, P. Bold Frogs or Shy Toads? How Did the COVID-19 Closure of Zoological Organisations Affect Amphibian Activity? *Animals* **2021**, *11*, 1982. [CrossRef]
18. Kidd, P.; Ford, S.; Rose, P.E. Exploring the Effect of the COVID-19 Zoo Closure Period on Flamingo Behavior and Enclosure Use at Two Institutions. *Birds* **2022**, *3*, 117–137. [CrossRef]
19. Williams, E.; Carter, A.; Rendle, J.; Ward, S.J. Understanding Impacts of Zoo Visitors: Quantifying Behavioral Changes of Two Popular Zoo Species during COVID-19 Closures. *App. Anim. Behav. Sci.* **2021**, *236*, 105253. [CrossRef]
20. Jones, M.; Gartland, K.N.; Fuller, G. Effects of Visitor Presence and Crowd Size on Zoo-Housed Red Kangaroos (*Macropus rufus*) During and After a COVID-19 Closure. *Anim. Behav. Cog.* **2021**, *8*, 521–537. [CrossRef]
21. Bernstein-Kurtyez, L.M.; Koester, D.C.; Snyder, R.J.; Vonk, J.; Willis, M.A.; Lukas, K.E. ‘Bearly’ Changing with the Seasons: Bears of Five Species Show Few Behavioral Changes Across Seasons and at Varying Visitor Densities. *Anim. Behav. Cog.* **2021**, *8*, 538–557. [CrossRef]
22. Debruille, A.; Kayser, P.; Veron, G.; Vergniol, M.; Perrigon, M. Improving the Detection Rate of Binturongs (*Arctictis binturong*) in Palawan Island, Philippines, through the Use of Arboreal Camera-Trapping. *Mammalia* **2020**, *84*, 563–567. [CrossRef]
23. Grassman, L.I.; Tewes, M.E.; Silvy, N.J. Ranging, Habitat Use and Activity Patterns of Binturong *Arctictis binturong* and Yellow-Throated Marten *Martes flavigula* in North-Central Thailand. *Wildlife Biol.* **2005**, *11*, 49–57. [CrossRef]
24. Fink, L.B.; Scarlata, C.D.; VanBeek, B.; Bodner, T.E.; Wielebnowski, N.C. Applying Behavioral and Physiological Measures to Assess the Relative Impact of the Prolonged COVID-19 Pandemic Closure on Two Mammal Species at the Oregon Zoo: Cheetah (*A. jubatus*) and Giraffe (*G. c. reticulata* and *G. c. tippelskirchii*). *Animals* **2021**, *11*, 3526. [CrossRef] [PubMed]
25. Hamilton, J.; Gartland, K.N.; Jones, M.; Fuller, G. Behavioral Assessment of Six Reptile Species during a Temporary Zoo Closure and Reopening. *Animals* **2022**, *12*, 1034. [CrossRef] [PubMed]
26. Martin, P.R.; Bateson, P.P.G. *Measuring Behavior: An Introductory Guide*, 3rd ed.; Cambridge University Press: Cambridge, UK, 2007.
27. R Core Team. *R: A Language and Environment for Statistical Computing*; R Foundation for Statistical Computing: Vienna, Austria, 2013; Available online: <http://www.R-project.org> (accessed on 20 May 2022).
28. Mallapur, A.; Sinha, A.; Waran, N. Influence of Visitor Presence on the Behavior of Captive Lion Tailed Macaques (*Macaca silenus*) Housed in Indian Zoos. *App. Anim. Behav. Sci.* **2005**, *94*, 341–352. [CrossRef]

29. Wascher, C.A.F.; Baur, N.; Hengl, M.; Köck, C.; Pegger, T.; Schindlbauer, J.; Wemer, L. Behavioral Responses of Captive Crovids to the Presence of Visitors. *Anim. Behav. Cog.* **2021**, *8*, 481–492. [[CrossRef](#)]
30. O'Donovan, D.; Hindle, J.E.; McKeown, S.; O'Donovan, S. Effect of Visitors on the Behavior of Female Cheetahs (*Acinonyx jubatus*) and Cubs. *Int. Zoo Yb.* **1993**, *32*, 238–244. [[CrossRef](#)]
31. Hosey, G.; Melfi, V. Are We Ignoring Neutral and Negative Human-Animal Relationships in Zoos? *Zoo Biol.* **2014**, *31*, 1–8. [[CrossRef](#)]
32. Patel, F.; Whitehouse-Tedd, K.; Ward, S. Redefining Human-Animal Relationships: An Evaluation of Methods to Allow Their Empirical Measurement in Zoos. *Anim. Welf.* **2019**, *28*, 247–259. [[CrossRef](#)]
33. Carter, K.C.; Keane, I.A.T.; Clifforde, L.M.; Rowden, L.J.; Fieschi-Méric, L.; Michaels, C.J. The Effect of Visitors on Zoo Reptile Behavior during the COVID-19 Pandemic. *J. Zool. Bot. Gard.* **2021**, *2*, 664–676. [[CrossRef](#)]
34. Margulis, S.W.; Hoyos, C.; Anderson, M. Effect of Felid Activity on Zoo Visitor Interest. *Zoo Biol.* **2003**, *22*, 587–599. [[CrossRef](#)]
35. Riley, A.; Terry, M.; Freeman, H.; Alba, A.C.; Soltis, J.; Leeds, A. Evaluating the Effect of Visitor Presence on Nile Crocodile (*Crocodylus niloticus*) Behavior. *J. Zool. Bot. Gard.* **2021**, *2*, 115–219. [[CrossRef](#)]
36. Goodenough, A.E.; McDonald, K.; Moody, K.; Wheeler, C. Are “visitor effects” Overestimated? Behaviour in Captive Lemurs is Mainly Driven by Co-variation with Time and Weather. *J. Zoo Aquar. Res.* **2019**, *7*, 59–66. [[CrossRef](#)]
37. Rose, P.E.; Scales, J.S.; Brereton, J.E. Why the “Visitor Effect” is Complicated. Unraveling Individual Animal, Visitor Number, and Climatic Influences on Behavior, Space Use and Interactions with Keepers—A Case Study on Captive Hornbills. *Front. Vet. Sci.* **2020**, *7*, 236. [[CrossRef](#)]
38. Bourgeois, A.; Kayser, P.; Debrulle, A.; Veron, G. *Binturong arctictis* Binturong Conservation: The Relationship between the Zoo Community and ABCConservation for an Integrated Conservation Programme in Palawan, Philippines. *Int. Zoo Yb.* **2020**, *54*, 120–130. [[CrossRef](#)]
39. Nakabayashi, M.; Ahmad, A.H.; Kohshima, S. Fruit Selection of a Binturong (*Arctictis binturong*) by Focal Animal Sampling in Sabah, Malaysian Borneo. *Mammalia* **2017**, *81*, 107–110. [[CrossRef](#)]