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JZAR Research article

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Research article

Does zoo visitor presence and noise impact the behaviour and enclosure use of zoo-housed Siamese crocodiles? A case study.

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Keywords: Crocodilian; Electivity Index, enclosure design, Post Occupancy Evaluation; visitor presence

Article history:
Received: 13 Jul 2023
Accepted: 19 Jul 2024
Published online: 31 Jul 2024

Abstract

Investigations of captive reptile behaviour and welfare indicators are essential if management styles are to be advanced. Humans are an integral part of the zoo environment and are a factor to consider when evaluating animal behaviour and welfare. Although crocodilians have been kept in zoos worldwide for decades, there is limited research on captive individuals. As crocodilians are naturally sensitive to sound, the noise that zoo visitors generate has been suggested to affect how individuals behave and use their environment. This project investigated the behaviour and enclosure use of a pair of Siamese crocodiles *Crocodylus siamensis* in order to quantify their response to zoo visitor presence and noise output. Camera traps were used to record the behaviour of the crocodilians across 24-hour time periods. The sampling technique applied was an instantaneous focal sampling method with two-minute intervals for state behaviour and an Electivity Index was applied to measure enclosure use of biologically relevant zones within the enclosures. The results identified that several variables were significant predictors of crocodilian behaviour, including ambient temperature, individual, time of day, visitor numbers and ambient noise (dB). Additionally, correlation analysis found that visitor numbers and ambient noise had only a weak, significant positive correlation ($r=0.298$, $P=0.017$). Most zones within the enclosure were underutilised by the crocodiles apart from zone 3 (the water bank). This demonstrates that hauling out areas between land and water (haul-out zones) may be of great value to the study crocodiles and it is therefore expected that these areas would be over-used. There is considerable scope for future research on crocodiles in zoos focusing on the biological differences between crocodiles that may affect sensitivity to visitor presence.

Introduction

The World Association of Zoos and Aquariums (WAZA 2022) has announced that all regional associations must have an animal welfare evaluation process by 2024. Regional zoo associations have begun requiring member organisations to conduct regular animal welfare assessments (Binding et al. 2022). For example, the European Association of Zoos and Aquaria (EAZA) has created a publicly available Animal Welfare Assessment Library to assist institutions in this capacity (EAZA 2022). However, research into the public perception of zoos reveals public concerns about how zoos meet the needs of animals in their care (Maynard 2018). For zoos to address public concerns, it is vital that zoos educate the public about the actual welfare needs of animals and continue to develop science of animal welfare (Sherwen and Hemsworth 2019).

There is a need for more empirically derived information about how to measure and promote good welfare for many species in captivity (Rose et al. 2019). Melfi (2009) argued that welfare guidelines have often emerged from zoo traditions due to limitations in evidence-based scientific knowledge of many species. Therefore, the demand for welfare knowledge is high within the industry (Cronin 2021). A greater understanding of species' needs has the potential to improve animal welfare, reproductive success and longevity.

Maintaining captive populations can be challenging when there is disparity between an animal's natural habitat and the zoo environment (Mason 2010; Mason et al. 2013).

Determining how to care for captive animals using evidence-based decision-making is important for the continuing development of zoo animal welfare standards (Rose et al. 2017). Among many variables, the presence of other individuals in a zoo animal environment influences individual behaviour (Rose and Riley 2017). Animals in zoos can interact with both conspecifics and heterospecifics (Hosey 2013). Heterospecifics include humans, which are an integral part of zoo animal lives and are a factor to consider when evaluating animal behaviour and welfare. Human presence includes keepers and vets alongside other staff, but one of the key focuses is on the relationship between animals and visitors. How the behaviours of animals in zoos vary in the presence of visitors allows researchers to evaluate species welfare status (Brereton and Fernandez 2022a). The visitor effect, which is defined for the purpose of this study as the response of an animal to the presence of human zoo visitors, has often been regarded as negatively influencing animal behaviour but varies between species and individuals (Rose et al. 2019). However, Sherwen and Hemsworth (2019) reported that 90% of visitor effect studies focused on mammals, which leaves large gaps in understanding of how non-mammalian taxa respond to zoo visitors.

Although crocodilians have been kept in zoos worldwide for hundreds of years (Ziegler et al. 2017) they are less frequently the subject of behavioural research (Brereton and Brereton 2020; Riley et al. 2021) than charismatic megafauna such as giraffes *Giraffa camelopardalis.* While less popular than large mammals, crocodiles naturally attract some visitor interest given their carnivorous habits and large body size. Many of these species are now heavily threatened in the wild (Stevenson 2015; Vyas & Stevenson 2017). Studies of the behaviour and enclosure use of dwarf caiman *Paleosuchus palpebrosus* suggest that visitors may affect behaviour and enclosure use (Riley et al. 2021). Furthermore, crocodilians are sensitive to sound and vibration as they can perceive the presence of conspecifics through auditory means (Vergne et al. 2009), though this does not necessarily mean that ambient noises impact behaviour. The noise that zoo visitors generate has been suggested to affect how individuals behave and use their captive environment (Staniewicz et al. 2022). These studies show the importance of welfare research for zoo-housed crocodilians and the opportunity for further research on how visitors affect their welfare.

The ability of species to use their captive environment is a major behavioural component of their welfare needs (Seebacher et al. 1999). Observations of how species use their captive environment can be useful for evidence-based husbandry (Rendle et al. 2018). A method of collecting evidence is Post Occupancy Evaluations (POE) or enclosure use studies (Brereton 2020). Given the diversity of zoo enclosures across the globe, a range of enclosure use methods have been developed (Brereton and Fernandez 2022b). One of these indices is the Electivity Index developed by Vanderploeg and Scavia (1979). The Electivity Index can identify the needs and preferences of species and how visitors change the species' or individuals' utilisation of their enclosure. Enclosure use indices such as the Electivity Index have been used to measure enclosure use preferences of various captive species (Hunter et al. 2014; Lechowicz 1982; Wheler and Fa 1995) including crocodilians. These studies have allowed for informed, evidence-based management decisions to help keepers adjust areas of enclosures avoided by animals (Rendle et al. 2018) and allow zoo species to express their desired behaviours.

The Siamese crocodile *Crocodylus siamensis* is a freshwater crocodile that rarely exceeds a total length of 3.5 metres (Simpson 2006). Siamese crocodiles are one of the least known and most threatened crocodilian species in the world due to the species being highly endangered in the wild (Ihlow et al. 2015). Once found throughout Southeast Asia, today it is mainly found in Cambodia with a decreasing population of 5,000 individuals (Isberg and Shilton 2013). The Siamese crocodile occurs in many lowland freshwater habitats including slow-moving rivers and streams, lakes, marshes and swamps. In Cambodia, Siamese crocodiles are generally found in the less disturbed areas, away from human habitation (Simpson 2006). Like many other crocodilians, the Siamese crocodile feeds on a wide variety of prey, such as invertebrates, frogs, reptiles, birds and mammals, including carrion (Isberg and Shilton 2013). Siamese crocodiles are well represented in captivity with over 700,000 individuals held on farms and zoos worldwide (Simpson 2006). However, captive research of the species is limited to a farmed setting, which is not a true reflection of how the species is kept in zoos.

It is important to quantify which aspects of the visitor effect affect animal behaviour, so investigations of sound level versus crowd size are valuable. In captivity, Siamese crocodiles are understudied. As different species may respond to their environment and zoo visitors differently (Boultwood et al. 2021), behavioural research on the visitor effect in captive Siamese crocodiles is useful in investigating the impact of the visitor effect.

Materials and methods

Sample population and location

Once the University Centre Sparsholt ethical approval had been received (UCSEC2422), observations were conducted on a pair of Siamese crocodiles (Table 1) from Crocodiles of the World in the United Kingdom (51.7773° N, 1.5847° W). The pair had been housed together for several years and had successfully bred on several occasions.

Behaviour

A total of 64 hours of data were collected with two camera traps (Bluesmart trail camera, 4K 20MP IP66) eliminating the risk of the observer effect. The sampling method used was instantaneous focal sampling with two-minute intervals for state behaviours (Bateson and Martin 2021). Data were collected during both day and night recordings to measure behaviour change over the 24-hour period (Table 2 and 3). Cameras were initially set up and left for a 24-hour period to ensure that camera setup did not affect

Table 1. Sample population details of the crocodilians observed in this study.

Sex	Length of the individual (approx. in meters)	Hatch date	Origin
Male	3.3	April 1999	Thailand
Female	2.5	October 1999	Madras Crocodile Bank Trust, India

http://doi/org/10.19227/jzar.v12i3.778

Table 2. Ethogram refined from Gray and Brereton (2020).

Behaviour	Description
Terrestrial locomotion	Traveling taking place on land.
Immobile land-based behaviour	The individual is not in the pool and is resting on land.
Basking	Individuals resting in the known basking zone of the enclosure may perform thermoregulating behaviours such as gaping behaviour.
Surface swimming	Swimming on the surface of the water. Eyes and back are above the water surface.
Immobile water-based behaviour	Individuals are immobile on the water's surface with only the top of the head showing; the absence of any other behaviour.
Underwater	Completely immersed under the water.
Social	Any interactions involving two or more animals, including touching, bellowing, or signalling/posturing to a conspecific such as head-slapping, raised head, and arched tail.
Out of sight	Unable to identify the location of the individual or determine the behaviour accurately.

the initial observations. An ethogram was adapted from previous studies (Gray and Brereton 2022; Table 2) and an intra-observer reliability test was run on a randomly selected sample of the data with a result of 95% accuracy (Bateson and Martin 2021).

Daily total counts of visitors entering the zoo were used to estimate visitor presence. The zoo opened at 1000 and closed at 1700. A Professional Sound Level Meter (SLM-25) was placed at each enclosure to measure the visitor noise level in decibels (dB). Data were retrieved using the Noise Logger Communication Tool 1.0 software and downloaded into a Microsoft Excel 2022© spreadsheet. An Elitech RC-5+ temperature data logger was used to collect ambient temperature for each enclosure and the mean temperature was logged for the hour's observation. Data were retrieved using the Elitech LogWin V6.3.0 software and downloaded into a Microsoft Excel 2022© spreadsheet. Additional variables measured include date, days on which school trips were present, zoo records of ambient temperatures, water temperature, individual, sex and days when individuals were fed. These were recorded as behaviour and enclosure usage predictors.

Enclosure use

The enclosures were broken down into zones based on environmental differences for each area (Table 4 and Figure 1). The sizes of each respective zone were based on measurements completed by the researchers. The enclosures were broken down into unique zones to analyse which biological resources within an enclosure are being overutilised or underutilised. The aim was to separate the exhibit into areas where crocodiles could engage in different behaviours, such as basking, resting or submerging, but other techniques could additionally have been used such as whether crocodiles could have separated or thermal zones. Observations of enclosure use were conducted using an instantaneous focal sample technique at two-minute intervals. When an individual was located between two or more zones the location of the head and forelimbs was used to identify the zone occupied.

Electivity index

Once data were collected, the Electivity Index was used to analyse the results (Vanderploeg and Scavia 1979). Electivity Index values range between a maximum of 1 (over-utilisation) and a minimum of −1 (under-utilisation) in each zone. A value of 0 indicates that an animal is neither over-utilising nor under-utilising a zone (i.e. the zone makes up 50% of the exhibit and the animal spends 50% of its time in that area). Therefore, these values are produced based on expected observation values for each zone based on its size. In

Table 3. Times for which data were analysed

Day/Night	Definition
Night	0100–0300
Night	0400–0600
Day	0700–0900
Day	1000–1200
Day	1300–1500
Day	1600–1800
Night	1900–2100
Night	2200–0000

Table 4. Zone sizes and definitions for each zone of the enclosure

Zone	Definition
Zone 1(2.29m^2)	Open land zone.
Zone 2 (3.97m^2)	Primary basking zone.
Zone 3 (8.55m^2)	Bank zone.
Zone 4 (3.85m^2)	Open land zone next to the secondary viewing area.
Zone 5 (23.45m^2)	Open water zone.
Zone 6 (4.31m^2)	Open water zone next to the primary viewing area.

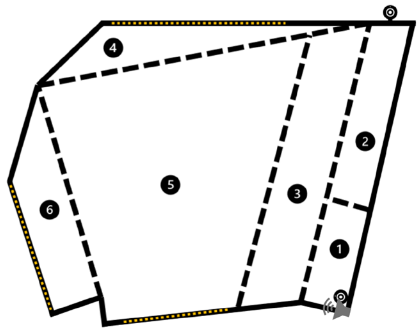

Figure 1. Siamese crocodile enclosure and numbered zones. The camera icons indicate camera trap positions and the yellow checker lines show the location of visitor viewing areas. The grey icon indicates where the dictaphone was located

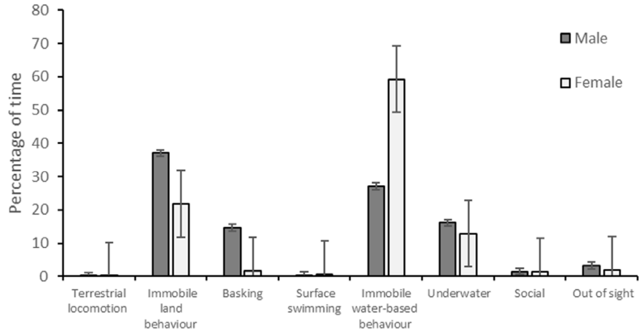

Figure 2. Activity budget for the Siamese crocodile pair (±SE)

this equation, *ri* refers to the practical use of a resource or zone and *pi* refers to the expected use of a given resource (generated using the proportional size of the zone compared to the total available space). The letter *n* denotes the total number of zones or resources available to the study species.

$$E^*=(W_i - (1 / n))/(W_i + (1 /n)) \quad W_i=(r_i / p_i)/\sum(r_i / p_i)$$

Data analysis

Behavioural and enclosure use data were collated in a Microsoft Excel 2022© spreadsheet and statistical analyses were undertaken using Minitab®22. For behaviour and Electivity index outputs, a series of general linear mixed effects models (using the Poisson distribution) were run. For the models, the date was set as a random effect and ambient temperature, time period, animal ID, daily visitor number and noise (dB, Table 5) were input as predictors. A Bonferroni correction factor was included by dividing the required alpha value by the number of predictors inputted into each model.

Results

Behaviour

Behaviours were converted into activity budgets (Figure 2). The predictors of temperature, visitor number and noise levels were significant predictors of some behaviours (Table 6).

Enclosure use

Electivity Index values differed between crocodiles and slight differences in use of space occurred between day and night (Figure 3). These differences are shown graphically (Figure 4). Occupancy of zones 2, 3 and 5 were significant predictors of Electivity Index values for specific zones (Table 7).

Discussion

The results suggest that the behaviour and enclosure use of zoo-housed Siamese crocodiles can be affected by several predictors. Significant values were found for all behaviours and the use of certain zones within the enclosure. The Poisson regression model found ambient temperature, visitor number, ambient noise, individual and time of day were significant predictors for the performance of certain behaviours but not all. The model predictive power ranged from 29.23% to 91.30%. The Electivity values regression model power was 18.95%. The Spearman correlation analysis on the relationship between ambient noise and visitor numbers found a significant positive correlation between the predictors (r=0.298, P=0.017) but this was weak, which suggests that other types of environmental noise may be at play.

Behaviour

Time of day and ambient temperature significantly influenced when the zoo-housed Siamese crocodiles performed all behaviours, as expected for crocodilians. Recent studies on Nile crocodiles *Crocodylus niloticus* and dwarf caiman found time of day and ambient temperature to be predictors of behaviour (Riley et al. 2021). Temperature is expected to play a strong role in reptilian behaviour, given the ectothermic nature of these animals and

Table 5. The Professional Sound Level Meter (SLM-25) parameters

Settings	Parameters
Record Interval	30 Sec
Immediately/Manual	Manual
Noise Alarm	30 to 100 decibels (dB)
Noise Sample Level	Fast
Noise Level	A

http://doi/org/10.19227/jzar.v12i3.778

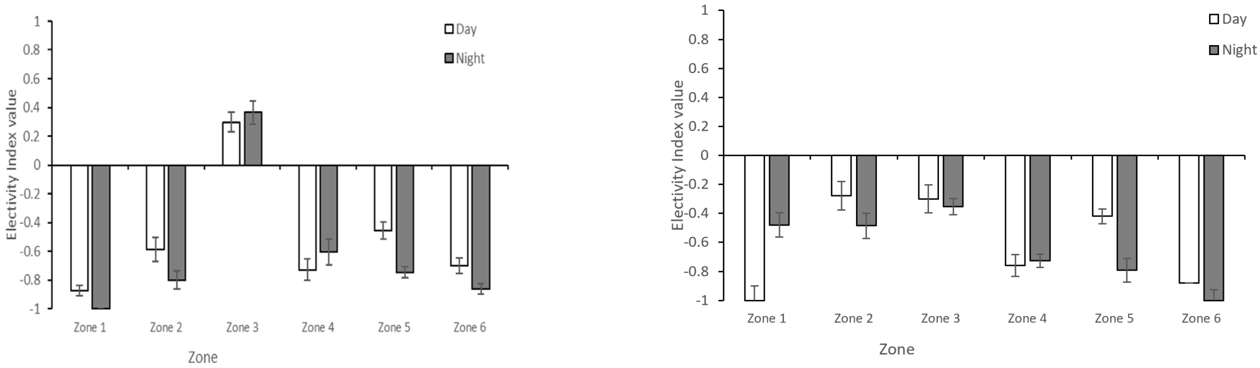

Figure 3. Mean Electivity index value of female (left) and male (right) Siamese crocodiles during day and night observations (+/- se).

their reliance on external heat sources (Terespolsky and Brereton 2021). Crocodilians must move from land to water environments to regulate their body temperature (Brazaitis and Watanabe 2011). Previous observations of broad-snouted caiman *Caiman latirostris* showed that individuals only left the water during the hottest points of the day (Prystupczuk et al. 2019). There were individual differences in basking behaviour, which could be due to their size differences. Investigations of wild gharials *Gavialis gangeticus* and mugger crocodiles *Crocodylus palustris* found that the size of individuals was a factor in basking behaviours (Choudhury et al. 2017). It is suggested that basking behaviour is used to elevate body temperature rather than maintain it (Downs et al. 2008). Therefore, smaller individuals (such as the female in this study) take less time to elevate their body temperature than larger individuals.

The correlation between visitor numbers and noise levels was positive and significant but weak overall. This may be because the number of visitors was the number of individuals per day rather than the specific number that visited the exhibit during any given hour. It is also likely that other types of noise such as from ventilation systems were picked up and this may have resulted in a weaker correlation overall. Consideration should also be given to the decibels and noise frequency, as it is likely that crocodiles may not be as sensitive to all frequency types (Jakob-Hoff et al. 2019). Instead, specific sounds and interactions from visitors (such as tapping of glass) may result in greater interaction from crocodiles: future studies should therefore study this in greater detail. Similarly, consideration of public feeding times at the collection, which tend to be both noisy and attract large numbers of visitors, should be considered in future studies in this area.

Inactive behaviours were the most prominent behaviour seen, which is expected from ectotherms that spend prolonged periods inactive (Lambert et al. 2019). However, immobile land behaviour decreased and underwater behaviour increased significantly

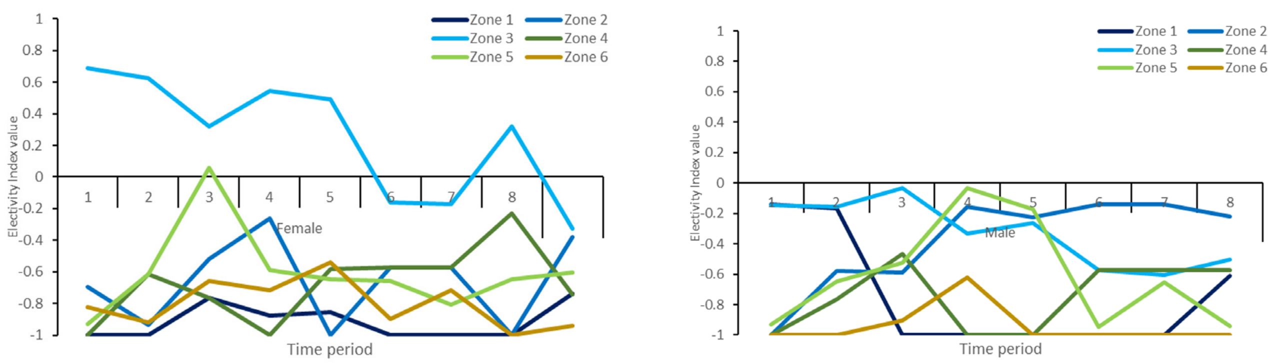

Figure 4. Electivity index values for female (above) and male (below) Siamese crocodiles, as separated by time of day. Time periods: 1: 0100–0300; 2: 0400–0600; 3: 0700–0900; 4: 1000–1200; 5: 1300–1500; 6: 1600–1800; 7: 1900–2100; 8: 2200–0000.

Table 6. Output of General Linear Mixed Effect models on crocodile behaviour

Behaviour	R^2 %	Predictor	Parameter estimate (Z)	DF	X2	P-value
Immobile land-based behaviour	36.87	Model	12.55	11	458.22	<0.001*
		Ambient Temperature	-3.49	1	12.17	<0.001*
		Visitor Numbers	-4.72	1	22.27	<0.001*
		Average Noise (dB)	-11.94	1	142.65	<0.001*
		Individual	-8.58	1	73.6	<0.001*
		Time Zone	04:00 - 06:00 = -1.00; 07:00 - 09:00 = - 4.74; 10:00 - 12:00 = - 0.05; 13:00 - 15:00 = 3.91; 16:00 - 18:00 = 7.87; 19:00 - 21:00 = 7.92; 22:00 - 00:00 = 7.34	7	222.72	<0.001*
Basking	54.21	Model	-0.02	8	196.7	<0.001*
		Individual	-11.68	1	136.48	<0.001*
		Time Zone	04:00 - 06:00 = -0.00; 07:00 - 09:00 = 0.02; 10:00 - 12:00 = 0.02; 13:00 - 15:00 = 0.02; 16:00 - 18:00 = 0.02; 19:00 - 21:00 = - 0.00; 22:00 - 00:00 = - 0.00	7	60.22	<0.001*
Surface swimming	37.54	Model	-0.02	9	28.41	0.001*
		Ambient Temperature	2.01	1	4.03	0.045
		Average Noise (dB)	2.98	1	8.9	0.003*
		Time Zone	04:00 - 06:00 = 0.01; 07:00 - 09:00 = 0.01; 10:00 - 12:00 = 0.01; 13:00 – 15:00 = 0.01; 16:00 - 18:00 = 0.01; 19:00 - 21:00 = -0.00; 22:00 - 00:00 = 0.01	7	23.19	0.002*
Immobile water-based	29.23	Model	3.08	10	427.59	<0.001*
		Ambient Temperature	2.12	1	4.5	0.034
		Visitor Numbers	3.34	1	11.16	0.001*
		Individual	14.77	1	218.15	<0.001*
		Time Zone	04:00 - 06:00 = 2.49; 07:00 - 09:00 = 2.19; 10:00 - 12:00 = - 0.30; 13:00 - 15:00 = - 0.07; 16:00 - 18:00 = - 4.90; 19:00 - 21:00 = - 3.82; 22:00 - 00:00 = -2.61	7	143.41	<0.001*
Underwater	33.77	Model	-1.40	10	304.98	<0.001*
		Ambient Temperature	- 6.32	1	39.94	<0.001*
		Average Noise (dB)	10.09	1	101.9	<0.001*
		Individual	-2.62	1	6.86	0.009*
Social	91.30	Time Zone	04:00 - 06:00 = 0.29; 07:00 - 09:00 = 6.15; 10:00 - 12:00 = 4.67; 13:00 - 15:00 = - 1.83; 16:00 - 18:00 = 2.14; 19:00 - 21:00 = 2.79; 22:00 - 00:00 = 3.06	7	81.8	<0.001*
		Model	-0.01	10	47.48	<0.001*
		Ambient Temperature	3.75	1	14.06	<0.001*
		Visitor Numbers	-4.66	1	21.67	<0.001*
		Average Noise (dB)	4.98	1	24.85	<0.001*
		Time Zone	04:00 - 06:00 = 0.00; 07:00 - 09:00 = 0.00; 10:00 - 12:00 = 0.00; 13:00 - 15:00 = 0.00; 16:00 - 18:00 = - 0.00; 19:00 - 21:00 = - 0.00; 22:00 - 00:00 = - 0.00	7	38.22	<0.001*

http://doi/org/10.19227/jzar.v12i3.778

Table 7. The regression outputs from investigations of the differences in individual zone. The response was the Electivity Index value, and the zone was included with the categorical predictors. * Indicates a statistically significant value. A Bonferroni correction factor has been applied

Terms	R^2	SE Predictor	Parameter estimate (T)	F	DF	P
Model	18.95%	0.0729	-11.5	18.91	5	<0.001*
Zone					5	
2		0.103	2.91			0.004*
3		0.103	8.16			<0.001*
4		0.103	1.3			0.196
5		0.103	2.27			0.024*
6		0.103	-0.22			0.826

during periods of increased ambient noise. Research by Hamilton et al. (2022) on dwarf caiman found comparable results when zoo visitors were present. Furthermore, hydrophone data collected on American alligators *Alligator mississippiensis* suggested that ambient noise was reduced underwater (Staniewicz et al. 2022). The increased underwater behaviour suggests that the Siamese crocodiles are evading the visitor noise, thus becoming less visible. The confounding factor of other sources of noise and their potential influence on behaviour should also be considered here.

The most powerful result from the model was the performance of the social behaviour (91.30%), indicating that most of the predictors affected this behaviour. Interestingly, visitor numbers and noise were a predictor of this behaviour. Social behaviour occurs relatively rarely in reptiles (in comparison to highly social animals such as primates) and the social behaviours are often subtle (Simpson 2006). Social behaviour may occur more frequently during times when people are not present because there are fewer distractions to the animals (Fernandez et al. 2009; Weldon and Fergusson 1993). A similar activity pattern for social behaviours has been observed with the previous pair of false gharials *Tomistoma schlegelii* at Crocodiles of the World, with less social behaviour observed during the day than at night (Staniewicz et al. 2022). However, the X^2 value suggests that time of day had a stronger influence on the pair's social behaviour than visitors.

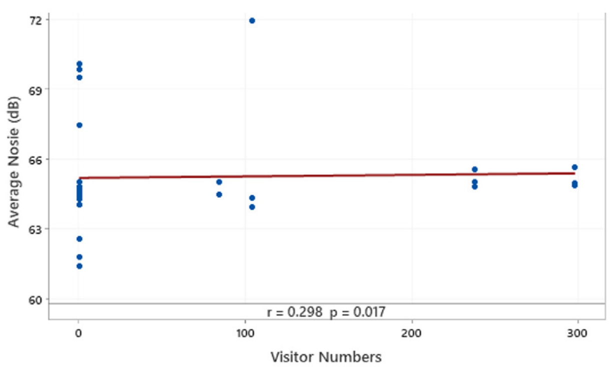

Figure 5. Correlation between visitor number and noise level

Enclosure use

Using behaviour as the basis for designing captive environments is not unusual but animal behaviour research is more insightful when combined with space use research (Ross et al. 2011). In this study the majority of zones were underutilised. Traditionally in enclosure use research it is assumed that uneven enclosure use is a negative welfare indicator, as animals are not using their available space proportionally (Brereton 2020). However, these conclusions are not appropriate when drawing conclusions for reptilian species that are often sedentary. For example, previous research on broad-snouted caiman identified high modified Spread of Participation Index values, indicating that much of the available space was rarely used (Prystupczuk et al. 2022). These animals naturally spend long periods of time inactive in the wild so uneven space use is to be expected. Instead, it is more important to identify which spaces are most commonly used as this may indicate valuable resources in the environment. Furthermore, some areas may be highly valuable yet used for only a brief period of time or only during specific times of year; examples include substrate areas for female nesting.

The parameter estimates from the analysis of the differences in usage of specific zones showed that the bank environment was used more than other zones in the enclosure. This enclosure use preference has been observed before with dwarf caiman (Gray and Brereton 2022). It was suggested that the individuals were using the bank zones as this provided the individuals with a good thermal environment (Reber et al. 2021) and as a haul out zone. These haul out areas are important for wild and captive crocodiles, so investigating whether haul out zones are present in other crocodilian enclosures would be a worthy future area of study.

By contrast Zone 1 was underutilised by both individuals. This area of land was developed as a nesting area and therefore it provides a valuable function for the female but only during the nesting period. During the period of study nesting was not expected, so use of this area should not be expected (Platt et al. 2012). One of the challenges of enclosure use analysis is that it expects that all zones should be used during all study periods; this should be reconsidered in future space use tools.

Future directions

The results show that the visitor effect may be more complicated than it appears and the presence of visitors alone is not the only factor in changing the behaviours of these crocodiles. Other environmental variables including those not perceived by humans may play a greater role than is normally anticipated. A focus on visitor interactions and behaviours such as banging on glass or rapid movements are likely to provide a much more in-depth explanation of crocodile behaviour change.

Like many zoo research projects, some limitations are unavoidable due to the availability of individuals, time and resources. One of the constraints of this study was the sample size and to complete observations under different conditions from visitors. A method to mitigate these limitations in future research is to investigate crocodilian behaviour from an early age (Reber et al. 2021). It is a common practice in captivity to harvest eggs from crocodiles to improve the hatch rate of offspring (Fukuda et al. 2014). Therefore, hatchlings are kept away from the public before being displayed. Completing research on crocodilians from an early age could provide further information on whether or how zoo-housed individuals develop their responses to visitor presence. Ethically, these studies could be used to better understand the welfare impact of the zoo environment on crocodilian welfare. This experimental design has the strength to retain a sufficient sample of individuals and could be developed into a longitudinal study where subjects can be housed under different conditions over a period of time.

Conclusions

This study identified that ambient temperature, individual, time of day, visitor numbers and ambient noise (dB) were predictors of behaviour change in Siamese crocodiles. Overall, the explanatory power of some of these predictors was not strong, so the visitor effect may be less pronounced especially in comparison to temperature and time of day effects . Correlation analysis found that visitor numbers and ambient noise had only a weak, significant positive correlation suggesting that other environmental factors were producing the majority of noise. Most zones within the enclosure were underutilised by the crocodiles apart from zone 3 (the water bank). This is useful to know as it shows the importance of haul out zones for the individuals in the study with these zones having potential value for other captive crocodilians.

This study was completed on one species of crocodilian; therefore the wide-scale application of these results to other species is limited, meaning there are still gaps in knowledge on how other species behave in response to zoo visitors. Future studies investigating crocodilian species will be informative to better understand how natural history relates to the visitor effect.

Acknowledgements

The authors are grateful to the staff at Crocodiles of the World for making this research possible. The authors would particularly like to thank C. Stevenson for his support throughout the study.

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