Author/s:
Zhou, K;Xu, J;Chen, Z;Williams, KJH;Liang, Z;Lin, W;Lee, TM;Hu, S

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From Iconic Species to Biodiversity: The Role of Zoos in Inspiring Visitors' Affinity for a Broader Range of Wild Animals

Kaiwen Zhou[1,2] | Jiakuan Xu[3] | Zujin Chen[3] | Kathryn J. H. Williams[4] | Zhijian Liang[2,5] | Wei Lin[1] | Tien Ming Lee[2,5] | Sifan Hu[2,5]

[1]School of Life Sciences, Sun Yat-sen University, Guangzhou, China | [2]National Park and Nature Education Research Institute, Sun Yat-sen University, Guangzhou, China | [3]Guangzhou Zoo, Guangzhou, China | [4]School of Agriculture, Food and Ecosystem Sciences, University of Melbourne, Parkville, Victoria, Australia | [5]School of Ecology, Sun Yat-sen University, Shenzhen, China

Correspondence: Kaiwen Zhou (zhoukw5@mail2.sysu.edu.cn) | Sifan Hu (husf@mail2.sysu.edu.cn)

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ABSTRACT

Preferences for animal species may influence public engagement in conservation efforts. However, urban residents often have limited opportunities to learn about and connect emotionally with a wide range of wildlife. Zoos can help bridge this gap, with enclosures and interpretive systems playing a key role in fostering understanding and positive attitudes towards animals. At present, little is known about how the characteristics of enclosures and interpretive systems work together to influence visitors' learning about wildlife. Over a 12-month period, we assessed the features of enclosures and interpretive facilities at Guangzhou Zoo, China, and captured visitors' wildlife preferences before and after their visits using an open-ended question. By examining how these features and the overall zoo experience influenced changes in preferences, we aimed to evaluate the zoo's potential for conservation education. Our results showed that zoo visits significantly impacted visitors' wildlife preferences, increasing their fondness for a broader range of species and fostering a greater affinity for relatively unpopular species or taxa. Importantly, the interaction between the number of interpretive signs and three other factors—enclosure size, enclosure type, and the interactivity of interpretive facilities—emerged as key determinants of these preference changes. This study provides valuable insights into improving the design of zoo enclosures and interpretive facilities to support conservation education.

1 | Introduction

The accelerating loss of global biodiversity underscores the critical importance of public awareness and action in enhancing conservation outcomes (Nielsen et al. 2021). Public interest in and affection for different species and biodiversity often play a key role in driving impactful conservation initiatives, such as donations and policy support (Colléony et al. 2017; Curtin and Papworth 2020; Echeverri et al. 2017; Kaltenborn et al. 2006). However, urban environments have increasingly disconnected city dwellers from nature, weakening their emotional bonds with diverse species (Miller 2005; Soga and Gaston 2021) and limiting opportunities for site-based conservation education. Such education is crucial for mitigating biodiversity loss by

Kaiwen Zhou and Jiakuan Xu are co-first authors.

Summary

People's preferences for certain animals can affect how much they care about wildlife. However, city dwellers often have limited opportunities to learn about or feel connected to a broad range of animals. Zoos can help bridge this gap with their animal exhibits and educational tools. In this study, we examined how zoo visits—along with their enclosures and interpretive facilities—can change visitors' preferences for animals. We found that after visiting the zoo, people liked a wider variety of animals, including those that are usually less popular. Key factors driving these changes included the number of signs, the size and types of enclosures, and the interactivity of interpretive facilities. This study provides useful suggestions for designing zoo enclosures and education tools to better support wildlife conservation education.

- **Practitioner Points**
  - Zoo visits can increase public affection for a broader range of animals, especially noncharismatic species and non-mammals, highlighting the role of zoos in biodiversity education.
  - Enclosures and interpretive facilities significantly influence visitors' animal preferences, with the number of signs playing a key role.
  - The combination of various enclosures and interpretation features can have complementary or reinforcing effects on educational outcomes. To maximize educational effectiveness, it is essential to consider how these elements interact when designing educational spaces in zoos or other educational settings.

raising public awareness of wildlife, encouraging conservation actions, and advocating for relevant policies (Jacobson et al. 2015). Fortunately, growing recognition of urban nature's significance has spurred global efforts to view it as a vital arena for field-based environmental education and a way of reconnecting residents with their local ecosystems, as exemplified by urban zoos (Russ and Krasny 2017).

Zoos are increasingly recognized for their important role in supporting conservation education and encouraging public engagement in wildlife protection (Escribano et al. 2021; Kruger and Viljoen 2023). They provide an informal learning environment where people can interact with and establish emotional connections with biodiversity, engage with conservation issues (Jensen 2014; McNally et al. 2024; Schilbert and Scheersoi 2023), and compensate for the lack of direct nature experiences (Bruni et al. 2008; Clayton et al. 2009).

Zoos integrate three physical elements into their exhibit systems that support informal learning: live animals, enclosures, and interpretive facilities (Figure 1). Encountering and observing live animals triggers a complex sequence of responses, from sensory impressions (e.g., vivid visual, auditory, and olfactory stimuli) to emotional affinity, reflective thought, and ultimately, conservation actions (Ballantyne et al. 2011; Miller et al. 2020). Enclosures are purposefully designed spaces that balance animal welfare with visitor engagement, providing animals with appropriate areas for activity while ensuring a safe and

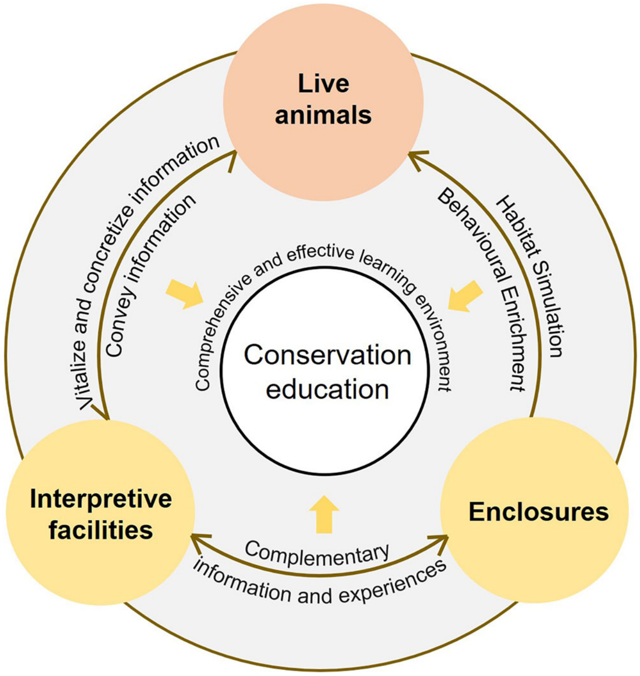


FIGURE 1 | Fundamental physical elements of zoo exhibit systems for informal education.

enriching experience for visitors (Fernandez et al. 2023; Godinez and Fernandez 2019). Interpretive facilities refer to the fixed educational tools used to convey animal knowledge and conservation information to visitors (Roe et al. 2014), such as signs, interactive displays, and digital media (Edney et al. 2023). These components may interact in complex ways to create a relatively comprehensive, self-directed learning environment for visitors.

Enclosure characteristics primarily shape how visitors encounter animals in two key ways. First, enclosure designs have a significant impact on animal behavior (Fernandez et al. 2009). For instance, larger and more complex exhibits can enhance animal activity levels and behavioral diversity (Jensvold et al. 2001; Scott and LaDue 2019), which subsequently affect visitors' attitudes and emotions toward zoo animals (Luebke et al. 2016). Second, enclosure characteristics, such as viewing area size, can directly impact visitors' interest and dwell time (Moss et al. 2008), potentially leading to deeper and more prolonged learning experiences (Moss and Pavitt 2019). Encounters with zoo animals are also shaped by interpretive facilities, which serve as the primary medium for enhancing visitors' understanding of animals, as well as their knowledge and intentions toward conservation (Pearson et al. 2013; Roe et al. 2014; Waller et al. 2012). Nevertheless, the effectiveness of different types of interpretation in engaging visitors and conveying information varies, often influenced by factors such as the level of interactivity, artistic appeal, inclusion of objects displayed, and the content itself (Edney et al. 2023; Fraser et al. 2009; Jensen 2006; Ross and Lukas 2005). Given these interactions, it is important to consider how both interpretive facilities and enclosure characteristics shape visitors' preferences for wildlife.

Most previous studies of conservation education outcomes of enclosure and interpretation features have methodological constraints, including limited comparison between multiple enclosure and interpretation features, and reliance on behavioral observation methods that do not directly assess learning. Assessments are often based on comparisons across several zoos or before-and-after improvements of enclosures or interpretive facilities (Lindemann-Matthies and Kamer 2006; Mallavarapu and Taglialatela 2019; Smart et al. 2021). These studies enable a direct evaluation of how changes in these features influence educational outcomes, but multiple differences between enclosures and interpretive facilities often make it challenging to isolate the effects of specific features or detect interactions between different characteristics. Additionally, such comparative studies often focus narrowly on one or a few species, which hinders robust comparisons and the evaluation of various enclosure and interpretation types. Furthermore, although previous research has conducted large-scale comparisons of different types of enclosures and interpretive features, these studies rely on behavioral observation methods to record data, such as visitor numbers and dwell time (Edney et al. 2023; Kohut and Katona 2022). There are concerns that these behavioral measures may fail to provide direct insights into more complex phenomena, such as learning (Shettel 1997), making it difficult to link them to broader conservation education outcomes. A 2019 review further emphasized the limitations of existing research on zoo and aquarium conservation education evaluations, particularly the weak quantitative methods used in many studies, underscoring the need for new data-driven approaches to assess educational outcomes (Mellish et al. 2019).

In recent years, Chinese zoos have rapidly emerged as key centers for nature education (Askue et al. 2009; Du et al. 2023). In 2013, the Ministry of Housing and Urban-Rural Development of China issued the “National Zoo Development Outline,” which emphasized conservation education as one of the core missions of zoos and called for the optimization of enclosures and interpretive systems to better integrate education with conservation efforts (Ministry of Housing and Urban-Rural Development 2013). This underscores the need for scientific exploration of the key factors that can leverage zoos as nature education centers and enhance their potential to inspire visitors' enthusiasm and interest in biodiversity conservation.

Based on a typical urban zoo in a Chinese megacity, we sought to understand how zoo visits—including the presence of animals, as well as the features of enclosures and interpretive facilities—influence visitors' preferences for diverse wild animals. Visitors' preferences, or the animals they reported liking the most, are a significant predictor of subsequent conservation behaviors (Kaltenborn et al. 2006; Martín-López et al. 2007). Our study attempts to address the following questions: (1) Does a visit to the zoo influence adult visitors' preferences for wildlife? (2) If so, how do these preferences change? (3) How do the features of interpretive facilities and enclosures affect these changes in preferences? We employed an open-ended question to capture changes in visitors' wildlife preferences before and after their zoo visit to better understand how urban zoo visits may contribute to conservation education. We assessed the features of the zoo's enclosures and interpretive facilities and explored the relationship between these features and the changes in visitors' preferences. Our research aims to reveal the role of zoos in China as environmental education hubs and to provide practical recommendations for optimizing zoo enclosures and interpretive facilities to enhance the potential effectiveness of conservation education.

2 | Methods

2.1 | Study Site

Our study was conducted at Guangzhou Zoo, a municipal public welfare institution located in the city center of Guangzhou, Guangdong Province, a Chinese megacity. Established at its current location in 1958, the zoo covers an area of 42 hectares, housing over 300 species and 4000 individual animals. In recent years, Guangzhou Zoo has been at the forefront of modernization among Chinese zoos, optimizing various aspects, such as enclosures and interpretive systems, to prioritize animal welfare and conservation while also promoting high-quality public education. In 2005, the zoo was designated as a “National Wildlife Conservation Education Base” by the China Wildlife Conservation Association and the government, and in 2023, it was recognized as a “National Nature Education Base” by the Chinese Society of Forestry. Importantly, with over 5 million annual visitors, the zoo holds significant potential for engaging a large audience with conservation themes.

2.1.1 | Survey

To understand visitors' preferences for wildlife before and after their visit to the zoo, we piloted our survey in November 2020 and conducted the formal survey from August 2021 to August 2022 at Guangzhou Zoo. We placed posters with QR codes for the survey at both entrances of the zoo. Respondents were offered a small gift from the visitor center upon completion of the questionnaire. We obtained a total of 4182 responses, and after data screening and quality control (excluding those under 18 years old, $n = 788$; and those with excessively short completion time or logical inconsistencies, $n = 678$), we retained 2716 valid samples. Participants were informed of the project's objectives, the voluntary nature of participation, data confidentiality, and data management procedures before the survey began. All data were anonymized and used solely for research purposes.

To mitigate biases from repeatedly asking visitors about their preferences on a single day (Marsden and Torgerson 2012) and to encourage broader participation for a more comprehensive view of preferences, we adopted a cross-sectional pre-post survey to assess visitors' overall wildlife preferences before and after their visit. Specifically, we placed survey posters at the zoo's two main entrances and included a question in the questionnaire to identify the visit stage, categorizing the survey as pre-visit or post-visit. In total, 1285 pre-visit samples and 1431 post-visit samples were identified. The chi-square test showed no significant differences in demographic characteristics (including gender, age, education, and field of occupation or study) between the sample groups before and after the zoo visit (Supporting Information S1:Table S1). However, to improve comparability between the two groups, we employed

Coarsened Exact Matching (CEM) to obtain paired samples based on demographic characteristics. After matching, 1274 and 1406 respondents were retained for further analysis in the pre-visit and post-visit groups, respectively. To ensure transparency in data processing and to test the robustness of the results, we conducted all subsequent analyses using both the full set of valid responses and the CEM-matched responses.

2.2 | Wildlife Preference Measurement

Each respondent's favorite wild animals were identified through an open-ended question ("What are your favorite wild animals?") to avoid limiting participants' choices. We compiled all mentioned animal names, standardizing both common and alternative names and removing unidentifiable ones. A total of 344 identifiable animal names were retained. These names were categorized into two levels: category level and species level. Category-level names refer to general taxonomic categories, such as "monkey," "snake," and "parrot," while species-level names denote more specific taxa, including species, subspecies and variants, such as "golden snub-nosed monkey (*Rhinopithecus roxellana*)," "king cobra (*Ophiophagus hannah*)," and "grey parrot (*Psittacus erithacus*)." However, two exceptions—"tiger (*Panthera tigris*)" and "lion (*Panthera leo*)"—which, despite being species names, were treated as category level, because the zoo's exhibits and interpretive signs emphasize their subspecies or variants. Their subspecies, variants, or breed names (e.g., "South China tiger" and "white lion") were classified at the species level.

The differences in wildlife preferences for each animal between pre-visit and post-visit samples were calculated as follows:

$$\Delta\text{Preference mentioned}_i = (n\_\text{pre}_i / N\_\text{pre} - n\_\text{post}_i / N\_\text{post}) \times 100\%,$$

where n_pre_i and n_post_i represent the number of individuals who listed animal i as their favorite before and after their zoo visit, respectively. If respondents listed multiple favorite animals, each mention was counted individually (1 count per mention). N_pre and N_post denote the number of valid survey responses before and after the visit, respectively.

2.3 | Animals' Exhibit Status and Popularity

Whether an animal was exhibited at the zoo was considered an important potential factor influencing changes in visitors' wildlife preferences. To verify this, we conducted three on-site investigations based on the zoo's animal inventory to determine whether the animals mentioned by respondents were exhibited during the survey period. Since the animal names were mentioned at two different levels (i.e., category-level and species-level), we verified their exhibition status at each level. We classified all animals into four groups based on whether the animal was exhibited in the zoo and whether the name was at the category or species level: "Not Exhibit-Category," "Not Exhibit-Species," "Exhibit-Category," and "Exhibit-Species." This variable was referred to as "Exhibit Status of Animal Name Mentioned" (Table 1). Additionally, to minimize bias, we categorized species exhibited at the zoo but not mentioned by respondents as "Exhibit-species" and assigned them a preference score of 0.

Furthermore, considering that an animal's inherent popularity may also affect changes in preference, we classified each animal's pre-visit mention proportion into three popularity levels: Popular, Moderately Popular, and Unpopular. The classification thresholds were generated using the k-means method, with minor adjustments based on the original data. Animals classified as Popular were mentioned by over 5% of respondents, Moderately Popular by between 0.5% and 5%, and Unpopular by fewer than 0.5%.

2.4 | Enclosure and Interpretive Facility Features

Regarding enclosure characteristics, we identified three variables that allow for comparisons across various exhibit settings: enclosure type, enclosure size, and the average activity space of the animals. Previous studies have shown that exhibit openness (i.e., whether an enclosure is sealed or open) significantly influences visitors' experiences and behaviors (Xu et al. 2020) and, in turn, their observation and learning about the animals (Moss and Pavitt 2019). Based on the specific conditions at Guangzhou Zoo, we classified enclosure types into three categories according to their degree of openness: open exhibit, glass-enclosed exhibit, and cage or terrarium (Table 1).

Enclosure size refers to the exhibit area allocated for the animals' daily activities and partially reflects the available viewing area for visitors. This factor may directly influence visitors' interest (Moss et al. 2008) or affect their attitudes and emotions toward the animals by impacting the animals' activity levels (Jensvold et al. 2001; Luebke et al. 2016). Additionally, to estimate the available space for each individual animal—which may directly relate to behavioral diversity and visitor experiences—we developed an *Average Potential Activity Space Index (APASI)*. This index was calculated by dividing the exhibit area by the average number of animals on display and then adjusting for their average body mass, which serves as a proxy for animal size.

For interpretive facilities, we considered the wide range of educational signage, interaction facilities, and models accessible to visitors during their zoo visits. Building on previous research on interpretive facility characteristics (Edney et al. 2023), we identified and assessed the unique features of over 600 interpretive facilities at Guangzhou Zoo. We categorized all interpretive materials based on nine traits, encompassing the signage's form, style, and content (Supporting Information S1: Table S2). However, due to the limited number or high homogeneity of certain features across different animal exhibits, not all traits were included in the subsequent analysis. Ultimately, we considered the total number of signs, the number of signs addressing specific interpretive content, and the presence of illustrative signs, interactive displays, or model/object displays to capture the scope of interpretive efforts for each animal (Table 1). Since an animal may have multiple interpretive facilities, the characteristics of the interpretive content for each

TABLE 1 | Summary of the potential influencing factors in exhibit status and characteristic of enclosures and interpretive facilities.

Variable	Level	Definition	Example
Exhibit status of animal name mentioned ($N = 317$)	Not Exhibit-Category ($N = 33$)	The animal name refers to a general taxonomic category but is not exhibited in the zoo.	Penguin, Squirrel
	Not Exhibit-Species ($N = 59$)	The animal name refers to a specific species, subspecies, or mutant but is not exhibited in the zoo.	Snow leopard, Polar bear
	Exhibit-Category ($N = 170$)	The animal name refers to a general taxonomic category, and its subcategory is exhibited in the zoo.	Monkey, Snake, Tiger (exception)
	Exhibit-Species ($N = 55$)	The animal name refers to a specific species, subspecies, or mutant, and it is exhibited in the zoo.	Golden snub-nosed monkey, King cobra, South China Tiger
Enclosure type ($N = 73$)	Open Exhibit ($N = 34$)	The enclosures use low barriers or natural features such as ditches to separate animals from visitors, offering an unobstructed view.	
	Glass-enclosed Exhibit ($N = 28$)	The enclosures are relatively open but are enclosed by tall glass walls, providing a clear view while ensuring safety.	
	Cage or Terrarium ($N = 11$)	Enclosures with more traditional designs often use metal bars or glass tanks.	

Interpretive signs features

Trait	Variable	Definition	Example
N/A	Total Number of Signs	The total number of signs providing information about the animal, including all the interpretation forms and contents. If the animal name refers to taxonomic category, it encompasses all the signs related to this taxa and its included species.	N/A
Interpretation form	Illustration	Whether visual representations are used to clearly explain and clarify the information about the animals. (1: Yes; 0: No)	
	Object or Model Display	Whether the display involves models or objects as a holistic interpretation piece. (1: Yes; 0: No)	
	Interactive Facilities	Whether there are interpretive facilities involving interaction or activities, rather than just looking or reading. It can be digital or physical. (1: Yes; 0: No)	
Content	The number of signs introducing fun facts	Brief and engaging information that highlights surprising, or lesser-known aspects of animal behavior, biology, or ecology, usually in short form.	N/A
	The number of signs introducing animal's feature	Information about the physical characteristics and distinguishing features.	N/A
	The number of signs introducing animal behavior	Information about the animal's behavior, habits, and social interactions.	N/A

species were determined by aggregating data from all relevant signs and facilities.

2.5 | Data Analysis

To examine whether there were significant changes in visitors' preferences, we conducted chi-square analyses to assess variations in preference across taxa and the number of favored species mentioned before and after the zoo visit. All statistical analyses in this study were conducted using R version 4.2.1 (R Core Team 2022).

We then established a regression model to evaluate whether the exhibition of an animal at the zoo affected changes in preference. The model incorporated the exhibit status of the animal names mentioned and their pre-visit preference levels as explanatory variables. To reduce bias, the animal sample for this model ($N = 317$) included all identifiable animal names mentioned by visitors as well as all animals exhibited in the zoo.

To further explore which factors related to zoo enclosures and interpretive facilities influenced changes in animal preferences, we constructed another regression model focusing exclusively on animals exhibited at the zoo. Independent variables included all previously mentioned enclosure and interpretive facility characteristics, along with interaction terms to account for potential interdependencies. However, for certain taxa (e.g., snakes, turtles, and parrots), where multiple species were exhibited in enclosures with similar designs and interpretive features, we categorized them by taxonomic group. We also excluded some broadly defined animal names, such as "birds" and "monkeys," because these groups encompassed species displayed across multiple exhibit zones, making it challenging to associate them with specific enclosure and interpretation characteristics. The aggregated categorization retained 73 animal names, which aligned more closely with how visitors experienced and understood these animals in the zoo.

To identify the best subset models, we compared all models nested within the global model and selected those with a $\Delta AICc < 2.0$, based on Akaike Information Criterion corrected (AICc) (Burnham and Anderson 2002), using the "MuMIn" package (Barton 2023).

Before conducting the regression analyses, we applied an arcsin transformation to the dependent variables, selected based on normality statistics (Pearson P/df) using the "bestNormalize" package (Peterson 2021). In addition, we included different taxonomic groups (i.e., Order, Class, and Family) as random effects to build multilevel models, accounting for between-group variability and the non-independence of observations within groups. However, both unconditional and conditional intraclass correlation coefficient (ICC) values from all multilevel models were below 0.1 (Supporting Information S1: Tables S3 and S4), indicating negligible between-group variability and suggesting that multilevel models were unnecessary (Kianoush and Masoomehni 2015).

3 | Results

3.1 | Wildlife Preferences Before and After Zoo Visits

Overall, mammals were the most favored animal group by visitors both before and after the visit, with over 85% of respondents listing mammals among their favorite wildlife. Popular animals, defined as those favored by at least 5% of respondents, were exclusively mammals, followed in popularity by birds, reptiles, and amphibians (Figure 2a). The most popular mammal species included pandas, tigers, giraffes, elephants, lions, and monkeys (Figure 2c).

However, there was a significant decrease in preference for mammals after the zoo visit ($x^2 = 15.24$, $p < 0.001$), whereas preference for reptiles significantly increased ($x^2 = 42.22$, $p < 0.001$) (Figure 2a, Table S5). No significant changes were observed in preference for birds, amphibians, or other animals (including prehistoric extinct species, aquatic animals, and insects not displayed at the zoo during the survey period). Specifically, with the exception of the giraffe, visitors' preference for "popular animals" either decreased or remained relatively unchanged (i.e., monkeys) after their zoo visit (Figure 2c). Notably, visitors identified a broader range of species as favorites following their zoo visit ($x^2 = 22.34$, $p < 0.001$), particularly birds, reptiles, and amphibians (Figure 2b). The results from the analysis using the CEM-matched responses were consistent with the findings mentioned above (Supporting Information S1: Table S6).

3.2 | Increased Preference for Non-Popular Animals Exhibited in Zoos

The regression model using the full set of valid responses revealed a significant interaction effect between the exhibit status of zoo animals and their pre-visit popularity on changes in visitor preferences before and after their visit (Figure 3a, Supporting Information S1: Tables S7 and S8). Specifically, preference for non-exhibited animals declined after the visit. The analysis using the CEM-matched responses yielded consistent results, with the same significant variables and model explanatory power, as both models showed an adjusted R^2 of 0.36 (Supporting Information S1: Tables S9, S10, and S11).

For unpopular animals, preference increased for those exhibited at the zoo after the visit, with a greater boost for the general category compared to specific species ($\beta = 0.29$, $t = 1.94$, $p = 0.05$) (Figure 3a; Supporting Information S1: Tables S7 and S8). In contrast, for moderately popular animals, the increase in preference was more pronounced for specific species than for the general category ($\beta = 0.85$, $t = 2.58$, $p = 0.01$) (Figure 3a). The results were largely similar for mammals, birds, and amphibians/reptiles, although for moderately popular birds and amphibians/reptiles, visitors also showed a greater increase in preference for the general category (Figure 3b).

For popular animals, there was a significant decrease in visitors' preference after their visit, particularly for the general category

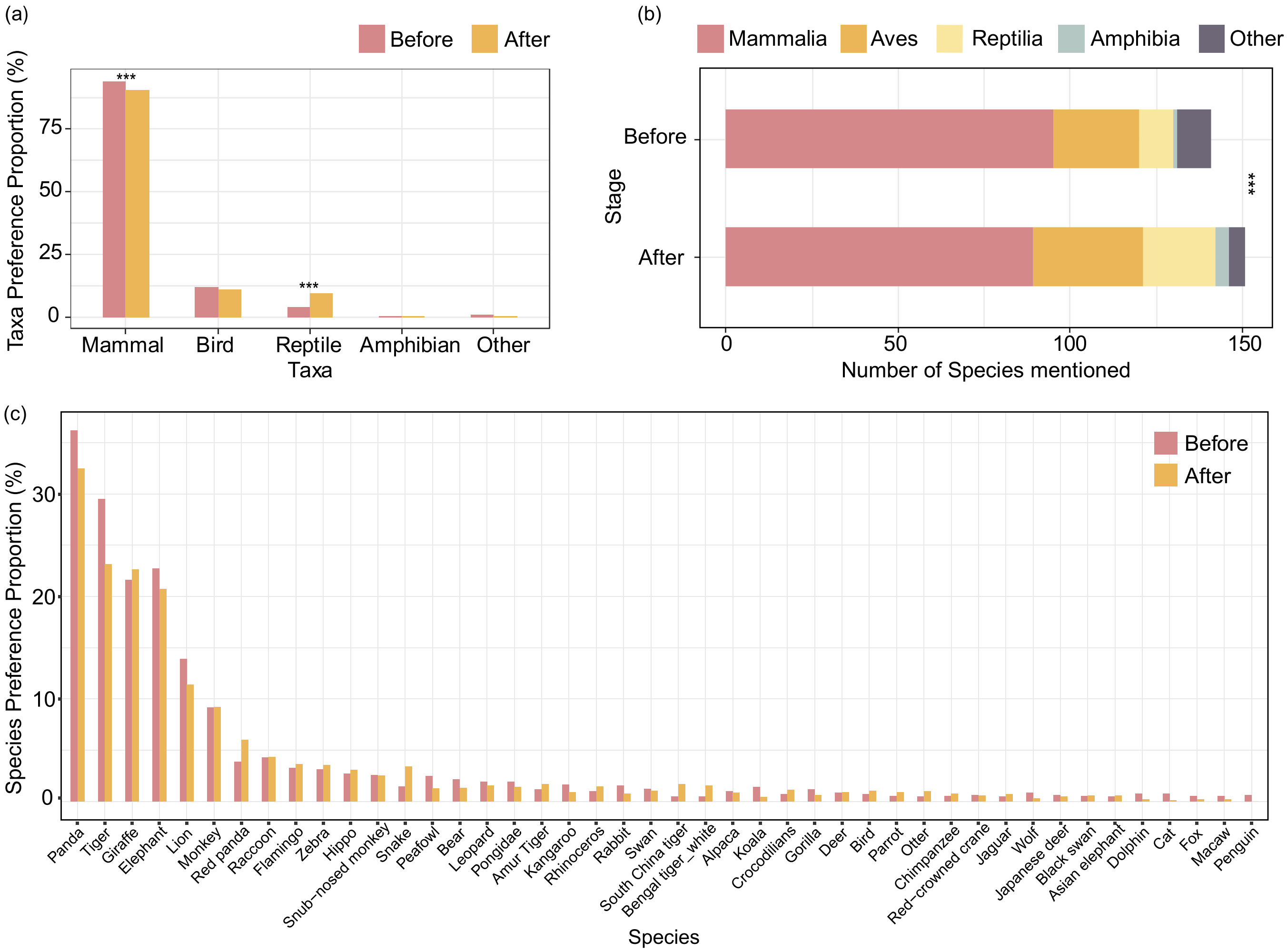


FIGURE 2 | Animal preferences before and after zoo visits (Full valid responses). (a) Proportion of preference for different taxa before and after the zoo visit; (b) Number of preferred species mentioned across different taxa before and after the zoo visit; (c) Proportion of preferences for various species or taxa before and after the zoo visit. *Note:* In (a) and (b), an asterisk indicates statistical significance based on chi-squared tests: $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$. In (c), all mentioned animal names are displayed to minimize information loss, without grouping species or taxa. Only the top 40 favorite species or taxa are shown, ranked by pre-visit preference.

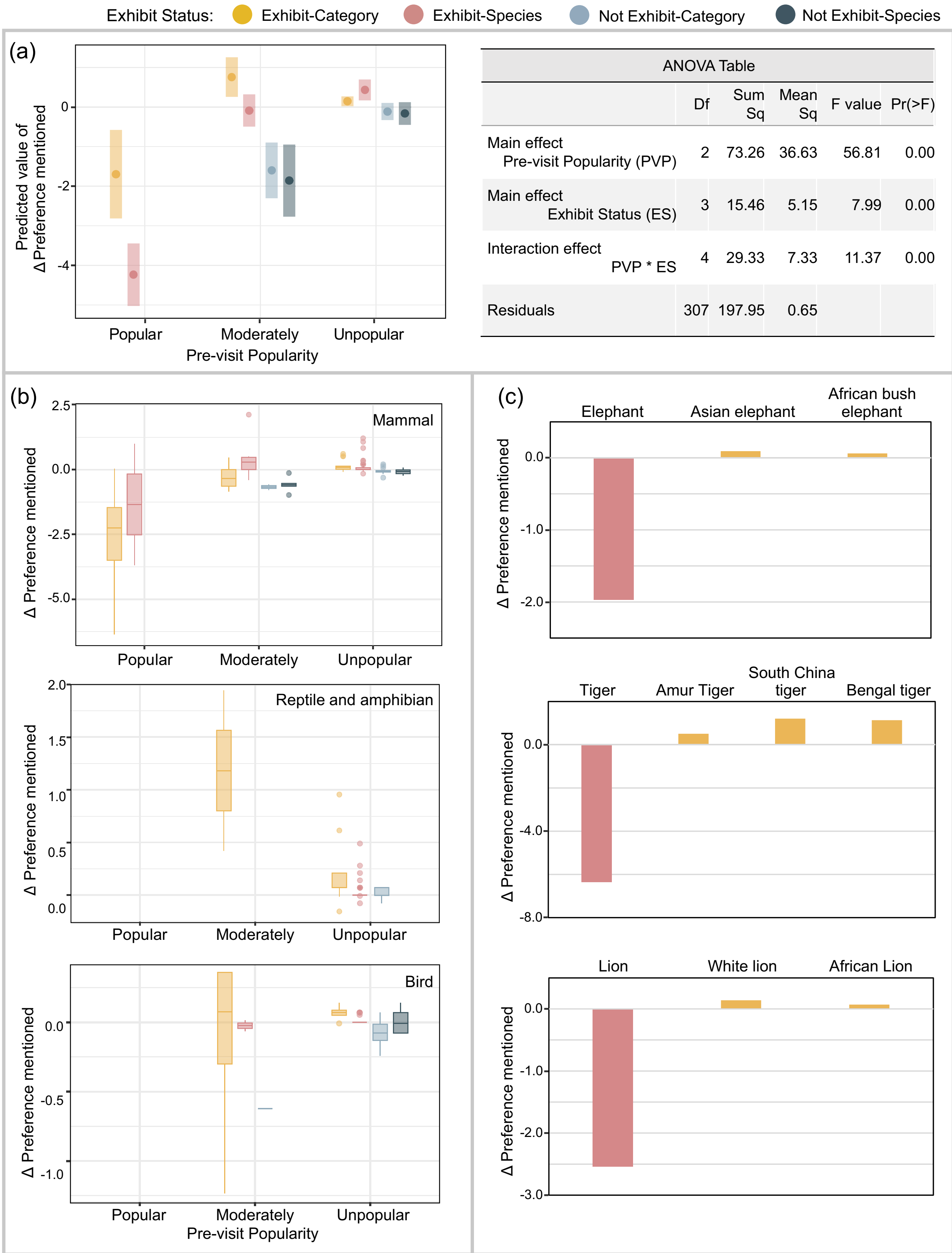
(Figure 3a). However, despite the overall decline in preference for popular general-category animals, their subcategories or subspecies—that is, specific animal names that exactly match the zoo's exhibited animals—were more frequently listed as favorites (Figure 3c). For instance, while the proportion of respondents listing "tiger" as their favorite decreased, the proportion listing specific subspecies, such as "South China tiger," "Siberian tiger," or "Bengal tiger," increased. Since all the popular animals mentioned were exhibited at the zoo, non-exhibited popular species categories were not estimated in the model.

3.3 | Factors Influencing Pre- and Post-Visit Changes in Wildlife Preferences

The best subset regression model using the full set of valid responses showed that the number and interactivity of interpretive facilities, enclosure size, and enclosure type significantly influenced changes in visitors' preferences before and after their zoo visit. Additionally, interaction effects were observed between the number of interpretive signs and the other three key factors (Figure 4a, Supporting Information S1: Tables S12 and S14). Specifically, in smaller enclosures, an increase in the number of interpretive signs was strongly associated with higher wildlife preferences, whereas in larger enclosures, this effect was weaker (Figure 4b). Moreover, in open exhibits, an increase in the number of interpretive signs had a greater impact on enhancing wildlife preferences (Figure 4c). Similarly, when fewer signs were present, interactive facilities effectively boosted wildlife preferences (Figure 4d).

The model selection using CEM-matched responses identified the best subset model with the same explanatory variables and similar model explanatory power as the best model obtained from the full valid responses (adjusted $R^2 = 0.43$ for the model using full valid responses and adjusted $R^2 = 0.44$ for the model using CEM-matched responses) (Supporting Information S1: Tables S13 and S15).

Although quantile deviations were detected for the best models (Supporting Information S1: Figures S1 and S2), no correlation



ANOVA Table

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Main effect Pre-visit Popularity (PVP)	2	73.26	36.63	56.81	0.00
Main effect Exhibit Status (ES)	3	15.46	5.15	7.99	0.00
Interaction effect PVP * ES	4	29.33	7.33	11.37	0.00
Residuals	307	197.95	0.65		

FIGURE 3 | The impact of zoo animal exhibit status and pre-visit animal popularity on preference changes before and after the visit (Full valid responses). (a) Interaction effect plot based on regression models and ANOVA results table; (b) preference changes for mammals, reptiles and amphibians, and birds, respectively; (c) preference changes for the top three popular animals at the category level, with displayed specific species or subspecies/mutation types in the zoo exhibits before and after the visit.

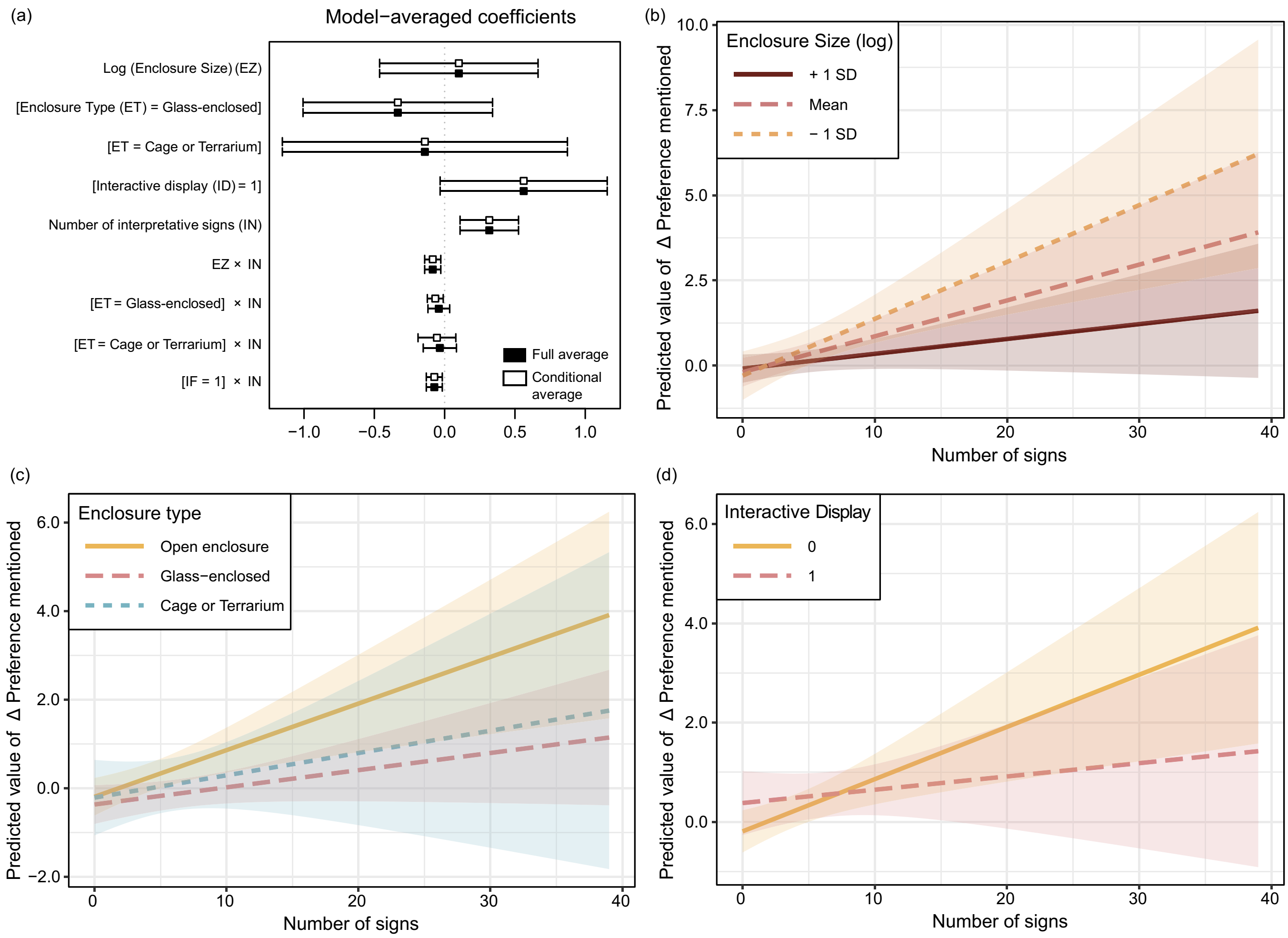


FIGURE 4 | Regression model results for factors influencing preference changes (Full valid responses). (a) Model-averaged standardized coefficients for the best subset model with a ΔAICc < 2.0; (b–d) Interaction effect plots based on the best model. *Note:* 95% confidence interval is shown.

was found between residuals and predicted values ($t = 0.00$, $p = 1.00$), indicating an adequate model fit (Gelman et al. 2020).

4 | Discussion

Our study examined how zoo visits, along with the characteristics of enclosures and interpretive facilities, affect changes in visitors' wildlife preferences. Overall, zoo visits significantly influenced visitors' wildlife preferences, increasing the variety of animals they favored and enhancing their preferences for certain categories, especially less popular animals. The increased public preference for these species may help promote conservation intentions and support for these less charismatic yet deserving species (Echeverri et al. 2017; Kaltenborn et al. 2006; Mohamad Muslim et al. 2018). Key factors affecting changes in preferences included the number of interpretive signs, enclosure size, enclosure type, and the interactivity of interpretive facilities. Analysis of full valid and CEM-matched responses showed no differences in significant variables or model explanatory power, further validating the reliability of our conclusions. Our findings provide valuable insights into optimizing zoo exhibit design and interpretive facilities to better support conservation education.

Consistent with previous research showing that visitors are more interested in mammals than any other group (Carr 2016; Moss and Esson 2010; Nyberg et al. 2021), our findings indicated that mammals consistently had higher popularity both before and after the visit. However, despite over 60% of the exhibit space at Guangzhou Zoo being dedicated to mammals, visitors' preference for mammals—particularly iconic large species—declined notably after their visit. Instead, there was a shift in preference toward a more diverse range of species, particularly reptiles such as snakes, lizards, turtles, and crocodiles. While reptiles have generally been perceived as the least favored or even feared animals in previous studies (Carr 2016; da Silva et al. 2021; Yorek 2009), the significant increase in visitors' preference for reptiles in our study highlights the potential role of zoos in enhancing public recognition and interest in these typically aversive species, thereby fostering positive attitudes toward them.

Our results showed no significant changes in preference for birds and amphibians after the zoo visit. This may be due to the fact that, during our survey period, the largest bird exhibit was closed for renovations, and the amphibians were displayed in limited numbers in small terrariums, which may have constrained their exposure to the public. However, visitors still mentioned more species of birds and amphibians after their visit, and their preferences for exhibited species or categories increased. This suggests that even a limited number of species in zoos can potentially enhance public interest in a broader range of nonmammalian species.

The model results showed a clear increase in visitor preference for less popular animals (i.e., moderately popular and unpopular animals), highlighting the important role zoos play in cultivating public interest, awareness, and ultimately, potential conservation actions toward non-flagship species. Apart from mammals, other animal groups saw a greater increase in preference for names mentioned at the category level than at the species level. This may be due to the cognitive difficulty the public faces in distinguishing nonmammalian species (Hooykaas et al. 2019), suggesting that potential conservation education strategies for underappreciated species could benefit from integrating similar species of conservation interest and promoting them by category, thereby enhancing the overall impact of educational initiatives.

Additionally, we observed that the giraffe was the only popular animal to show an increase in visitor preference after the zoo visit. This may be attributed to the giraffe being the only animal in the regular exhibits that offers a "hand feeding" experience. This is a prevalent type of animal-visitor interaction (AVI) (Doodson et al. 2022), which has been shown to significantly enhance knowledge and foster positive attitudes toward animals (Collins et al. 2021). However, it should be noted that this does not suggest an endorsement of such feeding practices, as positive AVIs should be conducted under the professional guidance of zoo staff, with attention to animal welfare (Fernandez and Chiew 2021).

As our study used an open-ended question to capture a wide range of visitor preferences, rather than the traditional ranking methods (Moss and Esson 2010), the absence of mentions of any particular animal does not necessarily indicate a lack of interest. Therefore, a reduction in the number of mentions of certain animal names does not necessarily imply a decline in preference for those animals. This is especially true for taxa names—an observed decline in the proportion of mentions does not definitively represent a corresponding decline in preference. Instead, it may indicate that a zoo visit enhances visitors' recognition of specific species or subspecies. For instance, although mentions of "tiger" decreased, the specific mentions of "South China tiger," "Amur tiger," and "Bengal tiger" increased. This finding, derived from the open-ended question, indicates valuable opportunities for implementing more targeted conservation initiatives in zoos. We believe this approach provides a comprehensive understanding of visitor preference changes.

Furthermore, we found that an increased number of interpretive signs, larger enclosures, and the interactivity of interpretive facilities contributed to a greater increase in preferences for certain species. Overall, the number of signs played a crucial role, aligning with previous studies showing that more interpretation leads to greater conservation education outcomes (Madin and Fenton 2004; Weiler and Smith 2009). Interestingly, the addition of signs has a greater impact on the increase in visitor preferences in smaller enclosures. In large enclosures at Guangzhou Zoo, interpretive signs are more dispersed, and visitors may not stop at every viewing point and read all the signs. As a result, the benefits of increasing the number of signs in large enclosures may be less pronounced. However, this does not suggest that adding more signs in large enclosures is ineffective. Instead, larger enclosures may require additional signs to support visitors' learning at different viewing points. Meanwhile, the effect of more signs on preference enhancement was more noticeable in open exhibits. This is likely because open exhibits at Guangzhou Zoo often create more immersive environments with natural elements that mimic the species' native habitats (Moss et al. 2008), encouraging visitors to seek information about a species from interpretive signs when they feel more immersed in its environment (Edney et al. 2023; Smart et al. 2021). Future research and zoo designs could further explore the synergy between immersive exhibits and interpretive signs.

We found that interactive interpretive facilities can enhance visitor preference for animals when there are fewer signs. However, as the number of signs increases, interactive facilities diminish the effect of sign quantity on visitor preference. This may be because interactive exhibits engage visitors more, thereby reducing their attention span for other signs. This is consistent with previous research that highlights the importance of interactive facilities in engaging public interest and effectively conveying knowledge (Edney et al. 2023; Lindemann-Matthies and Kamer 2006). Nonetheless, the interaction effects in our model suggest that interpretation-based education could benefit from interactive facility designs that better integrate with other interpretive signs.

Although we acknowledge that the naturalness and complexity of exhibits are significant factors affecting visitors' experience and educational outcomes (Godinez and Fernandez 2019; Razal and Miller 2019; Ross et al. 2012), we encountered challenges in evaluating these aspects due to ongoing upgrades and renovations at Guangzhou Zoo. Some animals were displayed in both naturalistic and traditional settings, which complicated comparisons. Nevertheless, the ongoing wave of enclosure upgrades in Chinese zoos provides an excellent opportunity for intervention studies. Future research could systematically investigate how changes in specific enclosure characteristics, before and after renovations, impact conservation education outcomes across species and enclosure types.

In addition to interpretive facilities, other interpretation types, such as oral interpretations, guided tours, and lectures, are equally important for visitor learning (Kleespies et al. 2020; Weiler and Smith 2009). Although Guangzhou Zoo offers a range of interpretive events, their duration, participant numbers, and varied formats limited consistent and systematic evaluation within the project's resources. Future research could leverage broader and deeper surveys to evaluate the effectiveness of these diverse forms of interpretation and further improve zoos' conservation education efforts.

Although our cross-sectional pre-post survey method helps reduce bias from repeatedly asking visitors about their preferences, it only allows us to assess group-level differences and does not account for individual variability, which may reduce internal validity. Future research could use longitudinal surveys to examine the impact of individual factors and specific zoo experiences on conservation outcomes, as well as the long-term effects of zoo visits. Furthermore, this study was conducted with adult visitors, and the preferences and attitudes of children or adolescents toward animals may differ (Henseler Kozachenko and Piazza 2021). Thus, the applicability of our findings to other age groups should be interpreted with caution.

5 | Conclusion

Understanding how urban zoos can serve as valuable nature education spaces is vital for reconnecting residents with nature and engaging them in conservation efforts. While our study focuses on visitors' changes in wildlife preferences, findings worldwide highlight the pivotal role of such preferences in encouraging conservation actions and policy support (Echeverri et al. 2017; Kaltenborn et al. 2006; Mohamad Muslim et al. 2018), underscoring the potential of our China-based research to improve biodiversity education design in zoos. Our findings suggest that zoos can help foster affection for a broader range of wildlife, particularly less popular animals. In addition, we found that various enclosures and interpretation features can have complementary or reinforcing effects on educational outcomes. These insights provide valuable guidance for the design of exhibits and educational systems in zoos and other educational settings, such as museums and botanical gardens, potentially promoting public conservation actions and supporting conservation education efforts in China.

Author Contributions

Kaiwen Zhou and Sifan Hu designed research; Kaiwen Zhou, Jiakuan Xu, Wei Lin and Sifan Hu collected data; Kaiwen Zhou analyzed data and wrote the paper; and all co-authors revised the paper.

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Ethics Statement

The authors confirm that the ethical policies of the journal have been adhered to. All data were anonymized and used only for research purposes.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.