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An Investigation into the Perception and Prevalence of Mixed-Species Exhibits in Zoos and Aquaria

Hannah Green[1], Georgia Abernethy Palmer[1] & James Edward Brereton[1]

[1] University Centre Sparsholt, Westley Lane, Sparsholt, Winchester, SO21 2NF, United Kingdom
Correspondence: James Edward Brereton, University Centre Sparsholt, Westley Lane, Sparsholt, Winchester, SO21 2NF, United Kingdom.

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Abstract

Mixed-species exhibits (MSE) are a common occurrence within zoological collections. They increase species diversity and provide immersive yet naturalistic experiences for both species and visitors. Although mixed-species exhibits are a common housing method for animals in zoological collections, the literature on these enclosures is limited. Animals, keepers, and visitors have the potential to benefit, or be challenged MSE, so investigations of the benefits and limitations of this practice is necessary. This study investigated the presence of MSE in a range of England zoological collections and in zoo and aquarium-based literature. Additionally, zoo professional perception of MSE was investigated using online questionnaires. The study identified a mismatch between the types of species that feature in zoo and aquarium MSE, versus those that appear in the MSE literature. MSEs were identified as being enriching from both an animal and visitor perspective, yet there was sometimes limited information on the research output to support these statements. There is scope for zoo and aquarium professionals to widen the diversity of MSE projects, to ensure that the risks and benefits of this housing method are fully investigated.

Keywords: husbandry, enrichment, zoo management, reintroduction

1. Introduction

Mixed-species exhibits (MSE) are zoo or aquarium enclosures that house two or more animal species. These exhibits are prevalent in zoological collections globally, but their benefits which are believed to include species suitability, enrichment welfare, and post-captivity release, still require further empirical research (Dorman & Bourne, 2010). Through understanding natural history, zoological collections can identify naturally co-existing species in the wild to determine their suitability for captive housing. Exhibiting species that are sympatric in the wild may be successful within MSE if innate interactions are expressed within social environments (Daoudi & et al., 2017). Mixing species that fit different ecological niches (i.e., arboreal and terrestrial species) facilitates enclosure usage and reduces issues associated with competition, allowing species to coexist with minimal aggression. By considering ecologically informed missed, MSE can create an immersive and educational experience for visitors (Daoudi & et al., 2017). Larger enclosures that house multiple species often amplify physical activity including 'play' or 'exploratory' interactions, both intraspecifically and interspecifically which enhances social complexity (Hardie 1997; Buchanan-Smith & et al., 2017).

Kaandorp (2012) argued larger MSE are more susceptible to challenges, particularly surrounding physical or physiological traumas. Competition for resources (i.e., nesting sites/material or individual territories) are a potential risk in MSE. For example, seasonal aggression within rutting season of deer can lead to interspecific conflicts whereby males of different *Artiodactylae* will compete regardless of species or size, with a resulting risk of injury (Carisch & et al., 2016). Facilitating creeps (pole gates) whereby smaller species can escape from larger animals or use as hiding areas, and multiple feeding and water stations are preventative measures to avert trauma within MSE. Interspecific aggression is often reduced between taxonomically related species due to similar, identifiable threat behaviours, therefore preventing further aggression, opposed to distant species (Hanzlíková & et al., 2014).

MacDonals and Whiten (2011) reviewed the 'Living Links to Human Evolution' project at Edinburgh Zoo whereby two groups of brown capuchins *(Sapajus apella)* and squirrel monkeys *(Saimiri sciureus)* were housed in a 'suitable' environment. After close monitoring aggressive behaviours caused by stress, including territory defence began to form as a result of overlapping territories (Buchanan-Smith, 2011). Naturally *S. apella* and *S. sciureus* would form interspecific assemblages, with *S. apella* dominating due to size differences. Therefore, a degree of dominating or aggressive behaviours is expected, particularly in captivity due to restricted resources and space. Buchanan-Smith et al., (2013) identified that after the enclosure was modified via proximal expansion, aggressive behaviours were reduced, allowing individuals to retreat away from other individuals. Moderate levels of stress towards captive animals are not always negative, as acute stress occurs often in wild environments (Romero & et al., 2015). However, spatial separation and food availability minimises the severity of these interactions.

2. Species Ecology

Understanding species behaviour and ecology is vital when designing *in-situ* and *ex-situ* conservation practises (Meise & et al., 2019). Whilst interaction between species in different ecological niches is essential for comprehending natural diversity, appreciating coevolution is paramount for understanding ecosystem functionality. Thus, allowing natural relationships to be established between species diversity and ecosystem stability. Consolidating the importance of understanding species' ecology in relation to their suitability within MSE. Allesina and Tang (2015) reviewed how 'random' or 'unnatural' interactions were theorised to jeopardise stable coexisting species and found species that respond positively to 'random' interactions appeared more adaptable. Species living within complex environments become more adaptable within their surroundings and mixed-species communities, suggesting species that currently co-exist or historically co-existed would be able to evolve to meet captive mixed environments. Natural niche variation patterns were observed within four co-existing frog species which discovered four ecological factors for specificity: interspecific competition, intraspecific competition, predation, and ecological opportunity (Costa-Pereira & et al., 2018). Linking to behavioural considerations within MSE husbandry management, as competition can be challenging to avoid, causing welfare implications through the public eye (Buchanan-Smith, 2011). Those that obtain specific niches can be replicated within MSE with appropriate husbandry development.

Megaherbivores have established habitat heterogeneity through feeding behaviour and natural environmental disturbances (Hyvarinen & et al., 2021). They provide the resources required for supporting species expansion, driving biodiversity whilst maintaining ecosystem function and resilience. (Estes & et al., 2011; Svenning & Faurby, 2017). Their intrinsic link to natural history makes them appropriate species for being housed within MSE, as long natural requirements are maintained.

3. Collection Management

Kaandorp (2012) concluded aquaria and aviaries are commonly maintained as MSE exhibits. This often means that species diversity in zoo collections for birds, fish and invertebrates is high (Brereton & Brereton, 2020). Sloman et al., (2011) supported this by stating aquaria collections are renowned for mixing species in natural interspecific assemblages or habitats, however a lack of welfare understanding is still apparent. Irwin et al., (2013) highlights enclosure design as primary factor for influencing keeper perspectives, as this pinpoints habitat replication and suitability for all species, safety and practicality. Each species must be kept healthy and enriched, whilst maintaining quality of life which requires various assessments to be undertaken including behavioural analysis (Daoudi & et al., 2017), enclosure usage (Brereton, 2020; Brereton & Fernandez, 2022) and proximity analysis, alongside ensuring that sufficient staff training is upheld (Wolfensohn & et al., 2018).

4. Rationale and Aims

It is unclear whether the literature on MSE is reflective of the types of species commonly housed in MSE enclosures. Previous research (e.g., Melfi, 2009) has identified a species bias in animal literature, in which mammalian taxa tend to be better represented. It is therefore important that any gaps in the study of MSE interactions in terms of taxa, welfare, and visitor perception, are identified. The aims of the study were to compare zoo literature and MSE displays alongside discussing MSE representation from the keeper's perspective. Additionally, the study aimed to assess various perceptions of mixed species and discuss their prevalence and importance in the zoological industry and conservation.

This study aimed to address three research questions:

1) Will there be significant differences between the prevalence of published literature on MSE to actual mixed-species exhibits found within UK collections?

2) Is there a shared perspective that if a mixed-species exhibit is successful for the animal, will it be suitable for the keepers and visitors also?

3) Are there significant relationships between collection type and animal taxonomic representation in an MSE?

5. Methods and Materials

Following Institutional ethical approval from University Centre Sparsholt (Ethics code: UCSEC _1622), data were collected between December 2021 and July 2022 investigating zoo and aquarium MSE. The study consisted of a series of zoo exhibits (to determine what is kept in MSE), a literature review (to determine which species are studied in MSE) and a survey (to determine how MSE is perceived).

6. Zoo Visits

Following structured convenience sampling, 21 zoological collections were identified and visited between December 2021 and July 2022. Collections included but were not limited to; zoos, wildlife/safari parks (W/SP), and aquariums allowing collection diversity. Because of the structured convenience sampling method, bias was introduced because only collections within 150-mile radius were utilised for convenience. Collections were strategically chosen to ensure at least one of each collection type were considered. During collection visits two lists were created, one including MSE and one of single-species exhibits (SSE). Establishing these two lists provided visual insight to the prevalence of MSE between collections, allowing any patterns of species or taxa mixes to be highlighted. Once retrieved, data were transferred into a secure Excel 2019 spreadsheet (Microsoft 365, 2022) to comply with General Data Protection Regulations (GDPR), where only the author and supervisors had access.

7. Questionnaire

A questionnaire was designed comprising 16 questions, over four sections: Management, Perception, Taxa, and Future Directions, using standard platform Google Forms. Individuals within the zoo and ecology industry were contacted across social media platforms (i.e., relevant Facebook groups including, but not limited to, 'Zoo Keepers Europe', 'Students, Zookeepers, and Aquarists', and 'ZooAnlagen – onlyExhibits') alongside LinkedIn; and were asked to complete the questionnaire. It remained open for a duration of six weeks between 17 June 2022 to 31 July 2022, allowing adequate time for responses. All respondents remained anonymous ensuring confidentiality was maintained, whilst preventing bias. Should participants wish to withdraw their responses at any point they could. Respondents were asked to create a '3letter 3digit' code (i.e., abc123), and with the author's email easily accessible at the beginning of the questionnaire, participants could contact the author with their individual code allowing association and removal of responses if necessary.

8. Literature Review

A literature review investigating MSE was conducted, using the search criteria of 'mixed-species', followed by 'zoo,' 'aquarium', or 'wildlife park', plus one of the following taxa: 'mammal', 'bird', 'reptile', 'amphibian', 'fish' or 'invertebrate', from September 1980 – September 2021. While there are multiple classes of fish and invertebrate, these groups were classified in the results as fish and invertebrates on account of their scarcity in literature. The Web of Science and Google Scholar database were used to source published, peer-reviewed, and open accessed literature allowing investigations of relevant MSE information. Papers were included where they explicitly mentioned two or more animal species occupying a shared enclosure in a zoological collection. Ensuring data viability was maintained, specific information was retrieved from the literature (Table 1) and followed an eligibility criterion including but not limited to open access, peer-reviewed, and English written papers. Data from this method were compared with data from zoo visits, evaluating prevalence of MSE, highlighting any trends or patterns (i.e., overlap of species or taxa being housed together).

Table 1. Research criteria within mixed-species exhibit literature

Contents	Definition
Search Engine	The search platform such as Google Scholar and Web of Science.
Taxon	The species' common name, class, order, class, family, genus and species was recorded.
Country of Origin	The country to which the fauna species is resident.
Habitat	The environment type to which the fauna species naturally inhabits.
Diet type	The feeding strategy of the individual e.g., carnivore, herbivore, omnivore, frugivore, piscivore, nectivore, insectivore, fungivore, or folivore.
Threat Status	Their IUCN Red List conservation status: Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN) Critically Endangered (CR), Extinct in the Wild (EW), Extinct (E), or Data Deficient (DD).
Successful (Y./N)	Whether fauna species are successful in a mixed species exhibit (Y – yes, N – no).
Success Definition	- Affiliative - Aggression - Agonistic - Breeding - Enclosure use/proximity - Fatality. - Fearful - Interactive - Mortality - No change in behaviour - No interactions - Reintroduction/Release/Restoration/Translocation

	- Stable
	- Stress
	- Visitor impact
Mixing Strategy (1-5)	1= species always mixed (24/7)
	2= species mixed day or night
	3= separate areas within exhibit
	4= species are mixed mornings or evenings
	5= species are mixed on alternate days.
Other	DOI, Journal name and year

9. Data Analysis and Protection

Data collected abided by GDPR participant or collection information, data storage, data accessibility and participant consent (Evans & Mathur, 2018). Results were recorded using Excel 2019 and statistical analysis was conducted using Minitab version 23.

A test of 2 Proportions was run analysing prevalence between MSE in literature compared to MSE from zoo visits and allowed significant taxa to be highlighted. A Binary Logistics Regression was then run to assess prevalence between taxa and collection type to highlight patterns with 'MSE' as the response and 'Collection Type', '*Class*', *'Order'*, and 'IUCN' as the predictors. To enhance regression reliability, a Bonferroni correction (Armstrong, 2014) was included as this established new alpha numbers to determine significance. A Spearman correlation was undertaken for perspective analysis post questionnaire completion to highlight response relationships between perspectives of keepers, animals, and visitors. A combination of Chi-Squared Goodness-of-Fit Test and Thematic Analysis was utilised to analyse future directions and opinions of MSE (i.e., native or exotic species preference or ecosystem replication preference within an MSE).

10. Results

10.1 Prevalence: Literature Vs Collections

Figure 1 shows apparent differences of animal taxonomic classes in MSE between literature and collection visits. There was a significant difference between the following taxa: birds, mammals, reptiles, invertebrate, fish (P<0.001) opposed to amphibians which proved non-significant (P=0.20). All taxa appeared significantly more prevalent in collections than in literature: Amphibians 39:0 (n=39); Birds 455:84 (n=593); Fish 399:22 (n=421); Invertebrates 97:0 (n=97); Mammals 526:92 (n=618); Reptile 216:2 (n=218). Amphibians appeared to have the smallest sample size overall (n=39) which could indicate why there was a non-significant (P=0.02) difference between collections and literature. Zoos housed a higher quantity of MSE with lower numbers of species compared to other collection types. It was evident that aquariums were the only collection to facilitate 20+ species within a single MSE. W/SP had the smallest number of MSE.

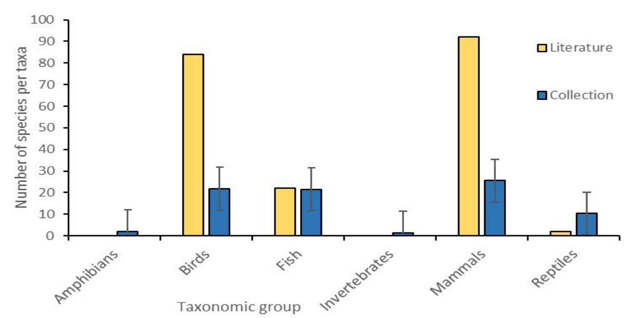

Figure 1. Difference in MSE prevalence between literature and zoo collection planes (+/- standard error)

10.2 Prevalence: Collection Type vs Taxa

Collection type was not a significant predictor of an animal's propensity to appear in MSEs (P=0.129), however it was evident that taxonomy was significant (P<0.001). An animal's IUCN status was not a significant predictor, however (P=0.141) (Table 2). The model explained 35.81% of variance in MSE (Table 3). Birds appeared to be a significant (P=0.040) predictor for MSE. Figure 2 shows zoos house significantly more MSE than W/SP, aquariums may house quantitively less MSE, but they house a significantly larger quantity and diversity of species than zoos and W/SP. Aquariums were not present with the regression test due to the limited sample size.

Table 2. 'Analysis of Variance' for identifying predictors for MSE

Predictor	P-Value
Collection Type	0.129
Class	<0.001
IUCN	0.141

Table 3. Coefficients from regression of a species' appearance in MSE rather than single species enclosures

Term	SE Coef	Z-Value	P-Value
Collection Type			
Wildlife/Safari Park	0.437	-1.74	0.083
Zoo	0.383	-0.91	0.362
Class			
Bird	0.601	2.05	0.040
Fish	0.597	-0.93	0.353
Invertebrate	0.689	-0.49	0.626
Mammal	0.588	0.31	0.759
Reptile	0.624	-0.46	0.643
IUCN			
CR	1.45	-0.20	0.839
DD	1.55	0.37	0.713
EN	1.45	-0.00	0.996
EW	1.65	0.01	0.995
LC	1.44	0.20	0.844
NE	1.46	0.26	0.797
NT	1.46	0.33	0.744
VU	1.44	-0.19	0.851

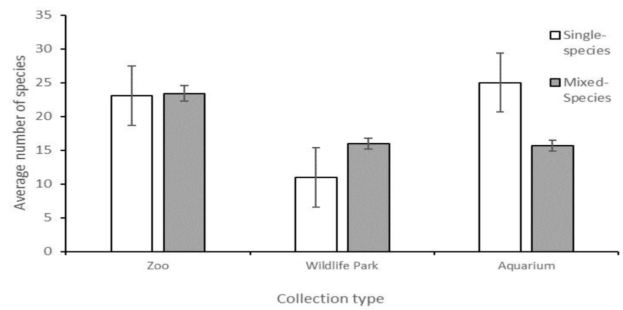

Figure 2. Quantity of MSE per each collection type: Zoos; Wildlife/Safari Parks; Aquariums (+/- standard error)

10.3 MSE Perception: Within the Zoo

The 'Perception' design denoted that respondents would focus on one specific MSE indicating exhibit-specific responses, resulting in potential keeper or collection bias. Table 2 displays 61% of categories showing a positive weak correlation, 22% a negative weak correlation, and 11% no correlation.

Table 4. Spearman's correlation results between three perceptions: Animal, Keeper, and Visitor

Perception	MSE Categories	Correlation	R-Value	P-Value
Animal	Enclosure Use + Habitat Replication	Positive/weak	0.187	0.208
Animal	Enclosure Use + Naturally Encounter	Positive/weak	0.125	0.403
Animal	Enclosure Use + Social Interaction	Negative/weak	0.005	0.975
Animal	Habitat Replication + Naturally Encounter	Positive/weak	0.282	0.054*
Animal	Habitat Replication + Social Interaction	No correlation	0.031	0.836
Animal	Social Interaction + Naturally Encounter	Positive/weak	0.094	0.531
Keeper	Enclosure Design + Health Checks	Positive/weak	0.308	0.035

Keeper	Enclosure Design + Husbandry Ease	Positive/weak	0.352	0.015
Keeper	Enclosure Design + Safety	No correlation	0.004	0.977
Keeper	Husbandry Ease + Health Checks	Positive/weak	0.322	0.027
Keeper	Husbandry Ease + Safety	Positive/weak	0.426	0.002*
Keeper	Safety + Health Checks	Positive/weak	0.215	0.147
Visitor	Education + Message/Theme	Positive/weak	0.477	<0.001*
Visitor	Education + Safety	Negative/weak	0.004	0.977
Visitor	Education + Species Visibility	Positive/weak	0.162	0.276
Visitor	Message/Theme + Safety	Negative/weak	0.173	0.245
Visitor	Species Visibility + Message/Theme	Negative/weak	0.051	0.733
Visitor	Species Visibility + Safety	Positive/weak	0.085	0.568

10.4 MSE Perception: Preferences

From allowing respondents to design their own MSE with a relevant theme and message; figures 4 and 5 display a Word Cloud highlighting trends and patterns within this. Figure 4 shows that the following categories created patterns that were significantly more preferred within new MSE: 'single taxon', 'bird', 'African savanna', 'zebra', 'antelope', 'tapir', 'giraffe', 'native UK species', 'capybara', 'giant anteater', and 'Amazon Forest'. Figure 5 highlights the following themes created significantly correlated patterns regarding preference of MSE: 'ecosystem replication', 'ecosystem role', 'lost ecosystem', 'coexistence', 'interaction', 'natural function', 'interconnection', 'conservation', and 'biodiversity'.

Figure 4. Word cloud displaying the results from Q16: If you could create a MSE, what would be in and what would the theme/message be?, categorised into 'Species Preference, Species/Taxa, Mixed/Single Taxa, Enclosure Design'.

Figure 5. Word cloud displaying the results from Q16: If you could create a MSE, what would be in and what would the theme/message be?, categorised into the chosen Themes.

11. Discussion

11.1 Prevalence

This study demonstrated that there are differences between the animals that feature in zoo MSE literature, versus those that are normally features in these exhibits (Figure 1 and 2). This indicates that there are many potential interspecies interactions in the zoo that are not yet being empirically studies. Lack of evidence can jeopardise efficiency, and reliability of current zoo practises as it means that animal compatibility or exhibit educational value may not be suitable (i.e., relevant signage, themes and messages of exhibits).

Zoos strive to provide optimum *ex-situ* conservation practises given the current global crisis. Kagan et al., (2018) concluded that zoos and aquaria often pose a reluctance in publishing gaps in zoo science as it could be considered as a 'failure' within that collection due to public pressures, indicating a limitation on MSE published literature. Organisations including The Detroit Zoological Society (DZS), US, has challenged this by encouraging collections to embrace gaps in zoological science as a form of progressing within practises. This is beneficial within MSE if collections are provided with sufficient research upon exhibit successes and failures allowing failures not to be repeated, allowing enhanced messages in the future.

Publishing literature about species mortality as a result of an unsuccessful MSE poses complexities, referring to pressures within industry and public eye. However, the most prevalent cause for mortality in MSE is interspecies disease (Kaandorp, (2012). Kaandorp (2012) refers to the importance of understanding issues surrounding animal health particularly in interspecific environments as this can provide valuable information to improve current MSE husbandry protocols. Publishing this literature, even if it does include mortality, could counteract challenges of facing industry pressure as management could be improved. Krishna et al., (2016) believe from understanding failure there can be progression, if this attitude were applied toward MSE literature, a greater understanding of species mixes to avoid, behavioural occurrences, and relevant enclosure modifications could be incorporated. Kaandorp (2012) suggested trauma is a prominent result of resource competition (i.e., territories), yetBuchanan-Smith (2013), highlighted relevant enclosure modifications (i.e., expansions) reduced trauma-related aggression signifying correct enclosure design information is paramount for optimal welfare. This study evidenced limited current MSE research, therefore through updating current research, appropriate enclosure design can be applied, preventing any trauma or mortality caused by insufficient space.

There are fewer less-charismatic species within both literature and MSE, particularly amphibians (Figure 1). Amphibians had the smallest sample size which could have influenced the lack of MSE found opposed to them completely being ruled out as unsuitable MSE candidates. Amphibian cannibalism has been researched suggesting why amphibians are rarely found in mixed communities in the wild as they have been observed predating singular or similar species (Crump 1983; Vaissi & Sharifi, 2016). Mammals appeared most popular within literature and collections, closely followed by birds with just slightly fewer MSE. Melfi, (2009) discussed patterns within zoological research and highlighted a significant 'mammal bias', particularly surrounding primates due to human relation and what researchers already know; this research supported the primate-dominating findings from this study. Through assessing a sample of research, they discovered 89% was mammal based (60% primate based), 8% was bird based, and 1% on remaining taxa, therefore supporting this bias. Bird research appears to be increasing, encouraging scientists to research taxa other than mammals. In conclusion, it appeared that both *Class,* and *Order* influenced the prevalence and diversity of MSE.

Regarding collection type, aquariums house more fish and invertebrate species, alongside more species within a single MSE. Cracknell et al., (2016) concluded aquariums often house multiple species to naturally represent ecosystems, providing visual interpretation of oceanic restoration. Aquariums have been mixing species for much of their existence (Hvilsom & et al., 2020).

Smaller collections within the data housed a greater diversity of species within MSE. Sherwen & Hemsworth, (2019) identified that research needs expanding to encompass species specificity within collections due to multiple study focusses surrounding charismatic species, like primates. Smaller primates appeared more commonly than larger primates, supported by both literature and this study's findings. Reptiles are often suitable candidates for MSE; however, literature does not support this, suggesting research must expand around taxas. Moss & Esson, (2010) suggests species who pose higher conservation value are more commonly presented within collections, raising awareness.

11.2 Perception: Within the Zoo

The following categories appeared had the most significant correlation: from an animal perception 'habitat replication' and 'naturally encounter in the wild'; from a keeper perception 'husbandry ease' and 'safety'; and from a visitor perception 'education' and 'message/theme'. This was evidenced by an increase of people who believed the categories to be 'suitable for all species' from each perception (Figure 4 – Figure 9). Irwin et al., (2013) discussed how in 1941 naturalism in zoo enclosures increased when Bronx Zoo displayed its naturalistic African plain exhibit. Yet toward the 1980s the theory of landscape immersion evolved, expanding exhibit naturalism further by enabling visitors to experience the same habitat as the species. Supporting the significant categories for animal and visitor perception. Fuller et al., (2012) assessed keeper management of a mixed *Lorisidae* exhibit, and stated species within a MSE were often managed be two or more keepers ensuring optimal husbandry was maintained, supporting this study. Robbins & Margulis, (2016) promotes MSE as cognitive enrichment, particularly auditory enrichment as it is easier for keepers to create. Audios are more prevalent in bird enrichment due to various vocalisations.

Housing sympatric species together in a replicated habitat creates an immersive experience allowing exhibition of natural intraspecific and interspecific behaviours. From the zoo visits data, a collection housed two crocodilian species together: Nile crocodile *(Crocodylus niloticus)* (Africa) and Morelet's crocodile *(Crocodylus moreletii)* (Central-North America). Both species are located in different continents yet have been successfully housed together within a MSE, effectively displaying (wild) niche overlap and spatial separation; whereby species hold similar ecosystem niches yet are distributed through separate geographical ranges (Schmidt & et al., 2012). Although this does not support the results of the study regarding natural encounters of species, it does prove that certain species that are not naturally associated can coexist in captivity. Benefitting advanced conservation projects including reintroduction projects as MSE could be used as an experimental platform for introducing a species into a new environment, supporting species conservation. Further research would be required ensuring viability and reliability of the practise. Another data example was capybara *(Hydrochoerus hydrochaeris),* lowland tapir *(Tapirus terrestris),* and lesser rhea *(Rhea pennata)*. Three species inhabiting the same geographic location of South America and from the dataset were housed in a MSE more times than not (n=3:1) (BirdLife International 2018; Deer & et al., 2018; Reid 2016). Collection planning is often categorised by continents due to its easy navigation so housing suitable, naturally associated species would benefit as it would occupy less space than housing individually (Hutchins & et al., 1995; Brereton & Brereton, 2020). If collections continue to design their continentally, it could be argued that creating more MSE could be more beneficial if done appropriately.

Kleiman et al., (2010) argues MSE engages visitors due to increased activity, increasing education. (Moss & Esson, 2010) argues MSE detracts species-specific education at it allows visitors to be selective with the species they engage with like 'popular' species regardless of the broader theme of the exhibit, however they can promote education for the preferred species. Ressurreição et al., (2011) supports this by reiterating taxonomic bias toward charismatic mammalian species. H. Buchanan-Smith (personal communication, September 2022) said "Affording larger more complex (physically and socially), naturalistic enclosures would be beneficial for the animal. Also, if interpretation is done well, then highlighting to visitors the inter-connectedness of different species".

11.3 Future Directions

During zoo visits, it was highlighted by prior communication with staff that not all species were on display to the public therefore limited data. Although this does not directly jeopardise the data, it could impact its reliability as off-display species. Additionally, utilising UK collections proved useful for piloting this study however for a broader scale of collections and data, expanding to a European and UK sample would allow vaster, more comparable results. Additionally, the selection of zoos visited was limited by the 150-mile radius restriction due to the convenience sampling technique, indicating not all UK collections were utilised, therefore not showing a true representation of UK collections.

12. Conclusion

This study demonstrated significant disparities between MSE literature and collection exhibits emphasising importance of further research encompassing MSE husbandry, enclosure design, and education. It was evidenced aquariums housed more fish and aquatic invertebrates than any other collection type, yet there was no specific trend between zoos or WS/P. A successful MSE for its resident species appeared to suit keepers and visitors accordingly. However, it was evidenced that enhanced education on exhibit theme and messaging was necessary to accurately represent relevant conservation concerns, despite well received visitor perception.

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