



## Article

# Correlates of Bird Collection Compositions in Thai Zoos: Implications for Conservation and Management

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**Abstract:** Zoo collection management is increasingly driven by meeting global conservation needs. Many avian species have experienced population declines throughout Southeast Asia, underscoring the importance of ex situ conservation in these countries. We focus on Thailand, a bird diversity hotspot with a long tradition of keeping birds in captive settings. We aimed to understand what drives species acquisition and maintenance in Thai zoos. To that end, we surveyed 55 zoos, making a complete inventory of reptiles, birds, and mammals on display. We recorded 249 bird species, of which 149 are not native to Thailand. Bird species diversity was positively correlated with mammal species diversity but not with the entry ticket price, the Gross Domestic Product of the province in which the zoo was based, or the size of the zoo. Diversity did differ significantly between zoo types (accredited, government and private zoos). There was a clear difference in the proportion of native and non-native species between zoos, with private zoos containing the highest number of non-native species, which may be related to the licensing status of these zoos. The composition of bird species in Thai zoos appears to be largely driven by their availability, the legal status for keeping them and serendipity. The conservation status seems to be of minor importance, contradicting the typical role of a zoo. To be considered global conservation players, zoos in countries of high species diversity, such as Thailand, have the unique opportunity to provide breeding programmes for some of the rarest species, yet they must improve their collection management plans to focus on such aims.

**Keywords:** avian diversity; CITES; conservation; collection planning; welfare; zoological collections



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## 1. Introduction

Zoos are well-placed to be at the forefront of conservation efforts [1–3]; indeed, most modern zoos claim that conservation is a core institutional priority [4,5]. However, to make meaningful contribution gains, zoos must carefully select which species they hold within their collections [6,7]. Collection planning decision-making should be made at global, regional, and institutional levels [6,8] and encompasses multiple factors, including collaboration with regional zoo associations, taxon advisory groups (TAGS) and species studbooks [9]. Increasingly, the importance of conserving biodiversity has been emphasised by the United Nations Convention on Biological Diversity and, specifically, Aichi Target 12, which aims to prevent the extinction of threatened species [10]. Here, zoos play an important role in maintaining sustainable collections that advance conservation efforts [11–14].

As zoos inherently have limited space and resources, zoo management may plan their collections according to institutional conservation goals [6,15]. Because of these limitations, zoos only house a small percentage of global biodiversity [2,16]. Instead, collections typically focus on the large charismatic megafauna, partly because of their popularity with zoo visitors [7,17,18], making them popular flagship conservation species that may generate increased donor funding [3,19,20].

An analysis of the International Zoo Yearbook collection data found that birds typically represent just over a third of zoo collections, the highest of all taxonomic groups [21]. A study of bird compositions in 550 modern zoos worldwide found that zoos tended to keep species with larger spatial ranges that were less likely to be endemic or threatened with extinction and were more likely to be distributed in more economically developed parts of the world [2]. Essentially, most birds held in zoological collections are those that contribute the least to conservation, whereas birds in need of priority conservation action are not well represented in zoos. Evidently, such practices are not conducive to meeting biodiversity sustainability targets, including Aichi Target 12.

Only 17 of the 550 modern zoos in Martin et al.'s [2] study are located in Southeast Asia, a region with over-exploited bird populations due to hunting pressures, overcollection and habitat degradation [22,23]. The situation facing birds in Southeast Asia is alarming, with some predictions that by 2100, one-third of bird species will be extinct [24]. One of the predominant drivers of the trade in birds is the pet trade, with many countries having a long tradition of keeping birds as pets [25–28]. Thailand, for example, has experienced the widespread capture of wild birds such as the Hill Mynah *Gracula religiosa* and Red-whiskered Bulbuls *Pycnonotus jocosus* that are in demand for their song [29,30]. Thailand also has well-documented wildlife markets [31] and commercial breeding operations of numerous bird species known to take place on a large scale primarily to cater to the songbird trade [32]. Given the extent of the multiple and increasing threats to birds in the region, it is imperative that zoos act in concert to mitigate this risk by collaborating through regional collection plans to prioritise the captive breeding of species most at risk.

Thailand was rather late in opening its first public zoo despite animal collections long held by the royal family. The first public zoo, Dusit Zoo, opened in 1938 from a collection of animals and land donated by King Chulalongkorn [33]. Since then, a majority of zoos comprise an assortment of facilities with different institutional objectives and priorities, broadly divided into three zoo types that, in Thailand, are mutually exclusive. Accredited zoos are members of the Southeast Asian Zoos Association (SEAZA) and the World Association of Zoos and Aquariums (WAZA) that conform to the established roles of a modern zoo (conservation, research, education recreation and provision of good animal welfare) [12]; government zoos are usually small and dated facilities in provincial towns or zoos that are attached to the Department of National Parks, Wildlife and Plant Conservation (DNP) that operate Wildlife Rescue and Breeding centres that focus more on conservation and research; and private zoos are usually for-profit businesses that generally focus on being places of recreation without attention to the four other established roles of modern zoos. Because of the lack of many well-established zoos, and indeed with most zoos in Thailand opened in the last couple of decades, individual zoo managers and, in fact, Thai zoos as a collective, are in an excellent position to carefully consider collection management plans and the acquisition of new animals and species to maximize the conservation contribution of their collections.

We aimed to investigate which bird species are on display in Thai zoos and which factors influence bird compositions. First, we conducted surveys of zoo collections and collated information on zoo characteristics, including the size, Gross Domestic Product (GDP) of the province where the zoo is located and the ticket price of the zoo. We assume that zoos located in more affluent provinces may be willing to invest in more rare animals, and equally, that the public in these provinces are willing to pay higher ticket prices. Specifically, we compiled data on the proportion of globally threatened birds as listed by the International Union for Conservation of Nature (IUCN) Red List, non-native species, bird species protected under Thai law and the proportion of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) listed bird species. Second, we evaluated whether bird compositions and the most commonly displayed birds are similar to global collections and if this differed across zoo types. We predicted that:

- (1) The proportion of bird taxa would be similar to global collections;
- (2) The proportion of threatened and native species would be similar to global collections;

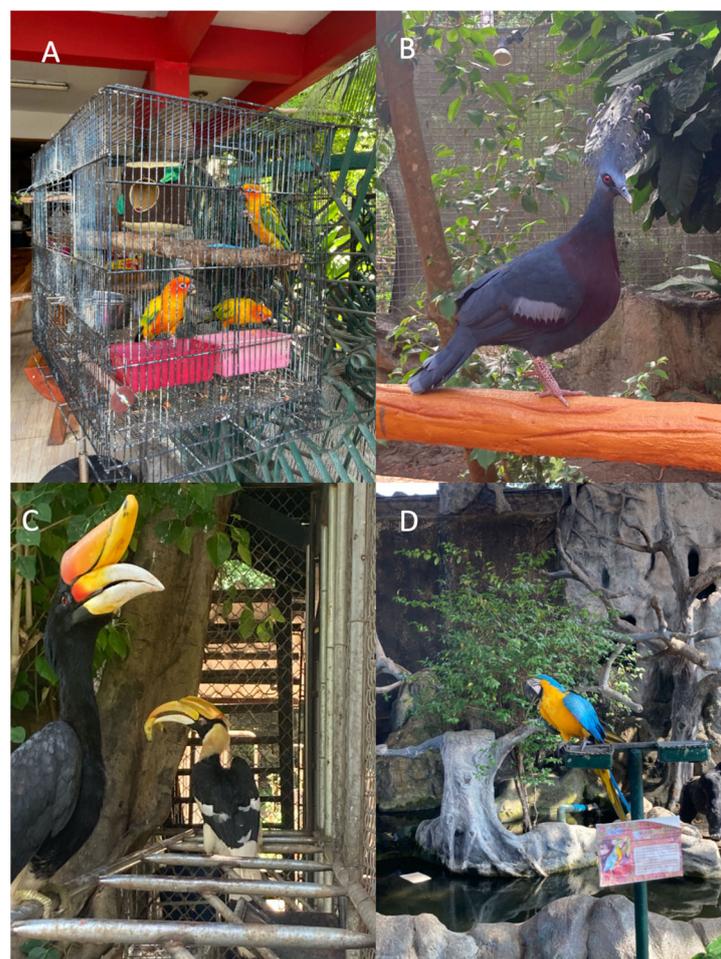
- (3) Larger-sized zoos located in provinces with a higher GDP and with higher ticket prices will influence the number of bird species and the proportion of threatened species on display;
- (4) The type of zoo (accredited, government and private) will impact collection composition (the proportion of non-native bird species, threatened species, species protected under Thai law and CITES-listed species).

Given the threats facing many Southeast Asia's bird species, our work is an important insight into bird species richness in Thai zoos that provides an indication of their commitment to global bird conservation.

## 2. Materials and Methods

### 2.1. Zoo Surveys

We visited 55 zoos throughout Thailand between July 2020 and July 2022. We only recorded species on display to the public (Figure 1).



**Figure 1.** (A) Sun conures at a private zoo. (B) Victoria crowned pigeon at an accredited zoo. (C) Great hornbill and Rhinoceros hornbill exhibited together at a government zoo. (D) Blue-and-yellow macaw at a private zoo.

We are aware that some zoos also have birds in back-of-house and quarantine areas, but we did not access these areas. We first checked exhibit signage to see which species were claimed to be on display; then, we observed the bird to confirm identification [34]. Species were identified to the species level and not to the subspecies level. In a small number of cases (3% of exhibits), we did not see a bird inside the exhibit. However, if the

exhibit looked occupied (evidence of food and water) and had an animal identification sign, we recorded the species from the sign.

We did not count the number of individual birds during our surveys as it was unfeasible, especially in large aviaries. We also did not count multiple exhibits within the same zoo that displayed the same species; instead, we simply recorded a species present at a zoo and recorded it as an event. Zoos were excluded from the analysis if they did not display any bird species. Finally, some COVID-19-related zoo closures during our study period may have resulted in reduced collections.

## 2.2. Bird Composition Variables

We used the International Union for Conservation of Nature (IUCN) Red List data to attribute each species with a threat status (Critically Endangered, Endangered or Vulnerable) [35]. We also used the Red List individual species assessments to specify whether a species was native or non-native to Thailand. In 1983, Thailand became a party to the CITES to regulate the trade in internationally traded species. We checked the CITES Appendices I, II or III [36] to determine whether each species was listed. Thailand enacted the Wild Animal Preservation and Protection Act B.E 2535 (1992) (WARPA) (amended B.E 2562 (2019)) to help regulate and enforce CITES. The act aims to afford protected status by controlling the possession, trade, and breeding of listed species; however, this legislation does not currently grant protected status to most non-native species. After the legislation was amended in 2019, 29 non-native CITES-listed bird species were given protected status, but generally, controlling the trade in non-native CITES-listed species is challenging [32,37].

## 2.3. Zoo Characteristics

We noted the type of zoo (accredited, government or private) and identified the province where the zoo was located and took the province's GDP data from 2019 calculated as a percentage of the national GDP [38]. For zoo size (hectares), we used information from the zoo website or calculated the size using Calcmaps [39]. We used adult ticket prices; where zoos had a dual-price system for Thai and foreigners (as is common in leisure venues in Thailand), we used the price for foreigners. Some zoos did not charge for walk-ins but had multiple packages that frequently included photo and feeding opportunities or animal rides. In these cases, the price was given as a free entrance. Prices were converted into USD using rates on 9 June 2023 (rate 1 THB = 0.0289 USD).

## 2.4. Statistical Analysis

As most of the data were not normally distributed, we used non-parametric tests. Spearman's rank correlation was used to test for differences between composition variables (e.g., non-native bird species, threatened bird species, protected and CITES-listed bird species) and zoo characteristics (zoo type, GDP, size, ticket price). We used Kruskal–Wallis if the proportion of threatened bird species differed between zoo types, and Mann–Whitney U tests to test for differences between zoo types and non-native bird species, threatened species, protected and CITES-listed species. We retained outliers within the dataset due to the broad data range for the assessed variables; thus, removing all outliers for all variables would have impacted data variability. We took the results as significant when  $p < 0.05$  and ran the analysis on SPSS v.28 (IBM). We present the means  $\pm$  S.E.M.

# 3. Results

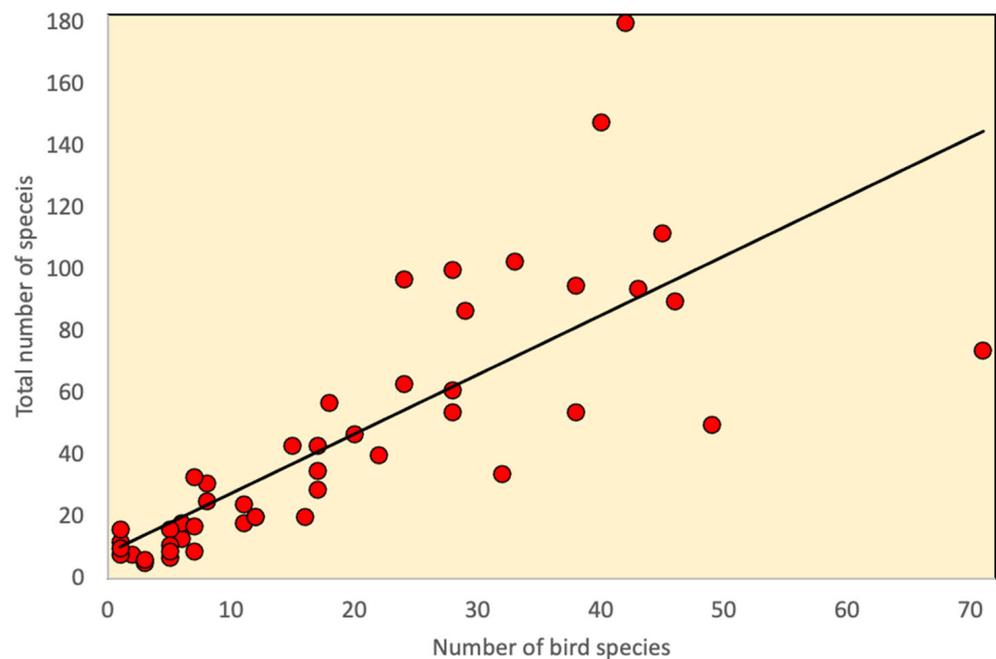
## 3.1. Species Richness

We found birds displayed in 47 of the 55 zoos visited. Seven zoos were accredited, ten were government zoos, and thirty were private zoos. The eight zoos that did not display birds were all private. Overall, birds represented the largest taxonomic group within zoos, with a mean of  $44.73 \pm 3.20\%$  of all animals being birds. Birds comprise the majority of government zoo collections (mean  $51.72 \pm 6.22\%$  of all animals), followed by private zoos (mean  $45.03 \pm 4.39\%$ ) and accredited zoos (mean  $33.49 \pm 3.75\%$ ) (Table 1).

**Table 1.** Summary of investigated variables per zoo type (number of zoos in parentheses) with mean and standard error of the mean. The highest mean value per zoo type is given in bold. Mann–Whitney U tests were used to calculate significant differences. A = Accredited zoo; G = Government zoo; and P = Private zoo.

Variable	Accredited (7)	Government (10)	Private (30)	Total (47)	Sig. Diff.
Province GDP	2.61 ± 0.65	0.99 ± 0.24	<b>6.53 ± 1.89</b>	4.77 ± 1.25	A, P > G
Zoo size (Ha)	<b>399.52 ± 189.93</b>	12.08 ± 5.44	57.51 ± 43.04	98.78 ± 42.06	A > G, P
Ticket price (USD)	7.44 ± 3.10	0.46 ± 0.30	<b>8.20 ± 1.52</b>	6.44 ± 1.15	A, P > G
Total no. species	<b>113.14 ± 14.80</b>	43.50 ± 4.03	30.63 ± 5.40	45.66 ± 5.88	A, P > G
Total no. bird species	<b>35.71 ± 3.29</b>	23.20 ± 3.95	14.17 ± 2.93	19.30 ± 2.38	A > G > P
% of bird species	33.49 ± 3.75	<b>51.72 ± 6.22</b>	45.03 ± 4.39	44.73 ± 3.20	G > A
% of threatened bird species	27.05 ± 2.98	26.58 ± 6.38	<b>29.24 ± 4.19</b>	28.35 ± 2.99	
% of non-native bird species	50.72 ± 4.93	29.83 ± 6.63	<b>76.00 ± 5.38</b>	62.41 ± 4.67	P > A, G
% of CITES-listed bird species	53.11 ± 3.10	43.55 ± 3.28	<b>74.92 ± 4.23</b>	64.99 ± 3.43	P > A, G
% of protected bird species	39.09 ± 5.45	<b>53.94 ± 6.11</b>	23.56 ± 5.99	32.34 ± 4.47	G > A > P

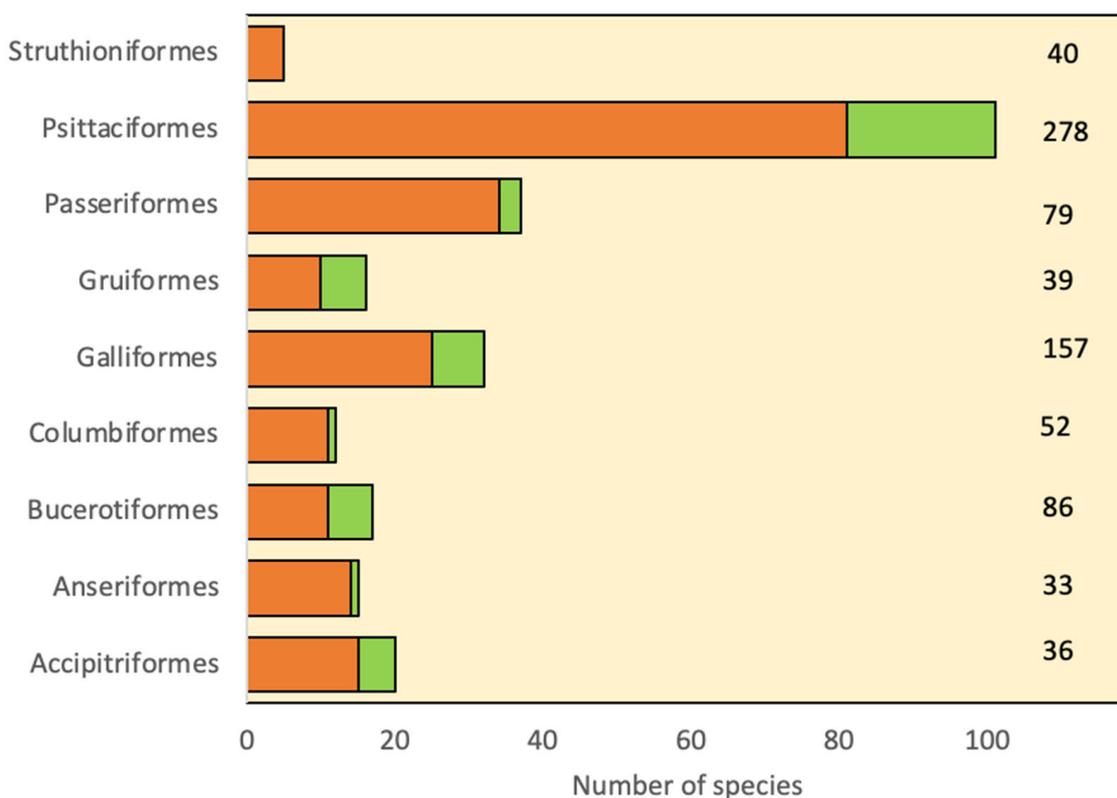
On average, zoos held  $19.30 \pm 2.38$  bird species, ranging from 1 to 71. Accredited zoos held the most species (mean  $35.71 \pm 3.29$ ), followed by government zoos (mean  $23.20 \pm 3.95$ ) and private zoos (mean  $14.17 \pm 2.93$ ). The total number of species and the total number of bird species were positively correlated (Spearman’s correlation  $\rho = 0.910$ ,  $n = 47$ ,  $p < 0.001$ ) (Figure 2).



**Figure 2.** Positive correlation between the total number of birds and the total number of terrestrial vertebrate species in 47 zoos in Thailand. The line represents a linear trendline.

Specifically, we found that the number of bird species positively correlated with the number of mammals ( $\rho = 0.444$ ,  $n = 47$ ,  $p = 0.002$ ) and the number of reptiles ( $\rho = 0.475$ ,  $n = 47$ ,  $p < 0.001$ ). In total, we recorded 909 exhibits (excluding multiple exhibits of the same species in the same zoo) from 20 orders, 42 families, 156 genera and 249 species (Table 1).

The top 9 orders comprised 206 species. Psittaciformes was the largest represented order among the 249 species, with 278 events and 81 species, including 76 non-native species (Figure 3). Of the 278 Psittaciformes events, 199 (71.58%) were in private zoos.



**Figure 3.** The representation of species of nine avian orders in Thai zoos. Numbers indicate the number of times each species was represented in zoos; the bars show how many species within each order were recorded (orange, not globally threatened; green, globally threatened).

The Indian peafowl *Pavo cristatus* was the most displayed bird species and could be found in over half of all zoos (55%,  $n = 26$ ). Four hornbill Bucerotidae species featured in the top ten were predominantly found in accredited and government zoos. Four species on this list were displayed in all seven accredited zoos: Indian peafowl, silver pheasant *Lophura nycthemera*, greater flamingo *Phoenicopterus roseus*, and the common emu *Dromaius novaehollandiae*. The Oriental pied hornbill *Anthracoceros albirostris*, a native species, was the most represented bird species on this list displayed in government zoos (90%,  $n = 9$ ). In contrast, the blue-and-yellow macaw, *Ara ararauna*, was the most represented species in private zoos (53%,  $n = 16$ ). Seven species (35%) were globally threatened, with three (15%) classified as Endangered (Table 2). Four species (20%) were listed as Vulnerable. The majority of the most displayed species on the list were non-native (13; 65%), including the top five species in private zoos. However, the opposite was true for government zoos, where the top five species were all native.

**Table 2.** The twenty most displayed bird species in Thai zoos showing the IUCN Red List status, whether the species is native (N) or non-native (NN), status under Thai law and CITES appendix listing (A = accredited zoo; G = government zoo; P = private zoo).

Species	% of Zoos (A: G: P)	IUCN Status	N/NN	Protected Status	CITE Appendix
Indian peafowl <i>Pavo cristatus</i>	55 (100: 86: 43)	LC	NN	None	III
Blue-and-yellow macaw <i>Ara ararauna</i>	51 (71: 30: 53)	LC	NN	None	II
Great hornbill <i>Buceros bicornis</i>	43 (86: 80: 20)	VU	N	Protected	I
Sun parakeet <i>Aratinga solstitialis</i>	43 (71: 10: 47)	EN	NN	None	II
Silver pheasant <i>Lophura nycthemera</i>	40 (100: 70: 17)	LC	N	Protected	Not listed
Rhinoceros hornbill <i>Buceros rhinoceros</i>	38 (86: 60: 20)	VU	N	Protected	II
Oriental pied hornbill <i>Anthracoceros albirostris</i>	34 (71: 90: 7)	LC	N	Protected	II

Table 2. Cont.

Species	% of Zoos (A: G: P)	IUCN Status	N/NN	Protected Status	CITE Appendix
Red-and-green macaw <i>Ara chloropterus</i>	34 (71: 20: 30)	LC	NN	None	II
Wreathed hornbill <i>Rhyticeros undulatus</i>	34 (71: 60: 17)	VU	N	Protected	II
Golden pheasant <i>Chrysolophus pictus</i>	32 (43: 50: 23)	LC	NN	None	Not listed
African grey parrot <i>Psittacus erithacus</i>	32 (57: 0: 37)	EN	NN	None	I
Siamese fireback <i>Lophura diardi</i>	32 (71: 60: 13)	LC	N	Protected	Not listed
Nicobar pigeon <i>Caloenas nicobarica</i>	30 (86: 40: 13)	NT	N	Protected	I
Eclectus parrot <i>Eclectus parrot</i>	30 (29: 20: 33)	LC	NN	None	II
Southern cassowary <i>Casuarius casuarius</i>	28 (57: 30: 20)	LC	NN	None	Not listed
Grey-crowned crane <i>Balearica regulorum</i>	28 (71: 10: 23)	EN	NN	None	II
Salmon-crested cockatoo <i>Cacatua moluccensis</i>	28 (29: 10: 33)	VU	NN	None	I
Greater flamingo <i>Phoenicopterus roseus</i>	28 (100: 10: 17)	LC	NN	None	Not listed
Common emu <i>Dromaius novaehollandiae</i>	28 (100: 0: 20)	LC	NN	None	Not listed
Victoria crowned pigeon <i>Goura victoria</i>	26 (57: 20: 20)	NT	NN	None	II

### 3.2. Bird Composition Variables

Of the 249 recorded species, 100 (40.16%) were native (385 exhibits), and 149 (59.84%) were non-native (524 exhibits). Just under one-half (47.39%,  $n = 118$ ) of the species were recorded only once, of which 61.01% ( $n = 72$ ) were non-native, 52.54% ( $n = 62$ ) CITES-listed and 17.80% ( $n = 21$ ) were listed as threatened.

We found that 56 (22.49%) species had a threatened status, representing 229 events (25.19%) of the bird species held in zoos. Of these 56 threatened species, 11 were Critically Endangered, of which only 3 were native to Thailand, 16 were Endangered (6 native) and 29 were listed as Vulnerable (9 native).

On average, the proportion of threatened bird species within collections was 28.35%, with no relationship between the number of bird species per collection and the number of threatened species (Spearman’s rho =  $-0.061$ ,  $n = 47$ ,  $p = 0.683$ ). There was a strong negative correlation between the number of non-native and protected birds (rho =  $-0.848$ ,  $n = 47$ ,  $p < 0.001$ ), as most non-native birds are not protected (Figure 4). There was also a negative correlation between the number of protected and CITES-listed birds (rho =  $-0.466$ ,  $n = 47$ ,  $p < 0.001$ ).

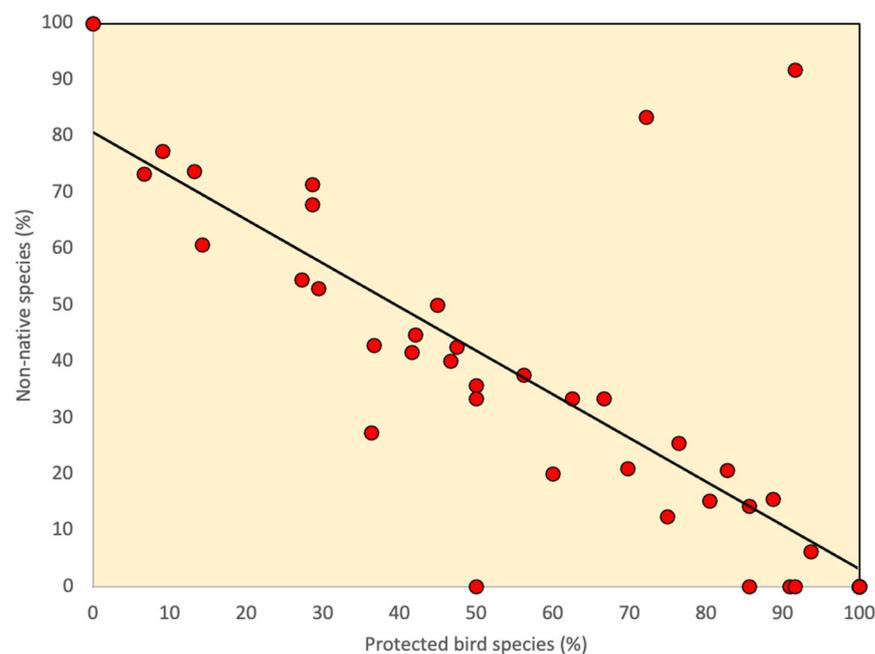


Figure 4. Negative correlation between the percentage of protected birds and the percentage of non-native bird species in 47 zoos in Thailand.

### 3.3. Relationship between Zoo Characteristics and Bird Composition Variables

We found a significant difference in relation to the type of zoo and zoo size, ticket price and GDP (Table 1). The number of bird species was significantly related to zoo size ( $\rho = 0.466$ ,  $n = 47$ ,  $p < 0.001$ ). Ticket price did not impact the number of bird species held by a zoo ( $\rho = -0.057$ ,  $n = 47$ ,  $p = 0.705$ ), nor did the provincial GDP ( $\rho = 0.121$ ,  $n = 47$ ,  $p = 0.419$ ). The proportion of threatened bird species within collections was not influenced by zoo size ( $\rho = 0.056$ ,  $n = 47$ ,  $p = 0.708$ ) or ticket price ( $\rho = -0.023$ ,  $p = 0.878$ ), despite the larger size of the zoo and the higher ticket price paid by visitors. Neither zoo size, ticket price, nor GDP had any significant relationship with the proportion of non-native, protected or CITES-listed bird species.

The zoo type influenced some bird composition variables. Private zoos displayed significantly more non-native bird species than both accredited zoos (Mann–Whitney  $U = 40.500$ ,  $Z = -2.527$ ,  $p = 0.011$ ) and government zoos ( $U = 36.000$ ,  $Z = -3.589$ ,  $p < 0.001$ ). Thirty-three per cent of private zoos ( $n = 10$ ) displayed only non-native birds (ranging from one to 17 species), whereas no accredited or government zoos displayed only non-native species. There was also a significant difference between the number of non-native species displayed in accredited and government zoos ( $U = 11.000$ ,  $Z = -2.344$ ,  $p = 0.019$ ). As a result of government zoos displaying fewer non-native species than other zoo types, they exhibited significantly more protected bird species than accredited zoos ( $U = 14.000$ ,  $Z = -2.051$ ,  $p = 0.040$ ) and private zoos ( $U = 59.000$ ,  $Z = -2.905$ ,  $p = 0.004$ ). Accredited zoos displayed more protected species than private zoos ( $U = 49.000$ ,  $Z = -2.233$ ,  $p = 0.026$ ).

In terms of CITES-listed bird species, we found that private zoos displayed significantly more than both government zoos (Mann–Whitney  $U = 33.500$ ,  $Z = -3.691$ ,  $p < 0.001$ ) and accredited zoos ( $U = 53.500$ ,  $Z = -2.033$ ,  $p = 0.042$ ). In total, we recorded 128 different CITES-listed species on 518 occasions, with 28 species listed on CITES Appendix I (128 events in 42 zoos), with 17 CITES-listed Appendix I species comprising the order Psittaciformes. We did not find a difference between zoo types and the proportion of threatened bird species (Kruskal–Wallis  $H = 0.944$ ,  $df = 2$ ,  $p = 0.624$ ).

## 4. Discussion

We investigated species richness and which variables influence bird compositions in Thai zoos. We found that birds comprised a comparable proportion of taxa in collections compared to global norms and that Thai zoos displayed a comparatively higher number of non-native and threatened bird species. The type of zoo (accredited, government or private) affected composition variables, including the non-native, protected and CITES-listed status. Zoo characteristics such as the GDP of the province and ticket price had no impact on compositions.

### 4.1. Species Richness

Our results support research that birds represent the highest taxonomic group among global zoo collections [21,40,41]. We showed, however, that birds represent a higher proportion of taxa than the 31% found in the analysis of global zoos by Brereton and Brereton [21]. The reason for this is unclear, but culture may play a role in the popularity of birds within zoos, as was suggested to explain the high proportion of birds in South American Zoos despite a very high abundance of other taxa, such as reptiles in the continent's ecosystems [21]. Studies investigating popular species with zoo visitors in the West have found that birds are the least popular zoo taxa [7,42,43]. According to Moss and Esson [7], this may be related to visitor preferences for the larger, flagship mammal species, and that zoos tend to market and display mammals more predominantly than other taxa. Since no similar studies have been conducted in Asia, it is difficult to verify whether Thai zoos display a high proportion of birds because of visitor popularity or whether there are other responsible factors, such as the ease of species acquisition over other taxa.

We found the mean number of bird species to be lower than reported for global collections [21,40]. A probable reason for this distinction is due to the types of zoos

assessed. In these studies of global collections [21,40], zoos were accredited facilities that self-reported data, whereas our research had predominantly unaccredited facilities that did not provide collection data. Additionally, our study had a high number of private zoos, with a significantly lower number of bird species per zoo than accredited ones. Nonetheless, as Thailand is a country with high bird diversity, we would expect to see more species within zoos.

Our findings on the most common orders and displayed bird species yielded interesting results. There were striking differences from Conde et al.'s study [44], which suggests regional variation compared to our results. They found that Passeriformes had almost four times as many represented species in global collections as Psittaciformes, which is unsurprising given that Passeriformes form over half of all known bird species [45]. In contrast, in Thai zoos, there were markedly more Psittaciformes than any other order. The reason for this is likely related to the differences between the zoo types in our study, which noticeably showed patterns in the species held. For example, hornbills were highly represented in government zoos, likely because many of these birds are seized from the wildlife trade [46,47]. Additionally, government zoos did not display many Psittaciformes, most probably because most species are non-native to Thailand and, therefore, not likely to be seized under the Wild Animal Preservation and Protection Act (WARPA). On the other hand, private zoos displayed many Psittaciformes, especially the blue-and-yellow macaw and sun parakeet, which are ubiquitous species according to the specialised zoo forum Zoo Chat [48] and the website Zoo Institutes [49]. This suggests that displaying species popular with visitors in private zoos is prioritised over displaying less popular species that require more urgent conservation action.

Some species within the top twenty list in our results were identified as commonly displayed birds on Zoo Chat [48] and Zoo Institutes [49]. As in our study, the Indian Peafowl was shown to be the most displayed bird. To the best of our knowledge, there is no other specific research focusing on the most popular bird species within zoos, only work on the most popular overall zoo species [42,43,50]. In fact, no bird species were featured in these surveys of Western zoo visitors [42,43,50], highlighting an intriguing area of future research to understand the species preferences of zoo visitors in Asia. There was a strong representation of local species on the list, especially hornbills and the Siamese fireback *Lophura diardi*, Thailand's national bird.

#### 4.2. Bird Composition Variables

A notable finding of our study was that over three-quarters of birds displayed in private zoos are non-native species, including a third of private zoos that did not display any native bird species at all. This result suggests that private zoos actively choose to display non-native species, although the reasons for this cannot be definitively stated. Nevertheless, a 2009 paper on the use of wild animals in Thai tourism claims that from the early 2000s, zoos were encouraged by the government to display foreign animals instead of more familiar, domestic species, to “present a more cosmopolitan image of the country to the world” [51]. Another likely explanation is that zoos are not required to obtain a zoo license if they only display non-native species [37]. As most non-native species are not protected under the WARPA, they are not subject to stricter regulations for possessing, breeding, and trading, meaning that it is easier for zoos to acquire and breed non-native species.

A further unexpected finding is that zoos in Thailand hold a higher proportion (similar across all zoo types) of bird species in the IUCN Red List threatened category compared to global averages. From a 2014 study of 2308 avian species displayed in 195 zoos that used the Zoological Information Management System (ZIMS), only 195 species (8%) were threatened [44], significantly lower than the 28% of threatened bird species in our study. The study by Martin et al. [2] supports the results, finding mammals and birds housed in zoos tend to be less threatened with extinction. Our results are noteworthy, given the many non-native birds in Thai zoos.

Furthermore, the fact that just under half of species were displayed in only one zoo suggests that at least some captive populations are not self-sustaining, a concern especially as over one-fifth of these species are listed as threatened. While we did not count individual birds, it is unlikely that these zoos displayed enough specimens to have self-sustaining populations or to maintain sufficient genetic diversity, especially if they are not members of regional zoo associations and Taxon Advisory Groups [12,40]. Although there are some impressive captive breeding programs in accredited zoos, such as the Red-headed Vulture *Sarcogyps calvus* [52], Asian woolly-necked stork *Ciconia episcopus* [53] and Oriental pied hornbills *Anthracoceros albirostris* [54] programmes such as these represent a fraction of the actual need. As far as we are aware, government zoos open to the public generally do not engage in captive breeding programs. Instead, these are believed to be conducted in the Department of National Parks, Wildlife and Plant Conservation (DNP) Wildlife Breeding and Rescue centres that are not open to the public.

In addition, we found no published evidence that private zoos are collaborating in organised captive breeding programs. This issue was raised in a report on CITES implementation governing great apes and gibbons in Thailand. It stated that the lack of accredited zoos is a concern, partly because their collection data are not submitted to the appropriate studbooks [37]. A similar lack of collaboration has been observed in some zoos in China [55], where the authors highlighted the risk of unsustainable captive populations, potentially driving acquisitions from the wild [56] or poorly managed breeding.

Collaborative effort within a global zoo network is essential to effective regional and international collection planning [16], but individual institution collection planning remains a prerequisite [6,14]. The majority of zoos in Thailand do not have stated conservation objectives, and most private zoos engage in exploitative human–animal interaction activities [57,58]. Despite this, the Southeast Asia Zoo Association (SEAZA) should encourage membership of new zoos to help improve zoo standards, which could increase participation in captive breeding programs. Nevertheless, many zoos may be reluctant to apply for membership if they must meet accreditation standards, which they may not be able to meet and if improving standards is not legally required.

#### 4.3. Relationship between Zoo Characteristics and Bird Composition Variables

The positive correlation between zoo size and the number of bird species in our study was expected, as also found by Mooney et al. [3], whereby species richness increased with zoo size. However, our results showed considerably fewer bird species per hectare for accredited and private zoos compared to data from the International Zoo Yearbook [40]. These data showed that zoos in Asia reportedly hold a median of 2.3 bird species per hectare. The accredited zoos in our study displayed substantially less than this figure, most probably because the zoos were all very large and located in relatively rural areas, whereas many long-established accredited zoos are located in urban centres with space limitations [59,60]. However, for private zoos, bird species richness was significantly lower than the median found in data of the zoos from the International Zoo Yearbook [40] despite the significantly smaller zoo size than accredited zoos. One reason is that, as mentioned above, these zoos tend to focus on displaying large popular mammals such as tigers, *Panthera tigris*, and Asian elephants, *Elephas maximus*, popular species for visitor entertainment [57,58]. Furthermore, not only did private zoos hold fewer bird species per hectare, but they also displayed birds in smaller exhibits, as shown in a study on hornbill welfare in Thai zoos [61], whereby 71% of hornbill exhibits in private zoos did not meet the minimum size requirements by the European Association of Zoos and Aquariums (EAZA).

Government zoos displayed a similar proportion of birds per hectare to the findings from the data from the International Zoo Yearbook [40], and were significantly smaller facilities than other zoo types. Space within these zoos (particularly the DNP wildlife rescue and breeding centres) is often limited because they are tasked with receiving animals rescued or confiscated from trade, with one report of 5000 birds taken to government facilities in one year [62]. Clearly, the unpredictability of receiving such animals can

make collection planning very difficult. Moreover, recent budget cuts to government zoos have meant that some facilities struggle to provide for animals in their care [63], perhaps shifting priorities from conservation to simply sustaining the existing collection. Challenges withstanding, zoos are still obliged to contribute towards conservation goals [15], which can be achieved by displaying smaller species, such as birds, that require less space and staff [64].

Unfortunately, zoos may be reluctant to make such changes to their collections, as displaying the larger iconic species attracts more visitors [3,65]. As such, there are obvious financial implications with lower visitor numbers and the reduced finances available to fund in situ and ex situ conservation [3,13,66]. Some zoos advertise that a portion of the ticket price goes towards conservation projects, which helps increase visitors' conservation engagement [67]. However, in Thailand, this was not observed in any zoo, and it appears that zoos with higher ticket prices had no positive impact on conservation strategies, given our point made earlier regarding the exploitative activities of captive wildlife in some private zoos.

Finally, our finding that local GDP did not positively influence the number of bird species, or the proportion of threatened bird species was not what we expected. Provinces with a higher GDP attract more visitors, predominantly international tourists, which should translate to a higher number of zoo visitors, as found by Leader-Williams [68]. Nevertheless, the findings obtained in the present study appear to counter the expectation that this should translate to more available resources to contribute towards conservation.

## 5. Conclusions

Our results highlight the unrealised potential of Thailand to contribute to conserving bird populations, given its status as a bird diversity hotspot and the high number of zoos within the country. Zoos display a high proportion of birds within their collections and many threatened species compared to the global norm. Nevertheless, many of these threatened species are non-native, which is especially evident in many private zoos. These zoos should follow the IUCN technical guidelines [69] on holding native species needing conservation action. Still, institutional priorities and the seeming unwillingness of private zoos to join zoo associations suggest that active engagement in conservation strategies appears unlikely for the foreseeable future. Legislative changes will likely be required to obligate private zoos to contribute to conservation goals and utilise exhibit space within these facilities. Additionally, increased investment in government zoos is needed to support conservation activities, especially considering the high number of native and threatened species housed within government zoos.

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