

RESEARCH ARTICLE

Role of Brazilian Zoos in Ex Situ Bird Conservation: From 1981 to 2005

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Zoos may play an important role in conservation when they maintain and breed large numbers of animals that are threatened with extinction. Bird conservation is in a privileged situation owing to the extensive biological information available about this class. Annual inventories produced by the “Sociedade de Zoológicos do Brasil” in the years 1981, 1990, 2000, and 2005 were analyzed. Variables, such as the number of zoos per geographic region; number of birds held; number of bird species in each IUCN threat category; number of exotic and native bird species; number of potentially breeding bird species; number of bird species in each order; and number of threatened bird species breeding, were analyzed. Brazilian zoos kept more than 350 bird species. The number of bird species and specimens held by the Brazilian Zoos increased from 1981 to 2000, but decreased in 2005. The same pattern was observed for the number of species in each IUCN threat category. Results showed that the potential of the Brazilian zoos in bird conservation needs to be enhanced because they maintain threatened species but do not implement systematic genetic, reproductive, or behavioral management protocols for most species. *Zoo Biol* 30:655–671, 2011. © 2010 Wiley Periodicals, Inc.

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INTRODUCTION

According to the IUCN red list 2009, 12% of all bird species are threatened by extinction to some degree (1,223 of 9,998 species). The creation of nature reserves is the main in situ conservation measure for bird protection, but it is not always easy to implement owing to the economic constraints faced by biodiversity rich countries [Vanclay et al., 2001; Mathevert and Tamisier, 2002; Fonseca et al., 2005; Armsworth et al., 2006]. Sustainable exploitation of the natural resources allied to green politics and environmental education can contribute to animal protection around the world [Tudge, 1992; Magin et al., 1994; Primack, 2004; Rocha et al., 2006]. In association with in situ conservation measures, ex situ strategies should be conducted, such as captive breeding programs and genetic management of captive populations. In fact, these kinds of actions are already helping many bird species to be saved from extinction [Mallinson, 1991; Tudge, 1992; IUDZG, 1993; Rahbek, 1993; de Boer, 1994; Jones et al., 1995; Ballou and Foose, 1996; Whitfort and Young, 2004].

Modern zoos are often called conservation centers [Wemmer et al., 2001; Mallinson, 2003; Tribe and Booth, 2003; Young, 2003; Conway, 2004; Primack, 2004] because they are capable of maintaining large numbers of individuals. For threatened species, behavioral, nutritional, veterinary, and genetic information is being collected by zoos to produce management manuals and studbooks to improve ex situ conservation efforts [Strahl et al., 1995; Kaldenberg, 2004; Cornejo, 2006].

Official Brazilian zoos are represented by the non-governmental organization (NGO), “Sociedade de Zoológicos do Brasil” (SZB), founded in 1977. This NGO has published, since 1980, an annual inventory which lists the scientific and common name of each species held and brings together information about births, deaths, transfers, and acquisition of individuals by each associated Brazilian zoo [Ellis and Ellis, 1988]. These inventories constitute an important source of information for the evaluation of Brazilian zoos in species conservation.

ISIS is the main database available for the planning and evaluation of the quality and management of zoo collections [Hancocks, 1996; Earnhardt et al., 2005], but the evaluation of how much a zoo contributes to animal conservation is inferred only by qualitative parameters instead of quantitative ones [Hancocks, 1996]. The formulation of numerical indexes would be preferable because they are more objective and allow for comparisons between collections and institutions [Azevedo et al., paper submitted]. Counting the number of threatened species maintained by zoos in their collections, as well as the number of potential breeding pairs and births of such species, would be the first step in the evaluation of zoos in ex situ conservation [Whitfort and Young, 2004]. One prediction of such indexes would be that zoos have animal collections biased toward threatened species [WASA, 2005].

The aim of this study was to evaluate how Brazilian zoos have contributed to ex situ bird conservation from 1981 to 2005 by the analysis of zoos annual reports. It is predicted that, in the sampled zoos, the number of threatened species (based on IUCN categories of extinction risk), breeding pairs of these species, and birth rate of these species have increased during the study period.

METHODS

Data Collection and Variables Analyzed

Data were collected from the annual inventories of the SZB. The years analyzed were 1981, 1990, 2000, and 2005. The data comprises a variable number of zoos in each year [all the zoos that sent their annual report to the SZB in each year studied].

The variables analyzed (per year) were: the number of zoos per Brazilian region (North, South, center-west, Southeast, and Northeast); number of birds held (species and specimens); number of bird species in each IUCN threat category; number of exotic and native bird species; number of potentially breeding bird species (species held in at least one pair); number of bird species in each order [according to Sibley and Ahlquist, 1991]; and number of births in each threatened category (chicks that survived until at least 1 year old). An increase in these variables through the years is expected and would indicate an improvement in the role of Brazilian zoos in bird conservation.

Species Threatened Status Evaluation

The status of extinction risk of the bird species held by the Brazilian zoos in each analyzed year was used as a parameter to measure the role of the zoos in bird species conservation (it is expected that the number of species held by the Brazilian zoos in each year increased through time, showing a bias toward conservation). The species extinction risk for 1981 were evaluated using the 1986 IUCN Red list of Threatened Animals [IUCN, 1986] because there was no Red list for 1981; for 1990, we used the 1990 IUCN Red list of Threatened Animals [IUCN, 1990]; for 2000, we consulted the list proposed by Stattersfield and Capper [2000]; and for 2005, we consulted the 2005 IUCN Red list of Threatened Animals, available on the IUCN website [IUCN, 2005].

The threat categories defined by the IUCN varied between 1986 and 2005. In 1986, there were seven listed categories (“insufficient known,” “indeterminate,” “extinct,” “not threatened,” “rare,” “vulnerable,” and “endangered”); in 2000, after the implementation of the criteria proposed by the IUCN’s Criteria Review Working Group, the categories changed to “Data Deficient/Unknown,” “Least Concern/Low risk,” “Near threatened,” “Vulnerable,” “Endangered,” “Critically Endangered,” “Extinct in the Wild,” and “Extinct.” To allow statistical comparisons between 1981 and 2005, it was necessary to use the 2005 IUCN categories for all years. The 1981–1990 category “Rare” was found to overlap with the 2005 category “Near Threatened,” and therefore the data were reclassified into this category. All other 1981–1990 categories matched with the criteria adopted by IUCN in 2000 and were not reclassified (the categories “insufficient known,” “indeterminate,” and “not threatened” were grouped in the category “Low risk/Least concern/Data deficient/Unknown.” It is important to note that some species classified as Data deficient/Unknown could, in fact, be at risk of extinction; thus, the results presented in this research may change as new information about these species becomes known. However, in this study, this is unlikely to be a problem because of the low percentages of the Data deficient/Unknown species in the years evaluated (i.e. 1.08% in 1986; 1.55% in 1990; 0.88% in 2000; 0.74% in 2005). In this study, bird species were grouped in six threat categories, these being “Extinct in the Wild,” “Critically

endangered,” “Endangered,” “Vulnerable,” “Near threatened,” and “Low risk/Least concern/Data deficient/Unknown.”

Statistical Analysis

The data were tested using the Anderson–Darling test, to see if they met the requirements for parametric statistics, which they did not; therefore, nonparametric statistical tests were used throughout.

The data were analyzed, by comparing the variables “number of species,” “number of specimens,” “number of bird orders,” “number of potentially breeding pairs,” “number of births,” “number of bird species in each IUCN category,” and “number of births in each IUCN category,” for 1981 with those for 1990, 2000, and 2005 using Friedman’s nonparametrical statistical test. Statistical tests were run using data converted to percentages instead of absolute numbers, because the number of zoos varied between the years analyzed (mean percentages and standard errors are shown for most of the results).

A Spearman’s rank correlation was made to evaluate if the number of threatened birds increased with time (from 1981 to 2005). The percentage of bird species listed by the IUCN in each threatened category per year was compared with the percentage of bird species in each IUCN threatened category per year held by the Brazilian zoos using the Mann–Whitney’s Test [Zar, 1999].

RESULTS

The number of official Brazilian zoos, bird species, bird specimens, and breeding pairs held by these zoos, showed the same pattern: increasing from 1981 to 2000 and then decreasing in 2005 (Fig. 1; number of bird specimens is not shown in this figure owing to scale differences). Friedman’s test showed significant differences between all variables analyzed, except for the number of births (Table 1). In general, the years between 1981 and 2005 differed from the other years owing to the lowest number of zoos, and consequentially lowest percentages of bird species and breeding pairs (Table 1).

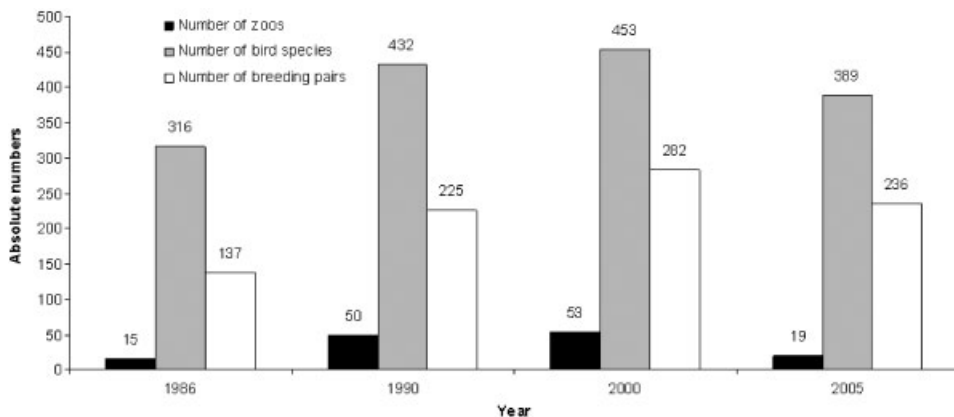


Fig. 1. Absolute number of Brazilian zoos as well as the absolute numbers of bird species and breeding pairs held by the Brazilian zoos from 1981 to 2005.

TABLE 1. Number of Brazilian Zoos, Total and Percentage Number (% Mean ± SEM) of Bird Species, Bird Specimens, Breeding Pairs, and Births in Each Year, and the Results of Friedman Tests (DF = 3 in All Cases)

Variable	1981		1990		2000		2005		Fr	P-value
	N	%	N	%	N	%	N	%		
Zoos	15 ^{a,b}	—	50 ^{a,c}	—	53 ^{b,d}	—	19 ^{c,d}	—	38.56	<0.01*
Bird species	316	7.69 ± 3.98 ^{a,b,c}	432	7.83 ± 1.22 ^a	453	9.03 ± 1.26 ^{b,d}	389	5.07 ± 1.41 ^{c,d}	28.17	<0.01*
Bird specimens	6,581	0.32 ± 0.05 ^{a,b}	11,837	0.23 ± 0.03 ^a	14,416	0.22 ± 0.02 ^b	8,915	0.26 ± 0.03	25.91	<0.01*
Breeding pairs	137	0.07 ± 0.01 ^{a,b,c}	225	0.09 ± 0.004 ^{a,d}	282	0.10 ± 0.004 ^{b,e}	236	0.03 ± 0.001 ^{c,d,e}	57.99	<0.01*
Births	1,446	0.75 ± 0.21	1,312	0.49 ± 0.11	999	0.36 ± 0.09	657	0.28 ± 0.06	1.10	0.77

* = results that differed statistically between the treatments. Fr, Friedman test statistic. Letters indicate the Tukey Test results; same letters represent treatments that differed significantly between each other.

TABLE 2. Number of Brazilian Zoos per Region, Total Number of Bird Species, Number of Bird Species by IUCN Threat Categories and Number of Breeding Birds per IUCN Threat Category

Year	Region	Number of zoos	Total number	Number threatened						Number Breeding					
				Ex	Cr	En	V	Nt	Lr	Ex	Cr	En	V	Nt	Lr
1981	SE	12	587	0	0	7	2	7	571	0	0	1	0	0	76
	CW	1	67	0	0	1	0	0	66	0	0	0	0	0	7
	S	2	245	0	0	3	2	3	237	0	0	1	0	0	40
1990	SE	36	1,659	0	10	10	70	35	1,534	0	2	0	6	3	129
	CW	2	180	0	1	0	5	2	172	0	0	0	0	0	27
	S	8	455	0	3	0	18	11	423	0	0	0	1	0	26
	NE	1	49	0	0	1	2	1	45	0	0	0	0	0	3
	N	3	86	0	2	0	4	0	80	0	0	0	0	0	6
2000	SE	30	1,600	0	8	65	62	83	1,382	0	1	5	4	16	86
	CW	2	210	0	0	9	8	14	179	0	0	1	0	2	14
	S	14	870	0	1	32	33	47	757	0	0	4	7	8	58
	NE	2	90	0	0	4	4	6	76	0	0	0	0	1	2
	N	5	215	0	0	7	4	13	191	0	0	1	0	2	14
2005	SE	14	854	1	5	32	40	68	708	0	0	1	1	7	58
	S	3	467	0	2	17	17	34	397	0	0	5	1	4	47
	NE	2	119	0	1	6	4	10	98	0	0	0	0	0	5

SE, South-east; S, South; NE, North-east; N, North; CW, Center-West; EX, Extinct in the wild; Cr, critically endangered; En, endangered; V, vulnerable; Nt, near threatened; Lr, low risk/least concern/data deficient/unknown.

Most of the zoos were located in the Southeastern Brazilian region; the Northeast and the central-west regions had only few zoos (Table 2). Every year, bird species classified as “low risk/least concern/data deficient/unknown” corresponded to more than 80% of the species held in Brazilian zoos (97.2% in 1981; 90.3% in 1990; 84.1% in 2000; and 83.3% in 2005). Most of the breeding species were held by the Southeastern zoos and they were classified as “low risk/least concern/data deficient/unknown” (Table 2). (The number of bird species from the Brazilian zoos differed between Table 1 and 2, because in Table 1 a species can be counted several times as it was housed in several zoos, whereas, in Table 2 a species was only counted once.)

The majority of species held by the Brazilian zoos in each year analyzed were native [1981: 220 native (69.6%); 1990: 313 native (72.5%); 2000: 319 native (70.4%); 2005: 288 native (74.0%)], and the percentage number of native species increased from 1981 to 1990, decreased in 2000, and then increased in 2005.

The percentage of bird orders varied little during the study period ($F = 0.63$; $N = 4$; $Df = 3$; $P = 0.89$), the largest number of orders occurred during 1990 and 2000 (17 in 1990 and 2000; 14 in 1981, and 16 in 2005—no Brazilian zoo kept individuals of all the bird orders listed by Sibley and Ahlquist [1991] in any of the years studied). The order Psittaciformes was the most represented in 1981 (22.5% of the species held), and the orders Trochiliformes and Musophagiformes were the least representative (0.32% of the species held each). The order Passeriformes was the most representative in 1990, 2000, and 2005 (22.5, 25.8, and 23.7%, respectively), but the least representative orders varied between these years; in 1990, they were

Galbuliformes, Bucerotiformes, and Coraciiformes; in 2000 and 2005, it was the Order Cuculiformes. Comparisons between the percentage of bird orders and the number of zoos in each year showed a statistically significant difference; the years 1990 and 2000 had less bird orders in relation to the number of zoos than in 2005 ($F = 14.54$; $N = 4$; $DF = 3$; $P = 0.002$; % mean \pm SEM: 1981: 85.20 ± 27.90 ; 1990: 37.60 ± 11.70 ; 2000: 37.20 ± 12.30 ; 2005: 89.00 ± 28.50).

The bird order with the highest number breeding in all years analyzed was the Anseriformes, and the bird order with the least breeding number varied between the years, being the order Gruiformes in 1981, the order Piciformes in 1990, the order Strigiformes (owls) in 2000, and the order Columbiformes (pigeons and doves) in 2005 (Table 3). There was a statistically significant difference between the number of births per year only for the order Columbiformes (Table 3), with births in 2005 less numerous than the births in 1981, 1990, and 2000. Using the percentage of births per order, none of the statistical tests found any significant results.

For almost all IUCN threat categories, we observed an increase in the absolute and percentage of bird species held from 1981 to 2000 and a decrease in the year 2005; only for the IUCN's category "near threatened" did we observe an increase for all years. The category "extinct in the wild" was registered only in the year 2005 (Psittacidae: *Cyanopsitta spixii*, Spix's macaw) (Fig. 2). For the IUCN threat categories "endangered" and "near threatened," there were significant increases in the number of bird species held (Table 4). Tukey's test detected the differences between the years 1990 and 2005 for the "endangered" category of threat and between the years of 1990 and 2005 for the "near threatened" category of threat. In all cases, there were more species in 2005 than in any other years. The IUCN's threat categories "extinct in the wild," "vulnerable," "critically endangered," and "low risk/least concern/data deficient/unknown" showed no statistically significant differences between the years in this study (Table 4).

The percentage of bird species in each IUCN category held by Brazilian zoos per year in relation to the total number of bird species classified by the IUCN in each year analyzed increased from 1981 to 2000 for almost all categories, declining in 2005 (the percentage of bird species in the "extinct in the wild" and "near threatened" increased from 1985 to 2005) (Fig. 3). The category "low risk/least concern/data deficient/unknown" decreased from 1985 to 2005 in both the IUCN classification and Brazilian zoos (1981: IUCN: 95.22%, zoo: 97.15%; 1990: IUCN: 94.23%, zoo: 90.27%; 2000: IUCN: 80.47%, zoo: 84.33%; 2005: IUCN: 79.54%, zoo: 83.29%). The same pattern was observed in IUCN threat categories, with the numbers of "endangered" and "near threatened" bird species increasing through the years and the numbers of "critically endangered" and "vulnerable" species increasing until the year 2000 then decreasing in 2005 (Fig. 3).

A Mann-Whitney test showed no differences between the percentages of bird species in each IUCN category of threat held by the Brazilian zoos in each year in relation to the total number of bird species classified by the IUCN in that particular year (1981: $W = 42.0$, $P = 0.69$; 1990: $W = 36.5$, $P = 0.75$; 2000: $W = 42.0$, $P = 0.69$; 2005: $W = 39.0$, $P = 1.0$; for all years analyzed: $N = 6$, $DF = 5$).

The results of the Spearman rank test showed a significant correlation between the "near threatened" and "low risk/least concern/data deficient/unknown" categories of threat with the years analyzed. The IUCN category of threat "near

TABLE 3. Comparison of the Number, Percentage of Births for Each Bird Order in Brazilian Zoos From 1981 to 2005, and the Results of Friedman Tests

Bird order	N	1981	%	1990	%	2000	%	2005	%	Mean ± SE	Fr	P-value
Struthioniformes	3	47	3.25	191	14.56	239	23.92	30	4.57	12.68 ± 5.20	0.30	0.35
Tinamiformes	9	35	2.42	51	3.89	29	2.90	14	2.13	32.25 ± 7.65	1.69	0.64
Craciformes	8	11	0.76	28	2.13	34	3.40	36	5.48	27.25 ± 5.68	1.48	0.69
Galliformes	26	407	28.15	195	14.86	132	13.21	81	12.33	203.80 ± 71.60	4.39	0.22
Anseriformes	29	740	51.18	582	44.36	290	29.03	343	52.21	489.00 ± 105.00	0.12	0.99
Piciformes	6	0	0.00	7	0.53	10	1.00	6	0.91	5.75 ± 2.10	0.97	0.81
Psittaciformes	42	87	6.02	74	5.64	138	13.81	101	15.37	100.00 ± 13.80	5.29	0.15
Musophagiformes	2	1	0.07	0	0.00	0	0.00	5	0.76	1.50 ± 1.19	0.40	0.94
Strigiformes	5	0	0.00	10	0.76	5	0.50	6	0.91	5.25 ± 2.06	0.80	0.85
Columbiformes	18	76	5.26	64	4.88	38	3.80	4	0.61	45.50 ± 15.90	7.98	0.04*
Gruiformes	6	7	0.48	18	1.37	16	1.60	3	0.46	11.00 ± 3.58	0.33	0.95
Ciconiiformes	19	24	1.66	80	6.10	49	4.90	21	3.20	43.50 ± 13.70	0.33	0.95
Passeriformes	14	11	0.76	12	0.91	19	1.90	7	1.07	12.25 ± 2.50	0.22	0.97
Total	194	1,446	100	1,312	100	999	100	657	100	—	—	—

*Difference is statistically significant. Df, 3; N varied between the orders owing to the different number of species that bred in each order [N total = 609; species that did not breed = 415—they are not shown in this table]; %, percentage; mean ± standard error; Fr, Friedman test statistic.

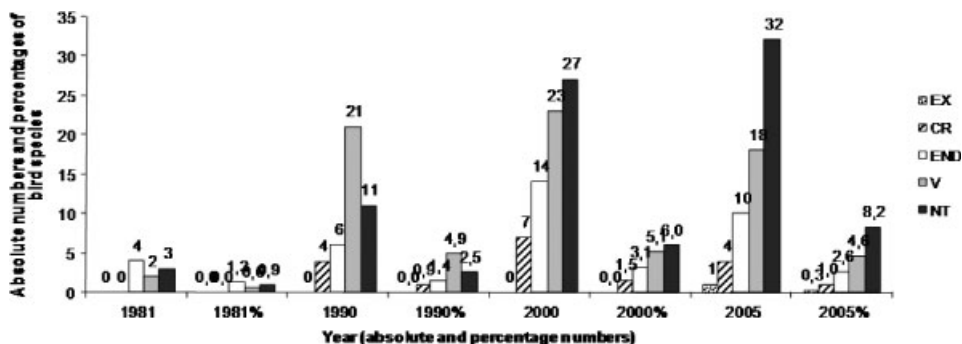


Fig. 2. Number of bird species and percentage of bird species (1981%, for example) held by Brazilian zoos from 1981 to 2005, in relation to the IUCN's threat categories. Ex, extinct in the wild; Cr, critically endangered; End, endangered; V, vulnerable; Nt, near threatened.

threatened" showed a positive correlation with the years; the number of species classified in this IUCN category increased over the years ($r_s = 0.99$, $N = 6$, $P < 0.05$). The "low risk/least concern/data deficient/unknown" IUCN category of threat showed a negative correlation (Spearman correlation rank) with the years; the number of bird species classified in this category decreased over the years ($r_s = -0.96$, $N = 6$, $P < 0.05$). No significant correlations were found for the remaining IUCN threat categories and the years evaluated.

The number of births in each IUCN threat categories did not differ statistically between the years evaluated (Table 5). The highest number of births occurred in the "low risk/least concern/data deficient/unknown" category of threat in all years, followed by the "near threatened" category. No species classified as "extinct in the wild" bred in Brazilian Zoos in the years analyzed, but the number of species in the "endangered" category bred more than the species classified as "vulnerable" in all years (Table 5).

DISCUSSION

The potential of Brazilian zoos to conserve birds is greater than what is actually occurring; although the number of species in each IUCN category of extinction and the number of breeding pairs had increased over the study period, the number of births in such categories did not follow the same pattern. The number of bird species in each IUCN threat category was in almost all years greater than the number of species held by Brazilian zoos [IUCN, 2009], but when the percentages were analyzed those numbers became virtually equal, showing that the zoos at least maintain in their collections a similar numbers of species which need conservation efforts to not become extinct. Although the Brazilian zoos held representative bird collections, their collection were not biased toward conservation.

The number of Brazilian zoos decreased from 1990 (50) to 2005 (19), owing to the closure of some institutions after inspection by IBAMA between 2001 and 2004. Some facilities, mainly those situated further from the large urban centers, did not maintain their animals correctly (without medical, nutritional, and welfare considerations) and were closed [Mikevis, 2004]. Although the number of bird

TABLE 4. Comparison of the Percentage of the Number of Bird Species Held by Brazilian Zoos in Each IUCN Threat Category From 1981 to 2005 and Their Statistical Comparison Using Friedman Tests

IUCN threat categories	Year [mean ± standard error]					Fr	P-value
	1981	1990	2000	2005			
Ex	—	—	—	0.06 ± 0.06	—	—	—
Cr	—	0.17 ± 0.06	0.08 ± 0.05	0.26 ± 0.16	0.16	0.98	0.98
En	0.61 ± 0.24	0.06 ± 0.03**	2.31 ± 0.52	4.72 ± 1.40**	10.44	0.01*	0.01*
V	0.30 ± 0.23	1.50 ± 0.38	1.36 ± 0.31	2.80 ± 0.82	5.78	0.12	0.12
Nt	2.55 ± 2.13**	0.69 ± 0.22**	5.00 ± 1.36	6.77 ± 1.69**	12.06	0.01*	0.01*
Lr	135.40 ± 42.70	52.38 ± 8.45	51.28 ± 7.74	100.00 ± 29.20	3.32	0.34	0.34

*Difference is statistically significant; Ex, extinct in the wild; Cr, critically endangered; En, endangered; V, vulnerable; Nt, near threatened; Lr, low risk/least concern/data deficient/unknown; Fr, Friedman test statistic; **Years that differed significantly according to the post hoc Tukey test. N₁₉₈₁ = 15, N₁₉₉₀ = 50, N₂₀₀₀ = 50, N₂₀₀₅ = 20; DF_{CR} = 2, DF_{EN,V,NT,LR} = 3.

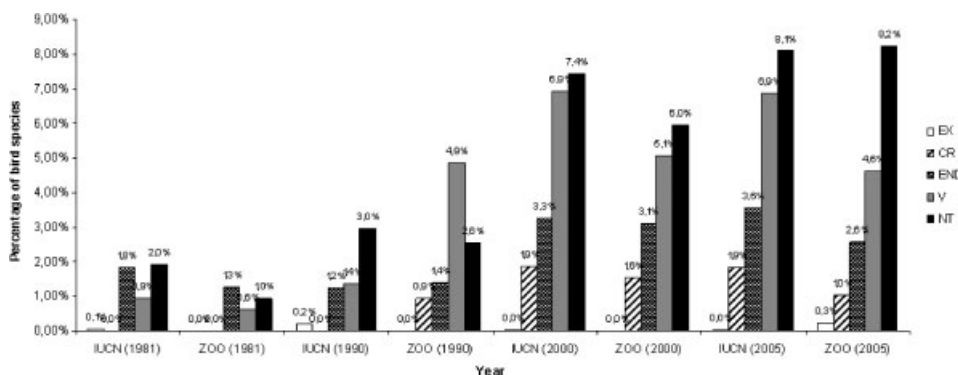


Fig. 3. Percentage of bird species held by Brazilian zoos (ex.: Zoo 1981), from 1981 to 2005 in relation to the percentage of bird species in each IUCN threat category per year (ex.: IUCN 1981). Ex, extinct in the wild; Cr, critically endangered; End, endangered; V, vulnerable; Nt, near threatened.

species, bird specimens, and breeding pairs have varied equally, as a consequence of the variation in the number of zoos in each evaluated year, it is important to note that their numbers increased over the years, showing that the participation of the Brazilian zoos in bird conservation may have increased (as discussed further, the participation of the Brazilian zoos in bird conservation must be improved, especially in terms of breeding rates). The percentage of species also increased over the years in all IUCN categories, but only significantly in the categories “endangered” and “near threatened,” confirming that the role of the Brazilian zoos in bird conservation increased across time.

Most of the Brazilian zoos are concentrated in the South and Southeastern regions, and this can be explained by the fact that these regions are industrialized and possess the highest development level in the country. These zoos receive greater amounts of money when compared with the zoos in other Brazilian regions, such as in the Northeastern and Northern regions. In Brazil, zoos can obtain money from their ticket-offices, from animal sales (rare), and/or from donations, but the majority of money comes from the local government [the values vary between the zoos and regions, but it is around 0.1% of the annual budget of the local government—municipal, State, or Federal—Young and Roncisvalle, 2002]; thus, richer Brazilian states invest more money in zoos than poorer states [IBAMA, 2002; Young and Roncisvalle, 2002]. Private zoos need to prove their financial sustainability to be licensed by the government [IBAMA, 2002]. However, zoos in the Northern region are important for conservation efforts, because they maintain local species that are difficult to obtain in other Brazilian regions.

Most of the bird species at risk of extinction, in Brazilian zoos, belonged to the Passeriformes and Psittaciformes orders, which is in conformity with the IUCN red list of 2007 [according to this list, the Order Passeriformes is the first in the number of species threatened (Ex, CR, End, and V categories), 573, and the Order Psittaciformes is the second in the number of species threatened (Ex, CR, End, and V categories), 94], but the number of breeding species of these orders was low (Passeriformes: under 2% of breeding and Psittaciformes: under 16% of breeding).

TABLE 5. Comparison of the Percentage of Births for Each IUCN Threat Category in Brazilian Zoos From 1981 to 2005

IUCN category of threat	N	1981	%	1990	%	2000	%	2005	%	Mean ± SE	Fr	P-value
EX	0	—	—	—	—	—	—	—	—	—	—	—
CR	2	—	—	2	0.15	—	—	—	—	—	—	—
END	7	28	1.94	31	2.36	28	2.80	31	4.72	29.50 ± 0.87	0.96	0.81
V	6	11	0.76	11	0.84	10	1.00	6	0.91	9.50 ± 1.19	0.16	0.98
NT	17	71	4.91	220	16.77	277	27.73	40	6.09	152.00 ± 57.30	1.92	0.59
LR	167	1,336	92.39	1,048	79.88	684	68.47	580	88.28	912.00 ± 173.00	1.58	0.66
Total	199	1,446	100	1,312	100	999	100	657	100	—	—	—

Df, 3; N varied between the orders owing to the different number of species that breed of each order [N total = 609; species that not breed = 410—they are not shown in this table]; %, percentage; mean ± standard error; Fr, Friedman test statistic.

The Order Anseriformes, which had the greatest reproduction in Brazilian zoos (more than 50% of the births), appears only in the 11th position in the same IUCN's red list (Ex, CR, End, and V categories). The five most threatened bird orders in the IUCN's red list of 2007 (Ex, CR, End, and V categories) are the Passeriformes, Psittaciformes, Galliformes, Procellariiformes, and Columbiformes. Of these, only the order Galliformes achieved more than 20% reproductive success in Brazilian zoos [the second bird order in terms of the number of breeding, and many of the bred species are not threatened by extinction]; Procellariiformes [Order Ciconiiformes in the Sibley and Alquist classification of birds, 1991], although held by some zoos in Brazil, did not reproduce in the years analyzed in this study.

Data produced in this study showed that Brazilian zoos need to invest in the improvement of captive breeding of threatened species, thus increasing their participation in conservation programs. No statistical differences were found between each IUCN category and the years analyzed for the number of births, although the number of births increased for the category "endangered." The creation of Conservation Assessment and Management Plans (CAMPs) or Global Captive Action Plans (GCAPs) could contribute significantly to the achievement of these goals [Seal et al., 1994; Wiggins, 2005]. According to IBAMA (the Brazilian National Agency for the conservation of nature—www.ibama.gov.br), only four species of Brazilian birds have CAMPs, these being the red-billed curassow [*Crax blumenbachii*: Wajntal et al., 2004], Lear's macaw [*Anodorhynchus leari*: Barros et al., 2006], the Araripe manakin [*Antilophia bokermanni*, Girão and Campos, 2006], and the Brazilian merganser [*Mergus octoetaceus*, Hughes et al., 2006]. The CAMP for albatrosses and petrels does not mention ex situ efforts, only in situ actions [Neves et al., 2006]. The Lear's macaw did not breed in the Brazilian zoos in the years analyzed, the Araripe manakin did not appear in the Brazilian zoo collections, and the red-billed curassow has increased their rates of breeding because the implementation of the recommendations proposed by their CAMP (from zero chicks in 1990 to seven in 2000 and two in 2005). The creation of CAMPs for the red-browed parrot (*Amazona rhodocorytha*), for the Spix's Macaw (*C. spixii*), for the Alagoas curassow (*Mitu mitu*), for Falconiformes (birds of prey) and curassows, pipiles and guans (Craciformes) are planned by IBAMA [IBAMA, 2007].

The number of bird species held by the Brazilian zoos in the "low risk/least concern/data deficient/unknown" category is greater than the threatened species in all years, but their percentages are in accord with the IUCN parameters. This result could indicate that Brazilian zoos did not participate consistently in bird conservation. Meanwhile, these species may play an indirect role in the conservation efforts of the zoos because they may attract visitors to zoos, which support their activities economically [IUDZG, 1993; Azevedo et al., 2003]. In fact, some species can be used as flagship species for in situ conservation efforts, thereby bringing money to the zoos (because of the numbers of visitors attracted) and promoting conservation knowledge of the visitors [Zacharias and Roff, 2001; Walpole and Leader-Williams, 2004; Mittermeier et al., 2005; Favreau et al., 2006]. This is especially true for large and charismatic birds [Dietz et al., 1994; Azevedo et al., 2003; Kruger, 2005].

Great numbers of bird species are changing from the lowest category of threat to higher categories of threat each year according to IUCN, and this is another parameter that illustrates the importance of the maintenance of species representing

the lowest IUCN's threat categories by the Brazilian zoos—their risk of extinction probably will increase over the years [Butchart et al., 2004, 2005; Lee and Marsden, 2006]. CAMPs or GCAPs could be implemented to avoid future management problems; gaining knowledge about a species biology when it is relatively abundant is preferable to the same action when the species is critically endangered; it is clear that “model species” [not threatened species that are closely related to species that are in great danger of extinction] can also contribute to the improvement of the management techniques [Benton, 2003]. Genetic information in studbooks is important for planning self-sustaining populations in captivity, as it helps to avoid the deleterious “founder effect” [Mayr, 1963] or high inbreeding rates, for example [Taylor, 2003; Whitfort and Young, 2004].

Brazilian zoos held more native species than exotic species, showing their relevance in local bird conservation. Garcia and Marini [2006] compared the number of Brazilian bird species in each threatened categories, according to the IUCN's red list, IBAMA's red list [national], and regional red lists, and they found that this number increases in almost all category according to the scale (global, national, or regional) of evaluation (regional: 71%; national: 33%; global: 26%). This phenomenon was also observed by Milner-Gulland et al. [2006] when they compared the threatened status of 163 Asian vertebrates using global, national, and regional red lists. Regional and national red lists thus assume great importance in cases of regional zoos [Rodriguez et al., 2000], helping conservationists in the protection of native fauna [Rodrigues et al., 2005]. National and regional red lists should be used by IUCN for the preparation of its own red list, turning it into a more realistic source of information about the worldwide threatened species [Gärdernfors, 2006; Miller et al., 2007]. National and regional lists should also be used in the analysis of the role of the zoos in bird conservation.

CONCLUSIONS

We conclude that the Brazilian zoos have a great potential in *ex situ* bird conservation (the number of individual birds held is enormous, for example). It is important to manage correctly the captive populations and to increase their breeding rates to transform them into sustainable sources of healthy individuals for reintroductions, restocking, or translocations [Gipps, 1991; Olney et al., 1994; Armstrong and Davidson, 2006]. The number of species in higher IUCN categories of extinction (i.e. “critically endangered,” “endangered,” “vulnerable”) should be increased, thus improving the participation of Brazilian zoos in bird conservation.

To be effective, zoos must keep healthy and self-sustaining populations; threatened species that bred eventually or present high inbreeding rates are not ideal for conservation purposes [Lafferty and Gerber, 2002; Waugh, 2005; Leberg and Firmin, 2008]. Thus, the cooperation between institutions would lead to a general improvement of the animal collections and in the global role of the zoos in species conservation [IUDZG, 1993; Diebold et al., 1999].

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