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Evaluating the Status of Lost, Found and Sighted Non-Native Pet Bird Species in South Africa

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Abstract: The global increase in the pet trade and ownership of pet birds has heightened the introduction of emerging invasive vertebrate species. We analyzed online databases of lost, found, and sighted non-native pet bird reports in South Africa to evaluate non-native pet bird statuses, investigate geographic patterns, assess species trends, and determine the factors associated with lost pet birds. We identified a total of 1467 case reports representing 77 species across nine families from websites (n = 3) and Facebook pages (n = 13). Most reports of lost birds were within large cities, in populated provinces, including Gauteng, KwaZulu-Natal, and Western Cape. Psittacidae, Psittaculidae, and Cacatuidae were the most dominant families, with African grey (*Psittacus erithacus*), Cockatiel (*Nymphicus hollandicus*), and Rose-ringed parakeet (*Psittacula krameri*) among the top species reported as lost. Lower-priced species were commonly reported as lost, and there was no association between the species' price and the likelihood of being found. In addition, we found a positive relationship between species reported as lost and the number of pet shops, human population size, species size, and docility. There was a sharp increase in lost cases from 2019 onwards; however, males were more frequently lost. Our findings highlight challenges in regulating and monitoring the pet ownership and trade of non-native pet birds and the need to address commonly kept species in conservation efforts. Online resources can be effective tools for passive surveillance of non-native pet bird species, especially potentially invasive ones.

Keywords: alien invasive species; case reports; distribution patterns; conservation status; surveillance; internet

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1. Introduction

The introduction rate of non-native species has increased over the years with global economies [1–3]. Different non-native species have been introduced for purposes such as ornamentation, entertainment, zoos, medicine, and pet trade [4–9]. The latter has been cited as one of the most contributing factors to the introduction of alien and invasive species (AIS) and the spreading of zoonotic diseases globally [3,10–12]. Invasive species have gained attention from biodiversity conservation authorities, researchers, government agencies, and the public due to the realization of their negative impacts on biodiversity, socio-economy, and human health [13–16].

Globally, approximately 1953 animal species traded as pets are invasive, of which 492 are birds [17]. Birds are among the most traded taxonomic groups, following fish and reptiles in the global market [17,18]. Online or traditional vendors (pet shops) are one of the important avenues where different non-native bird species are traded [19–21]. Most of these bird species, including protected, native, and potentially invasive ones, are exchanged between and within countries through these two avenues [19,22,23]. The

demand for non-native pet birds has resulted in illegal trade due to poor market and online regulations [15,24,25]. Factors such as birds' ability to mimic voices, ease of maintenance and breeding, and appealing looks have contributed to their demand in the trade [26,27].

The pet trade has contributed to the decline of some bird species in their native ranges [28,29]. For example, species such as macaws (*Ara* spp.), Amazon parrots (*Amazona* spp.), lovebirds (*Agapornis* spp.), African grey parrots (*Psittacus erithacus*), and cockatoos (*Cacatua* spp.) are endangered because of illegal collection [30,31]. The pet trade has also contributed to the introduction of invasive bird species such as rose-ringed parakeets (*Psittacula krameri*) and monk parakeets (*Myiopsitta monachus*), which are among the most popularly traded charismatic parrot species globally [12,21,32]. In addition, the founder populations of several bird species that have successfully established themselves outside their native ranges are linked to pet releases and escapees [10,12].

The number of released or escaped non-native pet bird species in the wild tends to be ignored, although they appear more likely to be reported as invasive and causing global impacts [12,33–36]. These impacts can be environmental or socio-economic. The major environmental impact of invasive bird species includes hybridization with native species, and competition with native species for nests and food [15,37]. Species such as Common myna (*Acridotheres tristis*) and Rose-ringed parakeets displace cavity nesters such as woodpeckers (*Picidae* spp.) from their nests [38], while House Sparrows (*Passer domesticus*) exhibit competitive behavior where they use nesting cavities intended for native bird species [39]. Nest competition can result in the killing of native species, for example, the killing of the threatened bat species the Greater noctule (*Nyctalus lasiopterus*) by invasive Rose-ringed parakeets in Spain [40]. Some of the invasive bird species have been reported to affect the genetic pool of native species through hybridization, leading to the genetic erosion of the original population [41,42]. For example, the pet escapee Mallard duck (*Anas platyrhynchos*) has been reported to pollute the genetic pool of endangered duck species such as the Hawaiian duck (*A. wyvilliana*), the African black duck (*A. sparsa*), and the Meller's duck (*A. meller*) [43].

An assessment of invasive pet escapees and releases is not only a matter of in situ (national) concern but also an international mandate and obligation to combat biodiversity loss and prevent the spread of alien invasive species [44–46]. Realizing and addressing the spread of invasive species through pet escapes and releases is crucial to fulfilling multilateral shared vision and responsibilities to safeguard ecosystems and biodiversity worldwide [45,47]. In South Africa, birds are the most traded group and are sold in all the provinces in the country [21]. Consequently, some of the pet birds have become invasive through escapees and accidental releases, e.g., Common myna, Rose-ringed parakeets, and House Sparrows [15]. Surveillance data is needed to determine which non-native pet birds sold as pets are likely to become established or invasive. As a result, we conducted our study to achieve the following aims: (1) assess the status of non-native pet birds reported as lost, found, and sighted through a comprehensive analysis of online databases and advertisements (e.g., Facebook, lost and found public database websites, and citizen science reports), (2) investigate the patterns of case reports and their distribution across geographic ranges in South Africa, (3) evaluate the trend of case reports over the years, and (4) determine the factors associated with lost pet birds. This information will help improve our understanding of the presence and distribution of non-native pet bird species in South Africa, contributing invaluable insights to biodiversity conservation efforts.

2. Materials and Methods

2.1. Data Collection

We collected a dataset of non-native bird introductions in South Africa through online reports of lost (missing), escapes, or found pet birds (see Supplementary Material Table S1). We covered online reports from all South African provinces between August 2011 and December 2023. We surveyed dedicated online platforms, including Facebook pages, notice boards, and websites, to assess the current trends and status of bird species reported as

either lost, found, or sighted. We examined records by conducting searches on various specialized websites such as CheekyBeaks, ParrotAlert ZA, TEARS Animal Rescue, and PowBoost, as well as Facebook pages including Reaction Unit South Africa, South Africa Bird Lost, Found, Rescue and Rehabilitation Network, and BIRD Missing Lost Stolen and Found (see Supplementary Material Table S1). Our searches on these platforms used search terms based on the common names or taxonomic groups of birds, such as conures, parrots, parakeets, doves, lovebirds, and finches in English. To ensure that relevant information was not missed, Google Translate was employed where other South African non-English languages were used. Furthermore, the search terms were utilized in combination with the search string containing the province or major city name, e.g., "Rose-ringed parakeets lost in Western Cape", "missing conure in Gauteng", "Cockatiel escaped in Mpumalanga", "pet African grey found in Cape Town" or "Monk parakeet/quaker parakeet sighted in Limpopo". Although it is common for websites, including Facebook, to remove aged records, the assessment of lost and found queries was conducted between August 2011 and December 2023, considering reports spanning multiple years on each respective platform.

The data collected for each report included essential details such as the species name, status (whether it was reported as lost, found, or sighted), the sex of the species, the number of species lost or found, the year of the incident, the geographical location, photographs for visual identification with a unique report number (Figure 1), and the source name (website or Facebook page) (Supplementary Material Table S1). For our final dataset, we only used the word "lost" instead of "missing" or "escaped" as it describes the same scenario. The standardization of common and scientific names for the lost, found, and sighted species followed globally accepted naming standards, utilized in the International Union for Conservation of Nature [48], Global Biodiversity Information Facility Taxonomic Backbone [49], International Ornithological Congress (IOC) World Bird List v. 12.2 [50], and the Integrated Taxonomic Information System [51]. The photographs obtained for each lost, found, and sighted species were used to identify all birds at the species level, utilizing established bird identification guides (Figure 1, [52–55]). The introduced geographic ranges for each reported pet bird species were sourced from various references, including Downs and Hart [56], IUCN [48], and the GBIF Secretariat [49].

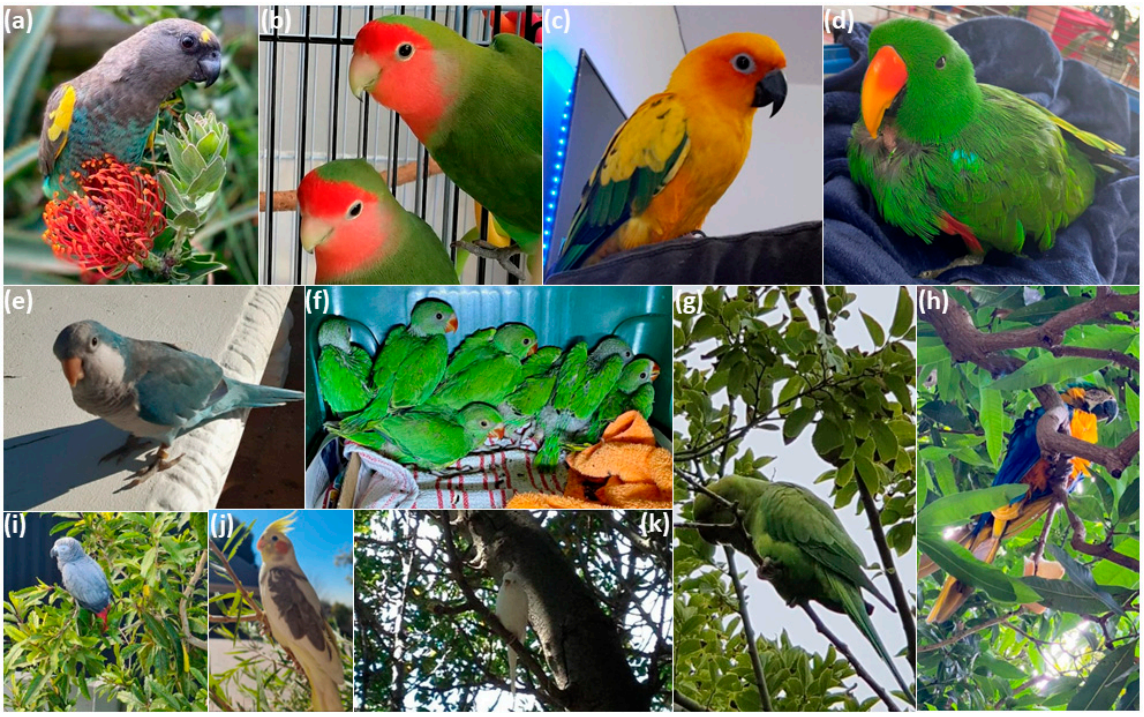

Figure 1. Illustrative photographs of pet bird species reported as lost (**a**) Meyer's parrot (*Poicephalus meyeri*), (**b**) Rosy-faced lovebird (*Agapornis roseicollis*), (**c**) Sun conure (*Aratinga solstitialis*),

and (**d**) Moluccan eclectus (*Eclectus roratus*), and (**e**) Monk parakeet (*Myiopsitta monachus*); found (**f**) Rose-ringed parakeet (*Psittacula krameri*) cheeks; and sighted outside captivity [(**g**) Rose-ringed parakeet, (**h**) Blue-and-yellow macaw (*Ara ararauna*), (**i**) African grey (*Psittacus erithacus*), (**j**) Cockatiel (*Nymphicus hollandicus*), and (**k**) Budgerigar (*Melopsittacus undulatus*)]. Photographs were sourced from websites and Facebook reports on lost and found birds.

2.2. Species Selection Criteria

We opted for common names and taxonomic group terms because many pet owners who have lost or found their birds use simple terms such as "African grey", "Cockatiel", "Blue-and-yellow macaw", "Red-fronted parrot", "Sun conure", "Indian ring neck/Rose-ringed parakeet", and "Pacific parrotlet". Only reports accompanied by clear photographs of the species were included in our study (Figures 1 and 2). This approach allowed us to verify the accuracy of the reported species names, prevent data redundancy, and employ the provided photographs for species identification using scientific identification guides.

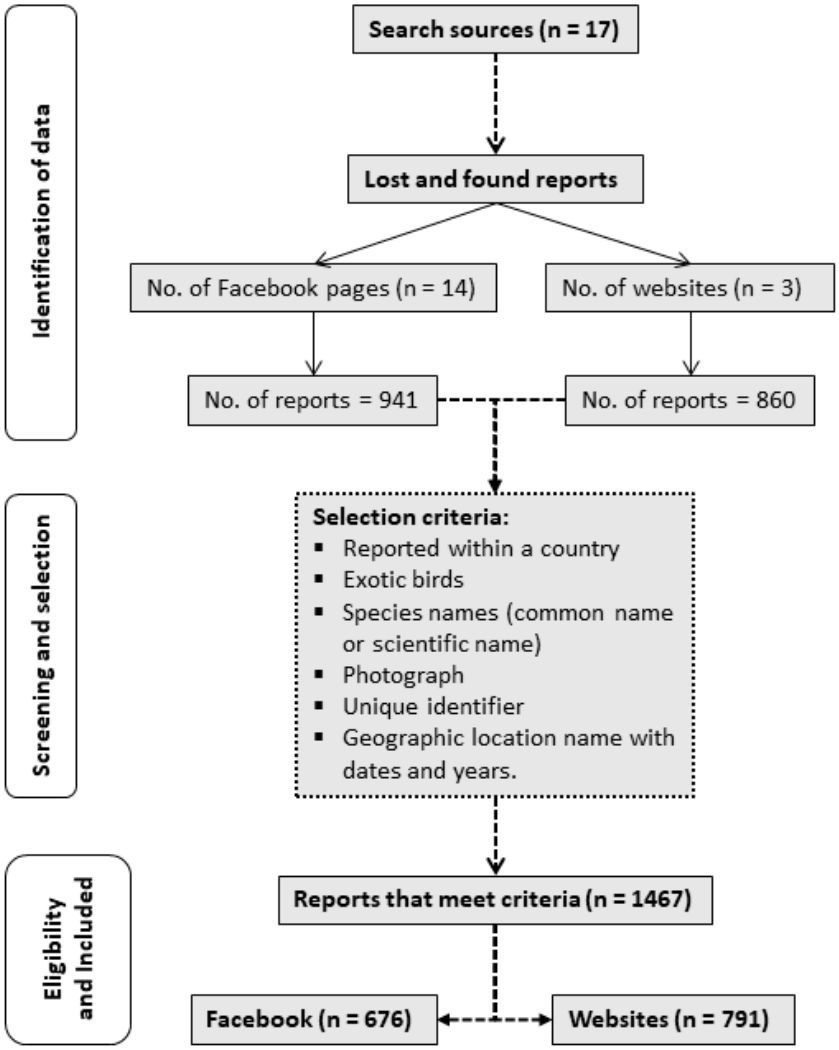

Figure 2. The yEd flow diagram shows stepwise selection criteria for non-native pet bird species reported as lost, found, and sighted in South Africa.

Additionally, a unique identification number for each report, coupled with a photograph of the species, was used to avoid redundant data entries for new lost and found reports originating from multiple sources (Figure 2). We cross-checked all the reports

across all online platforms to exclude duplicates. Instances where multiple reports for the same species were advertised across various dedicated pages or websites were infrequent. This was attributed to the restriction prohibiting a single pet owner from posting multiple reports for one species. Moreover, the report was modified from "lost" to "found" under the same identifier when a lost species is found. Additionally, most of these dedicated pages and websites undergo monthly monitoring where pet owners are contacted to determine if the lost species is found so that information can be updated. We also included average species prices in our dataset, using previously published data [21]. For species not documented in Shivambu et al. [21], we conducted searches on online advertising platforms to determine their prices. We then calculated the average price, considering that species are often sold at varying prices.

2.3. Statistical Analyses

All statistical analyses were performed using the R statistical environment (version 4.3.1, [57]). Reports of lost, found, and sighted cases were recorded as a single presence data point. Therefore, we calculated the overall number of case reports per species, province, and documented year. We examined the association between the reported cases of lost, found, and sighted over the years using linear regression analysis. The Pearson Chi-square test (χ^2) was used to determine if there is an association between the ratio of lost species to known species across different families. We also use the paired Wilcoxon signed-rank test to compare the overall case reports among the gender categories of reported pet bird species. The association between the price and the lost and found case report was determined using linear regression with the Pearson correlation test. Additionally, we performed generalized linear modeling to determine the relationship between the number of lost pet birds and each of the following predictor variables (average price, number of pet shops, human population size, surface area, color, size, and docility). The data was log-transformed to reduce highly skewed data to normal. Statistical significance was accepted when the *p*-value was at a significance level of 0.05. The 2019 global land cover of built-up area datasets were obtained from the Copernicus Global Land Monitoring Service (tiles E000S20 and E020S20) (https://lcviewer.vito.be/, accessed on 12 January 2024; [58]). The distribution of case reports (including lost, found, and sighted cases) and built-up land cover across South Africa was constructed in ArcMap using ArcGIS (desktop version 10.4.3, [59]). The diagram illustrating the flow of selection criteria was constructed using yEd Graph Editor software (version 3.23.2, [60]).

3. Results

3.1. Patterns of Case Reports and Geographic Distribution

We found two main sources reporting lost, found, and sighted pet bird species, including websites (n = 3) and Facebook pages (n = 13) between 2011 and 2023, with 1467 reports representing nine families. We recorded 77 species, with 63 lost, 44 found, and 14 sighted. The overall number of species (n = 77) overlapped, with some of the species represented in both cases (Supplementary Material Table S1). Most reported pet bird species were those reported as lost (n = 1034, 70.5%), followed by found (n = 388, 26.4%), and few reports on sightings (n = 45, 3.1%) (Figure 3). Most reports were concentrated in the Gauteng province regions, followed by the Western Cape and KwaZulu-Natal provinces (Figure 3). Reports were concentrated in urban areas, particularly around major cities, e.g., Johannesburg, Pretoria (Gauteng Province), Cape Town (Western Cape Province), and Pietermaritzburg and Durban (KwaZulu-Natal Province) (Figure 3).

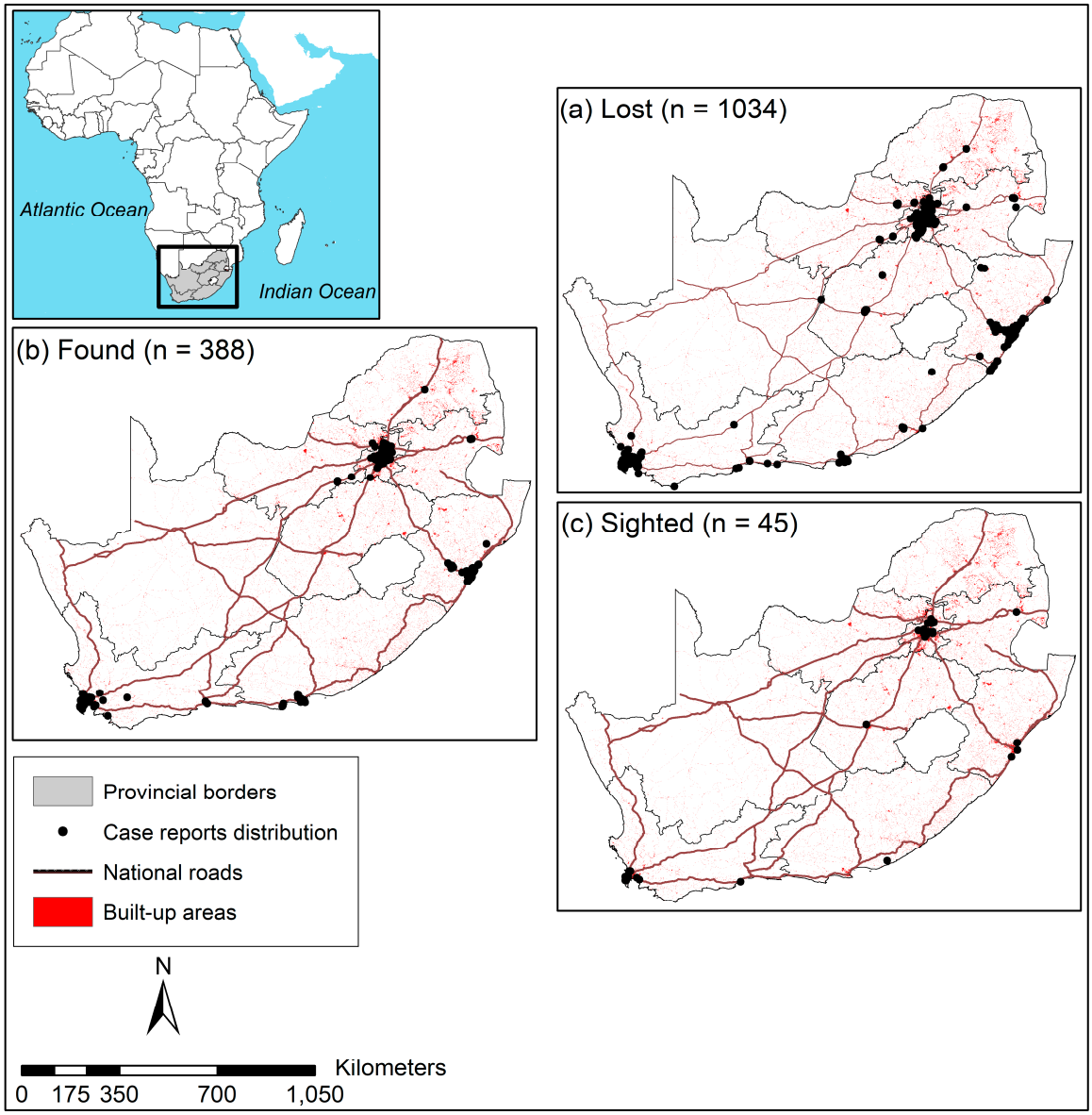

Figure 3. Map illustrating the distribution locations of reported as lost, found, and sighted pet bird species throughout South Africa. National roads (N1–N4, N7–N10, N12, N14) and built-up areas are included as indicators of anthropogenic activities and development in and around the documented localities.

3.2. Case Report Trends over the Years

The case reports of pet birds were documented between 2011 and 2023. We found that lost reports surpass found and sighted cases over the years (Figure 4). Most cases of loss occurred in 2016, with a sharp increase from 2019 (slope ± std err = 19.7 ± 3.56, t = 5.6, $p < 0.001$). A parallel trend was observed for found bird species, with a significant increase from 2019 to 2023 (slope ± std err = 9.4 ± 1.9, t = 4.9, $p < 0.001$). The sighted case reports, in contrast, remained lower across the years compared to lost and found cases, with a slight gain between 2019 and 2023 (slope ± std err = 1.2 ± 0.3, t = 4.3, $p = 0.001$) (Figure 4). While an overlap existed in 2011 between found and sighted case reports, the only instance of no documented cases occurred for sighted reports between 2011 and 2018 (Figure 4).

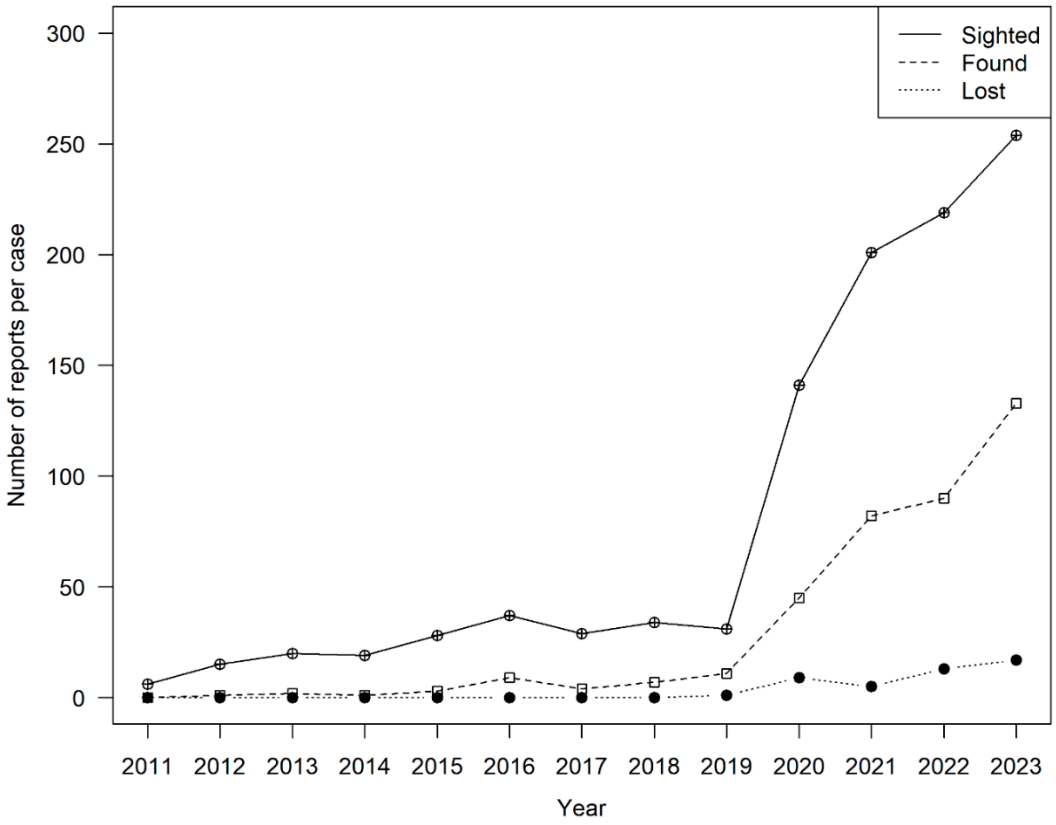

Figure 4. Trends in the number of case reports documenting instances of pet bird species reported as lost, found, and sighted in South Africa from 2011 to 2023.

3.3. Species Trends

Of the 77 species documented, we found that two bird species (Rosy-faced lovebird *Agapornis roseicollis* and Brown-headed parrot *Poicephalus cryptoxanthus*) have native ranges in some parts of South Africa. As a result, these species were included in the analyses. The African grey parrot *Psittacus erithacus*, Cockatiel *Nymphicus hollandicus*, and Rose-ringed parakeet *Psittacula krameri* were the most commonly lost species, with over 100 reports each (Figure 5; Table 1; Supplementary Material Table S1). These three species, including the Budgerigar *Melopsittacus undulatus*, were the most commonly found and sighted (Figure 5; Table 1). Of the dominating species, 59% have established feral populations outside their native ranges, and 12% are known to be invasive (Figure 5; Table 1). Only 43% have feral populations outside native ranges, and 5% are known as the worst invasive species (Table 1; [56,61,62]). Of the invasive species, four are already invasive in South Africa and listed in the NEM:BA A&IS Regulation list (e.g., Common starling, Common myna, Rose-ringed parakeet, and Rock dove), while the Monk parakeet has not established itself in the country (Table 1). However, the latter had more lost reports than found cases. We also found that there were a few cases where only 24 case reports documented stolen bird species from four provinces, namely Gauteng, Eastern Cape, KwaZulu-Natal, and Western Cape provinces (Table 1). Consequently, all instances of stolen birds were consolidated with cases reported as lost, acknowledging that stolen birds are categorized as lost from captivity due to theft.

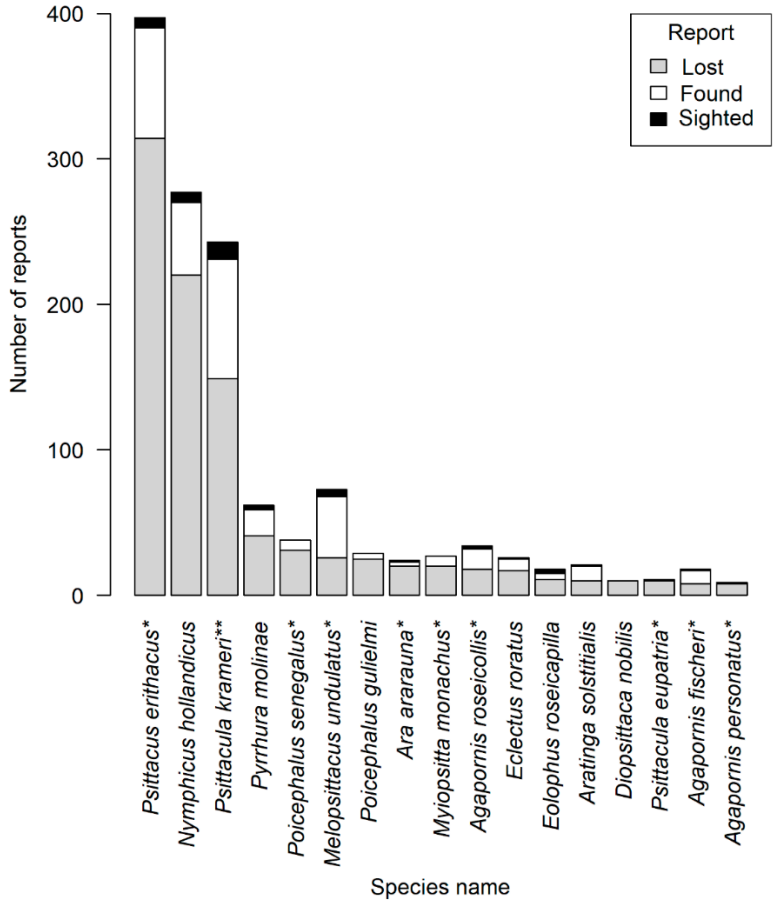

Figure 5. Stacked barplot depicting the top 17 most frequently reported pet bird species (lost, found, or sighted) in South Africa from 2018 to 2023. Species marked with one asterisk (*) have established feral populations beyond their native ranges, and those with double asterisks (**) are considered invasive in South Africa.

Table 1. A list of non-native bird species reported as lost (missing), found, or sighted by pet bird breeders, keepers, and traders. The National Environmental Management: Biodiversity Act (NEM:BA, Act 10 of 2004) Alien and Invasive Species Categories classifies species based on their ecological impact and management priority. An asterisk (*) indicates species with stolen reports, while those with a cross (†) are species with feral populations outside their native ranges.

Species Name	Common Name	Family	NEM:BA A&IS Categories (NL = Not Listed)	Number of Reports		
				Lost	Found	Sighted
Acridotheres tristis †	Common mynah	Passeriformes	3	2	3	0
Agapornis fischeri †	Fischer's lovebird	Psittaculidae	NL	8	9	1
Agapornis lilianae	Lilian's lovebird	Psittaculidae	NL	1	3	0
Agapornis nigrigenis	Black-cheeked lovebird	Psittaculidae	NL	1	0	0
Agapornis personatus *†	Yellow-collared lovebird	Psittaculidae	NL	8	1	0
Agapornis roseicollis *†	Rosy-faced lovebird	Psittaculidae	NL	18	14	2
Amazona amazonica †	Orange-winged amazon	Psittacidae	NL	4	0	0
Amazona autumnalis	Red-lored amazon	Psittacidae	NL	1	0	0
Amazona oratrix	Yellow-headed amazon	Psittacidae	NL	0	3	0
Amazona aestiva	Blue-fronted amazon	Psittacidae	NL	4	3	0

Table 1. *Cont.*

Species Name	Common Name	Family	NEM:BA A&IS Categories (NL = Not Listed)	Number of Reports		
				Lost	Found	Sighted
Anas platyrhynchos domesticus †	Domestic mallard duck	Anatidae	3	1	0	0
Anodorhynchus leari	Lear's macaw	Psittacidae	NL	0	0	1
Ara ararauna †	Blue-and-yellow macaw	Psittacidae	NL	20	3	1
Ara chloropterus †	Red-and-green macaw	Psittacidae	NL	1	0	0
Ara macao †	Scarlet macaw	Psittacidae	NL	1	0	0
Ara severus †	Chestnut-fronted macaw	Psittacidae	NL	1	0	0
Aratinga auricapillus	Golden-capped parakeet	Psittacidae	NL	1	0	0
Aratinga solstitialis	Sun conure	Psittacidae	NL	10	10	1
Aratinga weddellii	Dusky-headed Parakeet	Psittacidae	NL	1	0	0
Cacatua alba *	White cockatoo	Cacatuidae	NL	5	4	0
Cacatua galerita †	Sulphur-crested cockatoo	Cacatuidae	NL	1	0	0
Cacatua galerita eleonora †	Eleonora cockatoo	Cacatuidae	NL	1	0	0
Cacatua goffiniana †	Tanimbar corella	Cacatuidae	NL	2	0	0
Cacatua leadbeateri	Major Mitchell's cockatoo	Cacatuidae	NL	2	0	0
Cacatua sanguinea	Little corella	Cacatuidae	NL	2	0	0
Cairina moschata †	Muscovy duck	Anatidae	NL	1	0	0
Chloebia gouldiae	Gouldian finch	Estrildidae	NL	1	1	0
Columba livia †	Rock dove	Columbidae	2 and 3	1	2	0
Cyanoliseus patagonus	Burrowing parrot	Psittacidae	NL	1	0	0
Cyanoramphus auriceps	Yellow-crowned parakeet	Psittaculidae	NL	0	1	0
Cyanoramphus novaezelandiae	Red-crowned parakeet	Psittaculidae	NL	6	4	0
Diopsittaca nobilis	Red-shouldered macaw	Psittacidae	NL	10	0	0
Eclectus roratus *	Moluccan eclectus	Psittaculidae	NL	17	8	1
Eolophus roseicapilla	Galah cockatoo	Cacatuidae	NL	11	4	3
Erythrura cyaneovirens	Red-headed parrotfinch	Estrildidae	NL	0	1	0
Eupsittula aurea	Peach-fronted parakeet	Psittacidae	NL	2	0	0
Eupsittula canicularis †	Orange-fronted parakeet	Psittacidae	NL	1	0	0
Forpus coelestis	Pacific parrotlet	Psittacidae	NL	7	0	0
Geopelia cuneata	Diamond dove	Columbidae	NL	0	1	0
Melopsittacus undulatus *†	Budgerigar	Psittaculidae	NL	26	42	5
Musophaga violacea †	Violet turaco	Musophagidae	NL	1	0	0
Myiopsitta monachus †	Monk parakeet	Psittacidae	NL	20	7	0
Neophema pulchella	Turquoise parrot	Psittaculidae	NL	0	2	0
Neopsephotus bourkii	Bourke's parrot	Psittaculidae	NL	0	3	0
Nymphicus hollandicus *†	Cockatiel	Cacatuidae	NL	220	50	7
Pavo cristatus *†	Indian peafowl	Phasianidae	NL	2	1	0
Pionus chalcopterus	Bronze-winged parrot	Psittacidae	NL	1	0	0
Pionus maximiliani	Scaly-headed parrot	Psittacidae	NL	5	1	0
Pionus senilis	White-crowned poinus	Psittacidae	NL	4	0	0
Platycercus elegans †	Crimson rosella	Psittaculidae	NL	4	2	0
Platycercus eximius †	Eastern rosella	Psittaculidae	NL	1	1	1
Poicephalus cryptoxanthus	Brown-headed parrot	Psittacidae	NL	0	2	0

Table 1. *Cont.*

Species Name	Common Name	Family	NEM:BA A&IS Categories (NL = Not Listed)	Number of Reports		
				Lost	Found	Sighted
Poicephalus fuscicollis †	Brown-necked parrot	Psittacidae	NL	1	0	0
Poicephalus gulielmi *	Red-fronted parrot	Psittacidae	NL	25	4	0
Poicephalus meyeri	Meyer's parrot	Psittacidae	NL	0	4	0
Poicephalus rufiventris	Red-bellied parrot	Psittacidae	NL	2	2	0
Poicephalus senegalus *†	Senegal parrot	Psittacidae	NL	31	7	0
Polytelis anthopeplus	Regent parrot	Psittaculidae	NL	0	1	0
Primolius auricollis	Golden-collared macaw	Psittacidae	NL	2	1	0
Primolius maracana	Blue-winged macaw	Psittacidae	NL	4	0	0
Psephotus haematonotus	Red-rumped parrot	Psittaculidae	NL	2	4	0
Psittacara erythrogenys †	Red-masked parakeet	Psittacidae	NL	0	2	0
Psittacara leucophthalmus	White-eyed parakeet	Psittacidae	NL	1	0	0
Psittacula alexandri †	Red-breasted parakeet	Psittaculidae	NL	3	1	0
Psittacula cyanocephala	Plum-headed parakeet	Psittaculidae	NL	0	1	0
Psittacula eupatria †	Alexandrine parakeet	Psittaculidae	NL	10	1	0
Psittacula krameri *†	Rose-ringed parakeet	Psittaculidae	2	149	82	12
Psittacus erithacus †	African grey	Psittacidae	NL	314	76	7
Pyrrhura lepida	Pearly parakeet	Psittacidae	NL	1	0	0
Pyrrhura molinae	Green-cheeked conure	Psittacidae	NL	41	18	3
Pyrrhura perlata	Crimson-bellied parakeet	Psittacidae	NL	1	0	0
Pyrrhura rupicola	Black-capped parakeet	Psittacidae	NL	0	1	0
Sturnus vulgaris *†	Common starling	Sturnidae	3	1	0	0
Taeniopygia castanotis †	Australian zebra finch	Estrildidae	NL	2	0	0
Treron calvus †	African green-pigeon	Columbidae	NL	0	1	0
Trichoglossus moluccanus	Rainbow lorikeet	Psittaculidae	NL	2	1	0

NEM:BA categories: 2 = regulated species that may only be possessed, transported, and traded under a permit. 3 = species that are not prohibited require a permit for trade and must be managed to prevent them from becoming invasive.

3.4. Species Families and Sex Categories

We recorded nine families, with Psittacidae (number of reports (n) = 680, 44%), Psittaculidae (n = 492, 32%), and Cacatuidae (n = 345, 22%) accounting for most reports (Figure 6a). Pearson's Chi-squared test showed that there is a significant difference between the number of known bird species and species reported as lost across families (χ^2 = 1972.4, df = 8, $p = 2.2 \times 10^{-16}$). Psittacidae and Psittaculidae were overrepresented, with 36 and 20 species, respectively, while Cacatuidae had eight species. The remaining six families had case reports ranging from a minimum of one to six. The number of species for these families was four for Columbidae, two for Anatidae and Sturnidae, and three for Estrildidae, while Musophagidae and Phasianidae had one species each. We found that the number of male (n = 716, 49%), case reports was significantly higher than the overall female (n = 525, 35%) reports (paired Wilcoxon signed-rank test, V = 20,711, $p = 2.2 \times 10^{-16}$). Only 16% (n = 228) of reported cases had unverified sex. Male and female pairs represented the top 17 most reported species, with African grey parrot, Cockatiel, and Rose-ringed parakeet having both sexes in the same locations (Figure 6b; Supplementary Material Table S1).

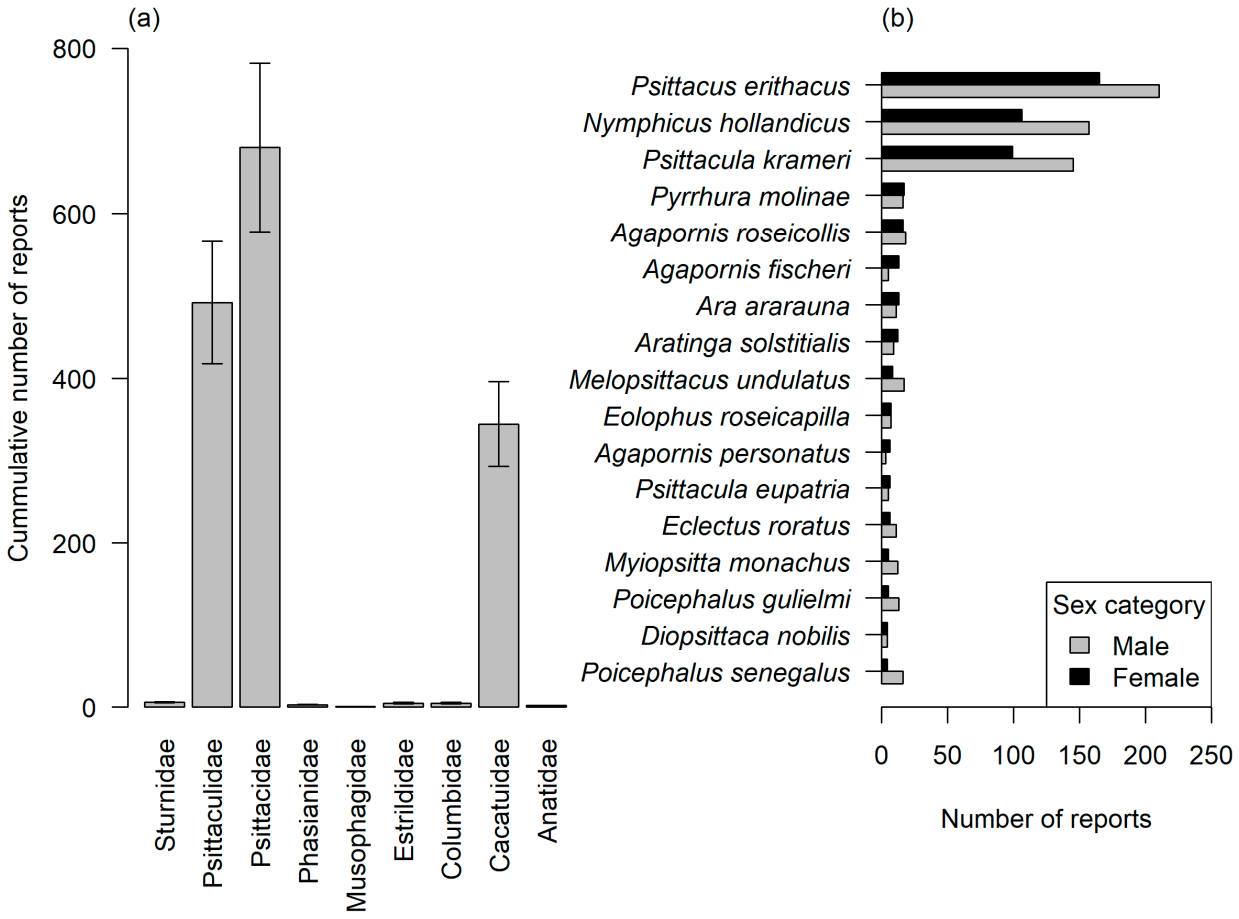

Figure 6. Figures illustrating (**a**) the error bar plot depicting the aggregate reports of lost, found, and sighted pet bird species per family and (**b**) a barplot highlighting the top 17 most reported pet bird species categorized by sex.

3.5. Explanatory Variables Influencing the Number of Birds Reported as Lost and Found

In terms of the relationship between the number of cases (found and lost) and price, we found a strong association. Species sold at relatively low prices were frequently reported as lost compared to the most expensive species, e.g., African grey (average selling price = ZAR 1941.67), Cockatiel (ZAR 485.92), and Rose-ringed parakeet (ZAR 511.35) ($r^2 = -0.57$; $p < 0.05$) (Figure 7; Supplementary Material Table S2). However, we found that there was no association between the price and the number of species reported found ($r^2 = -0.32$; $p > 0.05$). Overall, both lower and more expensive species were reported to be found (Figure 7). Our models showed that explanatory variables, including price, number of pet shops, and human population size, have a positive relationship with the number of species reported as lost (Supplementary Material Table S3). Provinces with large population sizes and more number of pet shops, such as the Gauteng, KwaZulu-Natal, and Western Cape, suggest a positive relationship with the number of lost pet birds (Supplementary Material Table S3). In addition, we found that predictor variables such as size (small and medium) and docility (not docile) have significant associations with lost pet birds, while color (not colorful) does not have a positive relationship (Supplementary Material Table S3, Figure S1).

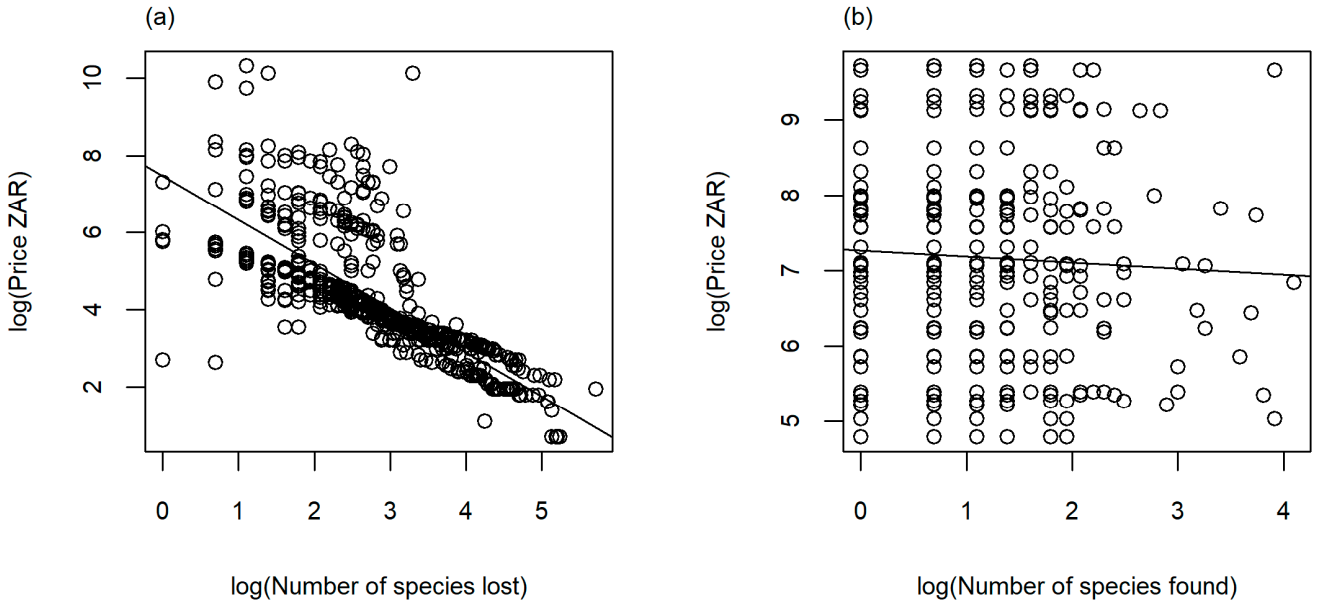

Figure 7. The relationship between species price and the number of case reports of (**a**) lost and (**b**) found species in South Africa.

4. Discussion

4.1. Geographical Distribution Patterns

The ongoing globalization of the pet trade has led to increased reports of non-native pet bird species outside captivity [9,12,34,63]. Patterns in case reports and species trends offer crucial insights into non-native pet bird dynamics in South Africa and across the globe at large [9,34,64]. We found that the distribution of reported pet birds is associated with populated provinces (Gauteng, Western Cape, and KwaZulu-Natal) and within urban settings. This trend was also observed in Australia [34], indicating that urban regions in South Africa and other global urban settings may play a crucial role in accommodating non-native bird species, e.g., invasive Rose-ringed parakeets in Durban and Johannesburg, South Africa [36,65], Monk parakeets in the city of Barcelona in northeastern Spain [66], and Common starlings in Llavallol Town, Argentina [67]. The high number of case reports in these provinces may also be attributed to various factors, including urban green spaces, urbanization, a large number of pet shops, and the availability of suitable habitats, which may help sustain their feral population [21,65].

4.2. Case Report Trends over the Years and Implications

The invasion success of alien bird species takes time and depends on various factors, including the presence of predators and favorable environmental conditions [68]. For example, Rose-ringed was introduced in the 1900s in South Africa, and its population started to boom in the 2000s, where it is spreading in major cities [21,34,69]. We found that the number of lost pet birds increased from 2019; consequently, some of the species may establish a feral population should they be released in large numbers. Duncan et al. [68] indicated that the success of some introductions relies on the release of a greater number of individuals, as they are likely to survive extinction risk due to environmental and genetic variability. The increase in lost reports may be explained by factors such as changes in pet ownership trends, increased reporting mechanisms through online platforms (websites and Facebook pages) or shifts in public awareness. Interestingly, most reports of lost birds spiked during the COVID-19 pandemic. As a result, the unique challenges presented by COVID-19 may have contributed to the incidence of lost pet birds. A recent study conducted in Japan between 2018 and 2021 also recorded a large number (n = 12,125) of bird escapees, where more than 60 species were recorded [12]. Even though our study showed a parallel increase in found case reports, lost cases were two times higher than

found cases. This emphasizes the need for proactive measures to prevent the establishment of feral populations. The slight increase in sighted cases, although lower than lost and found cases, may also indicate growing public awareness and reporting of non-native pet bird species, contributing valuable data for monitoring efforts. These trends offer valuable insights into regions where non-native species are likely to spill over and potentially become invasive, guiding management prioritization and conservation interventions.

4.3. Patterns in Case Reports and Species Trends

Our study showed that 77 species have been reported as either lost, found, or sighted. However, most of the species were reported as lost and were represented by Psittacidae, Psittaculidae, and Cacatuidae. Naturally, Psittaculidae has a greater number of species when compared to Psittacidae and Cacatuidae. Based on the Chi-sqaure test, we could not conclude that the number of species among families alone explains the distribution of lost pet birds. However, our results do suggest a significant relationship between the number of known and lost species across families, indicating that other factors could explain the distribution of species reported as lost. In addition, these families often comprise popular pet species, and their prevalence in case reports may reflect both their popularity in the pet trade and their adaptability, which can enhance the likelihood of establishment in local environments [12,21,70]. Notably, the African grey parrot, Cockatiel, and Rose-ringed parakeet emerge as the most frequently reported species, with over 200 reports each. Similar patterns have been reported by Symes et al. [36]; however, we found that lost, found, and sighted reports of these species are more frequent in this study than previously reported. In addition, a recent study in Japan by Nishida and Kitamura [12] showed an overlapping result with the Budgerigar, Cockatiel, Monk parakeet, and Rose-ringed parakeet among the pet birds most reported as lost and released. This has resulted in an influx of alien invasive (Budgerigar, Monk parakeet, and Rose-ringed parakeet) pet birds across the landscape of Japan, with the potential to cause environmental and socioeconomic impacts [12].

The dominance of lost cases, accounting for most reports, highlights the challenges of maintaining captive bird populations, particularly those with the potential of escaping captivity and becoming invasive, e.g., Rose-ringed parakeets and Monk parakeets [12,32,71]. Although in this study there were few lost reports for Common mynas and Common starlings, their population may likely integrate with those already outside captivity and establish further populations, given their potential distribution patterns in South Africa and elsewhere [15,36,56,72,73]. Furthermore, the identification of the native-alien populations in South Africa [74] indicates a rise in the within-country dispersal of native bird species facilitated by the pet trade. For example, there have been reports of pet escapees of Rosy-faced and Fischer's lovebirds in South Africa, particularly in the Gauteng region [34,36,75].

4.4. Sex Disparities in Case Reports

The establishment success of non-native species increases with propagule pressure that can range from as little as 10 to 100 individuals [68,76]. In cases where male and female pairs of the same species escape and breed, there is a likelihood of successful establishment [77]. Our study showed that both males and females of the species most reported as lost were recorded in the same locations. This includes breeding pairs reported as lost. As a result, species with the potential to find mates outside captivity are more likely to breed, establish propagule pressure, and become invasive, resulting in colonization pressure [77,78]. For example, Rose-ringed parakeet is likely to expand its distribution given that breeding pairs are reported as lost. Conversely, species that have not yet established feral populations but are frequently reported as lost, such as the African grey and Cockatiel, are likely to establish propagule pressure, particularly when both pairs are released in the same locations. A study by Brochier et al. [79] found that the arrival of Red-vented Bulbul (*Pycnonotus cafer*) in the Marshal Islands has been linked to the introduction of breeding pairs. Our study showed significant differences in observed case reports between male and female pet bird species, with males exhibiting the highest frequency of reports for

certain species. The differences in gender representation in case reports are not surprising, considering that captive populations of Psittacidae and Psittaculidae are known to show male-biased sex ratios [80]. It should be noted that a great number of reports for males in this study may be linked to preferences; for example, in most bird species, males are more colorful and attractive than females [81]. Understanding these sex-related dynamics provides an important perspective on the behaviors and interactions of non-native pet birds outside captivity.

4.5. Explanatory Variables Influencing the Number of Birds Reported as Lost and Found

Species sold at lower prices were more frequently reported as lost compared to the most expensive species. This could be because most people invest significant effort and finance in taking care of expensive species. For example, owners offered monetary rewards for expansive species (Blue-and-yellow macaw and Scarlet macaw) while cheaper species (Rose-ringed parakeet and Budgerigar) were mostly without rewards. Overall, more abundant, and cheaper species are likely to be reported as lost, given that they are sold in large numbers when compared to more expensive species [34]. Interestingly, we found no significant association between the number of species found and price. This suggests that the likelihood of species being found is not based on their price but on public awareness, where hobbyists and the general public assist in finding lost species [82]. In addition, small to medium-sized and not-docile species are more likely to be reported as lost when compared to larger, colorful, and docile species. This suggests that factors such as size, temperament, and color play crucial roles in determining the likelihood of bird escapes. For example, a study by Vall-llosera and Cassey [34] found that more docile parrot species were frequently reported as missing. In addition, more pet shops and a larger human population are associated with the number of pet birds reported as lost. As a result, this implies that areas with such factors may experience a higher incidence of lost bird species. Understanding this relationship could be important for developing effective strategies to mitigate the risk of species becoming established.

5. Conclusions and Recommendations

In South Africa, non-native pet birds are traded in high volume [21]; consequently, there has been an increase in the number of pet escapees in urban landscapes. Our study showed an increase in the number of pets reported as lost, particularly in urban areas of Gauteng, KwaZulu-Natal, and Western Cape provinces, from 2019 onwards. As a result, we recommend that provinces formulate regional-based legal tools to curb the influx of alien invasive species. This should also include establishing a national registry for birdkeeping and implementing monitoring systems for escaped birds. Collaborative efforts between governmental bodies, environmental agencies, and the public in enforcing and adhering to these regulations should be implemented [83–85]. Most of the birds reported as lost are sold at lower prices. Consequently, these species are likely to escape captivity or be lost as they are mostly kept or sold in high volumes compared to higher-priced species. For example, the Rose-ringed parakeet is one of the most traded species that has become invasive through pet escapes with small propagule pressure that exerts an impact in South Africa [15,65].

Although our top 17 list includes pet birds that might be considered low-risk, it is important to consider species that have become invasive or established elsewhere. For example, Budgerigar and Monk parakeets should be monitored to determine if they are breeding outside of captivity. These species should be included on a watch list for non-native species, in pre- and post-border control screenings, and in prioritizing alien invasive species for management and impact assessment [86,87]. This should also include species with the most reports, such as African grey, cockatiel, and grey-headed parrot. We believe that online resources can be effective tools for passive surveillance of non-native pet bird species and can be effective in finding lost pets and identifying potential invasive species. We recommend that regulatory measures be considered to manage the trade and ownership

of non-native pet bird species. This may involve reviewing the existing NEM:BA A&IS regulations to ensure the documentation of non-native species and promoting responsible pet ownership practices.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/d16050283/s1, Figure S1: A coefficient plot showing the logistic regression model estimates of factors affecting lost pet birds in South Africa. Positive estimates indicate a relationship; Table S1: A comprehensive list of case reports of non-native pet birds in South Africa from 2011–2023; Table S2: The average selling price of non-native pet birds reported lost, found, and sighted in South Africa; S3: The regression models showing the relationship between number of lost pet birds and average selling price, number of pet shops, human population size, and surface area. Asterisk indicate provinces with significant relationships. GP = Gauteng Province, KZN = KwaZulu-Natal, and WC = Western Cape.

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