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Spatio-temporal dynamics of consumer demand driving the Asian Songbird Crisis

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ABSTRACT

Many South-East Asian bird species are in rapid decline due to offtake for the cage-bird trade, a phenomenon driven largely by consumption in Indonesia and labelled the 'Asian Songbird Crisis'. Interventions aimed at reducing this offtake require an understanding of the spatial and temporal dynamics of the trade. We surveyed the bird-keeping habits of over 3000 households from 92 urban and rural communities across six provinces on Java, Indonesia, and compared prevalence and patterns of bird-keeping with those from surveys undertaken a decade ago. We estimate that one-third of Java's 36 million households keep 66–84 million cage-birds. Despite over half of all birds owned being non-native species, predominantly lovebirds (*Agapornis* spp.), the majority of bird-keepers (76%) owned native species. Ownership levels were significantly higher in urban than rural areas, and were particularly high in the eastern provinces of the island. Overall levels of bird ownership have increased over the past decade, and species composition has changed. Notably, lovebirds showed a seven-fold increase in popularity while ownership of genera including groups with globally threatened species such as leafbirds (*Chloropsis* spp.) and white-eyes (*Zosterops* spp.) also rose sharply. The volume of some locally threatened birds estimated to be in ownership (e.g., > 3 million White-rumped Shama *Kittacincla malabarica*) cannot have been supplied from Java's forests and research on supply from other islands and Java's growing commercial breeding industry is a priority. Determining temporal and spatial patterns of ownership is a crucial first step towards finding solutions to this persistent, pervasive and adaptive threat to the regional avifauna.

1. Introduction

Trade in wildlife is a multi-billion-dollar international industry increasingly driven by demand in certain countries for wildlife products from an emerging middle class (Drury, 2009; Davis et al., 2016; Veríssimo and Wan, 2018). Birds are a major component of this trade, identified as a threat to over 3000 wild species, approaching a third of the global avifauna (Butchart, 2008). Impacts of this trade are especially acute in South-East Asia, where > 1000 species of wild birds are traded for various reasons, a level of extraction that has precipitated an 'Asian Songbird Crisis' (Nijman, 2010; Su et al., 2014; Lee et al., 2016; Harris et al., 2017). Indonesia in particular represents a major regional market for cage-birds (Nash, 1993; Nijman, 2010; Chng et al., 2015), with trade significantly affecting at least 26 globally threatened bird species in Indonesia (BirdLife International, 2019).

Indonesia's most densely populated island, Java, with a population of over 140 million people, is considered the biggest source of demand for cage-birds within the region (Jepson and Ladle, 2005; Eaton et al., 2015). Keeping and breeding songbirds is a common pastime in Indonesia, with deep cultural roots (Jepson and Ladle, 2005). The potential of the trade to affect wild populations is significant: decade-old estimates indicated that across six cities in Java and Bali alone over two million native songbirds were kept as pets, almost a million of which were likely wild-caught (Jepson and Ladle, 2005, 2009). Moreover, in the last three decades keeping birds to enter them in singing contests has become increasingly popular in Indonesia (Jepson, 2008). Market

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surveys across Java have found over one hundred native Indonesian species for sale (Profauna, 2009; Chng et al., 2015) and revealed that the supply is now being met from Sumatra, Borneo and Peninsular Malaysia (Harris et al., 2017; Rentschlar et al., 2018). Expansion of the already strong bird-breeding industry in Java has previously been recommended to reduce pressure on wild bird populations (Jepson, 2010; Jepson et al., 2011), yet in recent years the breeding industry has lobbied for the removal of nationally protected status from widespread household species such as White-rumped Shama (*Kittacincla malabarica*) (ASEAN Post, 2018), highlighting the complexities faced in attempting to address the unsustainable offtake of wild birds. Accordingly, despite efforts from one national singing contest accreditation authority to reduce the number of wild-caught birds in their contests (Jepson et al., 2011), wild populations continue to suffer declines due largely to trapping pressure (Harris et al., 2017; Marthy and Farine, 2018; BirdLife International, 2019).

Here we seek to examine the extent and species composition of the cage-bird trade and identify patterns of consumption in all six provinces of Java to assess the scale of the threat trade poses to the regional avifauna. Demand for cage-birds is high across urban areas in Indonesia (Jepson and Ladle, 2009), but there has been little research into bird-keeping in rural communities, which are home to around 50% of the human population (Badan Pusat Statistik, 2010). We therefore investigate differences in the prevalence of bird-keeping in urban and rural communities across Java to determine what broad-scale demographic factors might influence demand for cage-birds. We extrapolate the numbers of households keeping cage-birds and the numbers of birds owned to assess the volume, composition, and patterns in ownership of species kept across the six provinces of Java. Finally, we reveal temporal trends in the extent and composition of the trade by comparing our results with those of surveys conducted a decade ago. The results of this study will both highlight the scale of the threat bird-keeping in Java poses to the regional avifauna and form an evidence base to inform and support future interventions aimed at demand reduction as a mechanism to increase the sustainability of songbird-keeping across South-East Asia.

2. Methods

2.1. Study design

We define a cage-bird as a bird kept or sold as a pet in either households or markets (Su et al., 2014; Chng et al., 2015). This definition encompasses passerine songbirds and other birds that can be entered in singing contests such as lovebirds (*Agapornis* spp.), various doves (Columbiformes) although not feral pigeons (Jepson and Ladle, 2005), owls (Strigiformes) (Nijman and Nekaris, 2017), woodpeckers (Piciformes), and cuckoos (Cuculiformes) (Chng et al., 2015). Taxonomy follows del Hoyo and Collar (2014) and del Hoyo and Collar (2016).

We conducted structured household surveys across six provinces on the island of Java, Indonesia (Banten, Daerah Khusus Ibukota [DKI] Jakarta, West Java, Central Java, Daerah Istimewa Yogyakarta [DIY] and East Java; Fig. 1). Study locations were chosen using a stratified sampling technique to ensure a representative sample for each province (Newing, 2010). The nested administrative levels of Indonesia are as follows: 1. Province, 2. Regency, 3. District, 4. Community (either a rural village or an urban community), 5. Neighbourhood. The national Indonesian statistics authority (Badan Pusat Statistik, BPS) uses a composite score across a number of factors to define urban and rural areas based on population density, number of households working in agriculture, and the availability of key infrastructure (Badan Pusat Statistik, 2010); we used the 2010 census data on the number and proportion of people living in BPS-defined rural and urban districts (i.e. administrative level 3). Districts were then ranked by the size of their rural populations to create quartiles for each province along a rurality gradient. Owing to the unavailability of recent data, the population density of urban districts we use (based on 2010 census data) is likely conservative as the values may now be higher due to migration from neighbouring rural communities (UNESCO, 2017), although the broad-scale differences between rural and urban districts will remain relatively constant.

Within each province, two districts were selected randomly from each quartile; within each district two communities were again selected randomly (see Fig. A.1.). In each community, a target number of surveys to be completed proportional to the population size was established (20–40 surveys per community). Communities were divided between teams (2–4 interviewers) by neighbourhoods, which were selected randomly. Research was conducted over two four-month periods between January and October 2018. Over each period research teams, comprising 6–10 trained Indonesian students and the principal investigator (HM), systematically searched assigned neighbourhoods for potential respondents in the first ten homes encountered. Once a neighbourhood had been fully searched or when at least five surveys were completed, another random number was used to find the next neighbourhood within the community until the target number of surveys was met.

Following the Indonesian statistical authority, a 'household' was defined as generally a family unit constituting an adult, spouse, and any children below the age of 18 (further examples in BPS, 2010). We aimed to complete surveys with the head of the household (male or female) if present, or else the most senior family member available. The survey was developed in the final quarter of 2017 and finalized after piloting in early 2018. The questions (see Appendix B) asked by the interviewers fell into three categories: (1) to collect data for household socio-economic and demographic profiles; (2) to determine whether respondents owned birds and, if so, which species, how many of each, and whether they were captive-bred or wild-caught; and (3) to establish their motivations for bird-keeping. Motivations explored in this paper are (a) to enter birds into singing contests and (b) to breed birds on a relatively small scale commercially or as a hobby. Owned birds were shown, or at least visible, to interviewers on > 80% of occasions, and were identified to species level. When birds were not seen, identification was made to genus level based on respondents' use of market names for their birds. Although the majority of songbird species are not protected by Indonesian legislation, the capture, transportation and sale of wildlife across provinces without permits are considered illegal offences, while the keeping of wildlife is not (Chng et al., 2018). Consequently, our questions do not directly relate to perceived illegal behaviour, and we therefore assumed respondents were answering questions about the origins of their birds truthfully, as in other research on songbird keeping in Indonesia (Jepson and Ladle, 2009; Burivalova et al., 2017)

2.2. Ethics statement

Research ethical approval was obtained from the Academic Ethics Committee at Manchester Metropolitan University and the Ethical Review Committee at Chester Zoo. A research permit (427/.A/SIP/FRP/E5/Dit.KI/II/2018) was obtained for Indonesia from the Indonesian research authority (RISTEKDIKTI) with the named research partner institution being Universitas Atma Jaya Yogyakarta. Prior to data collection, teams gained permission from the head of the neighbourhood, and agreed on stipulations laid out by the local higher administrative level (i.e. community, district or regency). Interviewers obtained prior informed consent from household members. Interview rejection rates were high (around 40%), more so in urban than rural areas and for the team's non-Javanese interviewers. Commonest reasons for rejection were lack of time or suspicion of a burglary plot. The time and date of the survey were recorded before data were collected, along with the name of interviewer; all data were subsequently anonymized.

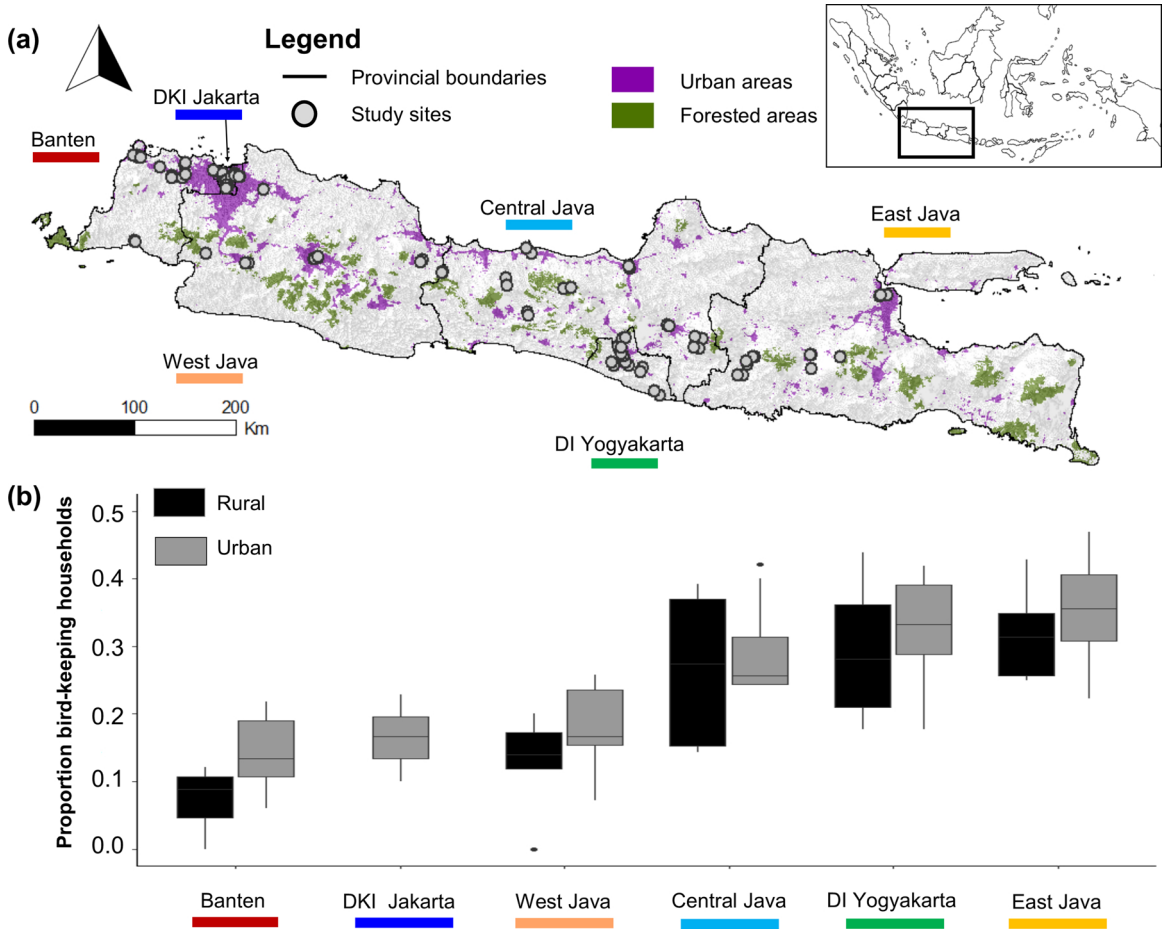

Fig. 1. Panel a: Study sites (communities) across the six provinces where households were surveyed between January and October 2018; highlighted in purple are densely populated areas and in green are areas of native forest. Panel b: Mean prevalence of households owning at least one native bird species for rural and urban communities across the six provinces of Java. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

2.3. Data analysis

To investigate the role of rurality in determining the prevalence of bird-keeping across Java, the top two quartiles for rurality were grouped together, as were the bottom two, to create a binary category of rural and urban communities. Mean proportions (± SE) of surveyed households keeping native and non-native birds were calculated for each urban and rural community within each province. The provinces of Java are commonly divided into two halves based on socio-economic differences between populations: the western provinces of Banten, DKI and West Java have a more ethnically mixed population with a relatively small Sundanese majority, while the eastern provinces of DIY, Central and East Java are overwhelmingly ethnically Javanese (Table A.1.; Na'im and Syaputra, 2010). To examine the broad-scale correlates of bird-keeping households, we fitted two Poisson generalized linear models (GLMs), using R statistical software (R Core Team, 2018), with the proportion of households keeping 1. native, and, 2. non-native birds, within communities as the continuous dependent variables in separate models. The predictor variables included in both models were binomial factors: whether the community was classed as rural or urban; and whether the community was in the eastern or western half of the island.

Overall cage-bird ownership and that of individual taxa (e.g. White-rumped Shama) were extrapolated to the whole of Java by calculating (a) the mean proportion (± SE) of households keeping each taxon across communities for each province, and (b) the mean number (± SE) of cage-birds owned per household, and then multiplying (a) by the number of households in each province, and (b) by the estimated number of households keeping those taxa. Taxa were then ranked by the estimated number of birds in households. We summarized the number of individuals of each bird species owned, along with the number of households keeping each species. All data on the number of households were obtained from the 2010 Indonesian Census (Badan Pusat Statistik, 2010). To identify the most common origin for each species, we calculated the proportion of that taxon reported as 'wild-caught' or 'captive-bred', excluding "unknown", summarized by the origin that represented the majority. A similar method to that above, without extrapolation, was also used to calculate the mean percentages of bird-owning respondents citing breeding and contest-going as motivations, and the prevalence of keeping the twelve most abundant taxa. Observed species richness and Chao 1 estimation of richness (Souto et al., 2017) were calculated for communities in each province and for urban or rural areas. As the majority of non-native species observed in this study and others (Burivalova et al., 2017) were bred and sourced in captivity, whereas native species found in markets are often sourced from the wild (Chng et al., 2015, 2018), our diversity measures included only species native to Indonesia so as to understand better how bird-keeping affects wild bird populations.

Data on cage-bird ownership and taxa recorded from households in Jepson and Ladle (2009) were obtained via Oxford University Research Archive (ORA) to examine changes in the prevalence of bird-keeping and the composition of bird taxa owned between 2007 and 2018. The methods employed to collect data in both studies were broadly comparable, but there were some differences regarding sampling strategy

and survey methodology: the data collected in 2007 were restricted to urban locations; and their survey was 'piggybacked' onto other consumer research (see Jepson and Ladle, 2009). As data collected in 2007 were obtained only from a sample of cities in Java and Bali, we used a subset of our data from the same or adjacent urban communities to make the comparison. For the purposes of this study, only data from Jepson and Ladle's (2009) random sample were used. We examined the difference in total proportion of songbird ownership levels between 2007 and 2018, and calculated the projected population size of native and non-native songbirds using the same method and same number of households as reported in Jepson and Ladle (2009). We also compared the percentage of people owning different taxa across the two datasets. In this analysis, to ensure congruency between the taxonomy in both studies, we grouped certain species together from our dataset (e.g. tailorbirds *Orthotomus* spp., prinias *Prinia* spp., *Alophoixus* bulbul spp., tits *Parus* spp./Java Sparrow *Lonchura oryzivora*, flycatchers *Cyornis* spp., and laughingthrushes *Garrulax* spp.).

3. Results

3.1. Prevalence of bird-keeping

Of 3042 households surveyed in 92 communities across all six provinces (Fig. 1), 958 (31.5%) kept 5967 individual birds belonging to 112 species or species groups (55% non-native and 45% native). Of bird-keeping households, 726 (76%) owned at least one native bird, and 545 (56%) owned a non-native bird. Communities in the eastern provinces of the island (Central Java, DIY, East Java) had significantly higher proportions of households keeping both native (32% vs 15%; $p < 0.001$) and non-native (23% vs 12%; $p = 0.003$) birds than those in the western provinces (Banten, DKI, West Java; Fig. 1 and Fig. A.2. for non-native bird ownership). Urban communities had significantly higher proportions of households keeping both native (25% vs 23%; $p = 0.034$) and especially non-native birds (21% vs 14%; $p < 0.001$) than rural ones (for the full GLM outputs see Table A.2.).

3.2. Species composition, total volume and extrapolations of ownership

We estimate that 11,973,000 ± 994,000 (SE) households kept 74,321,000 ± 8,490,000 cage-birds across Java in 2018. This equates to roughly one cage-bird for every two people on the island, or two per household. We estimate that over 30 million lovebirds and around 10 million Island Canaries (*Serinus canaria* var. *domestica*) were being kept on Java in 2018, but that there were also huge numbers of some native songbirds, including > 3 million White-rumped Shamas (*Kittacincla malabarica*) and > 2 million Oriental Magpie-robins (*Copsychus saularis*; Table 1). Three species and two genera had higher proportions of individuals reported to be wild-caught than captive-bred, and had estimated ownership levels exceeding one million birds (Table 1). Of all (112) species and genera kept, > 12% are listed as threatened or Near Threatened (Appendix C); of taxa with estimated ownership levels exceeding one million birds, Javan Pied Starling (*Gracupica jalla*) is listed as Critically Endangered and two genera (leafbirds *Chloropsis* spp. & white-eyes *Zosterops* spp.) include species listed as threatened or Near Threatened (Table 1) on the IUCN (International Union for Conservation of Nature) Red List of Threatened Species (IUCN, 2019).

3.3. Patterns of bird ownership across Java

We found considerable spatial variation across provinces and gradients of rurality in species composition and abundance, overall taxonomic diversity and motivations for keeping birds (Table 2). The nine most abundant taxa, including eleven species, were doves (Sunda Collared *Streptopelia bitorquata*, Zebra and Eastern Spotted Dove *Spilopelia chinensis*), White-rumped Shama, Oriental Magpie-robin, white-eyes, Yellow-vented Bulbul (*Pycnonotus goiavier*), leafbirds, Javan Pied

Table 1
The most abundant taxa reportedly owned ranked by the number of birds in households across the six provinces of Java.

Rank	Species: English name	Species: Scientific name	IUCN status[a]	Number of keepers	Number of birds	Primary source[b]	Estimated number of birds in households (SE)
1	Lovebirds	*Agapornis* spp.	–	386	2293	NN[c]	33,479,000 (5,957,000)
2	Island Canary	*Serinus canaria*	–	253	675	NN[d]	9,702,000 (2,467,000)
3	Dove spp.	*Streptopelia / Spilopelia / Geopelia* spp.	LC	223	824	CB	8,045,000 (1,272,000)
4	White-rumped Shama	*Kittacincla malabarica*	LC	133	294	CB	3,386,000 (707,000)
5	Budgerigar	*Melopsittacus undulatus*	–	34	209	NN	1,694,000 (788,000)
6	Oriental Magpie-robin	*Copsychus saularis*	LC	116	186	CB	2,457,000 (371,000)
7	White-eyes	*Zosterops* spp.	–c	83	174	WC	1,859,000 (427,000)
8	Yellow-vented Bulbul	*Pycnonotus goiavier*	LC	120	208	WC	1,644,000 (206,000)
9	Leafbirds	*Chloropsis* spp.	–d	92	123	WC	1,596,000 (211,000)
10	Javan Pied Starling	*Gracupica jalla*	CR	85	125	CB	1,144,000 (143,000)
11	Sooty-headed Bulbul	*Pycnonotus aurigaster*	LC	55	75	WC	1,028,000 (170,000)
12	Long-tailed Shrike	*Lanius schach*	LC	73	81	WC	1,011,000 (54,000)

[a] IUCN status; LC: Least Concern; NT: Near Threatened; VU: Vulnerable; CR: Critically Endangered.
[b] Primary source represents that most often reported other than 'unknown' for each species; NN: non-native, CB: captive-bred, WC: wild-caught.
[c] White-eye species: *Zosterops palpebrosus* (LC), *Zosterops montanus* (LC), *Zosterops atricapilla* (LC), *Heleia javanica* (LC), *Zosterops flavus* (VU).
[d] Leafbird species: *Chloropsis venusta* (NT), *Chloropsis sonnerati* (VU), *Chloropsis moluccensis* (LC), *Chloropsis cyanopogon* (NT).

Table 2
Patterns of ownership across Java's provinces, urban and rural communities, and overall.

Province / Urban Status	Total bird-keepers (% respondents)		% bird-keepers owning:				Species richness			% bird-keepers owning:								
	n	%	Native birds	Non-native birds	To breed	To enter singing contests	Observed	Expected Chao1	(SE)	Dove spp.[a]	White-rumped Shama	Oriental Magpie-robin	White-eyes[b]	Yellow-vented Bulbul	Leafbirds[c]	Javan Pied Starling	Sooty-headed Bulbul	Long-tailed Shrike
Banten	77	16.7	67.6	47.9	14.7	29.6	24	31	(6.6)	22.5	13.4	11.6	9.4	0.0	4.1	3.9	3.9	0.9
DKI Jakarta	106	24.3	69.8	68.5	22.5	31.1	37	88	(35.2)	16.9	22.5	14.8	7.5	13.1	12.6	10.6	3.0	2.9
West Java	104	23.2	73.9	50.3	17.3	30.0	29	43	(11.2)	14.3	14.2	12.2	7.3	4.2	4.7	8.3	12.5	1.9
Central Java	212	34.6	79.1	53.8	37.1	21.0	51	53	(2.4)	20.7	12.4	16.9	7.5	17.6	12.2	12.2	7.5	12.3
DI Yogyakarta	232	39.0	82.9	51.0	40.2	19.8	76	99	(12.2)	29.3	12.4	10.7	9.7	20.6	7.3	8.3	4.8	8.0
East Java	227	47.5	75.3	59.7	40.6	29.1	51	66	(10.0)	27.7	13.2	10.0	7.2	6.8	11.1	3.4	3.2	8.4
Urban	602	33.2	73.9	60.1	29.6	30.1	86	102	(8.7)	21.2	15.9	12.6	8.4	12.4	9.1	8.4	4.7	5.3
Rural	356	29.2	77.3	47.6	30.5	20.4	65	93	(15.8)	24.6	12.3	12.9	7.7	8.8	8.6	6.7	6.9	7.5
Overall	958	31.6	75.2	55.3	30.0	26.3	100	127	(13.5)	22.5	14.5	12.7	8.1	11.0	8.9	7.8	5.6	6.2

[a] Dove species include Sunda Collared *Streptopelia bitorquata*, Zebra and Spotted Doves.
[b] White-eye species include *Zosterops palpebrosus*, *Z. montanus*, *Z. atricapilla*, *Z. flavus*, *Heleia javanica*.
[c] Leafbird species include *Chloropsis venusta*, *C. sonnerati*, *C. moluccensis*, *C. cyanopogon*.

Starling, Sooty-headed Bulbul (*Pycnonotus aurigaster*) and Long-tailed Shrike (*Lanius schach*) (Table 2). Captive breeding of birds was more common in the eastern provinces, while ownership associated with singing contests was more common in the western provinces, and lower in rural areas than in urban areas across all provinces. Estimated total species richness of birds kept was highest in Yogyakarta and Jakarta. Jakarta had the highest levels of non-native bird ownership, but the locally threatened White-rumped Shama, a highly prized favourite of singing competitions, was also especially common (Table 2).

3.4. Decadal changes in ownership

Songbird ownership levels have risen markedly over the last decade in each of the five urban areas sampled in both studies (Table 3), with songbird ownership from our survey being double or treble (in Surabaya) that reported by Jepson and Ladle (2009). Accordingly, there has also been a sharp rise in the projected number of songbirds across all locations, most notably in non-native species such as lovebirds, canaries, and Budgerigars (*Melopsittacus undulatus*). The composition of songbird taxa owned has also changed (Fig. 2): lovebirds have become seven times more prevalent, and white-eyes, Javan Pied Starlings and leafbirds are now far more common. In contrast, Orange-headed Thrush (*Geokichla citrina*), Long-tailed Shrike, and several bulbul species (*Pycnonotus* and *Alophoixus* spp.) have seen dramatic drops in ownership.

4. Discussion

Investigating the broad-scale patterns of the trade is crucial to understand the impact on species and the ecological services they provide, and to inform interventions to reduce this impact either through demand reduction (Olmedo et al., 2018; Veríssimo and Wan, 2018) or supply management (Jepson and Ladle, 2009; Nijman et al., 2018). This study examined the spatial variability and temporal dynamics of consumer demand in Java both to highlight the scale of the threat it poses to the regional avifauna and as an evidence base that can inform future interventions aimed at increasing the sustainability of songbird-keeping in Java.

We estimate that some 66–83 million cage-birds are now kept in captivity on Java—one bird for every two of the island's human population. While the majority of these birds are captive-bred non-native species, the projected number of native songbirds kept in some of Java's largest urban centres has more than trebled over the last decade. Given that < 12,000 km^2 of Java's forest remains (Prasetyo et al., 2011) and that little of Java's non-forested land remains suitable for many bird species due to both intense land-use management (Higginbottom et al., 2019) and bird-trapping (Ng et al., 2017; Nijman et al., 2018), we suggest that the number of birds held in cages might approach or actually exceed the number of birds left in the wild on the island. The scale of demand for cage-birds has pushed more than a dozen species to the brink of extinction on Java and beyond (BirdLife International, 2019), and many species affected by trade which were once common and widespread, such as Java Sparrow and White-rumped Shama, have now become increasingly difficult to find (Eaton et al., 2015). Even so, despite significant drops in wild bird populations (Harris et al., 2017; Sykes, 2017), bird ownership levels have increased over the past decade.

There was significant variation in multiple bird ownership metrics both across provinces and between urban and rural communities. Overall ownership was higher in Javanese-dominated eastern Java, where both bird-breeding and the keeping of ornamental species such as Yellow-vented Bulbul were much more common. In western Java, bird-keeping was more associated with singing contests, with taxa such as White-rumped Shama and leafbirds more commonly kept. Even more striking were differences between Java's rural populations and its urban centres. Urban communities were more likely to keep birds, and kept a

Table 3
The percentage of households in each study location that kept songbird species (including lovebirds and canaries) and the projected number of songbirds kept (both native and non-native species) in 2007 and 2018.

City/province	2007				2018			
	n	% Keeping songbirds	Projected number of songbirds		n	% Keeping songbirds	Projected number of songbirds	
			Native	Non-native			Native	Non-native
Jakarta / DKI	293	8.9	260,812	94,908	371	22.6	124,621	154,573
Bandung / W. Java	299	8.4	90,718	61,495	194	25.8	980,290	2,074,973
Yogyakarta / DIY	300	14.7	34,124	9177	143	34.3	257,857	705,230
Semarang / C. Java	299	19.1	144,703	61,075	150	35.3	374,494	1,216,178
Surabaya / E. Java	290	20.0	312,974	126,931	125	62.4	912,774	1,899,143
Overall	1481	14.2	843,330	353,586	983	31.9	2,650,036	6,050,098

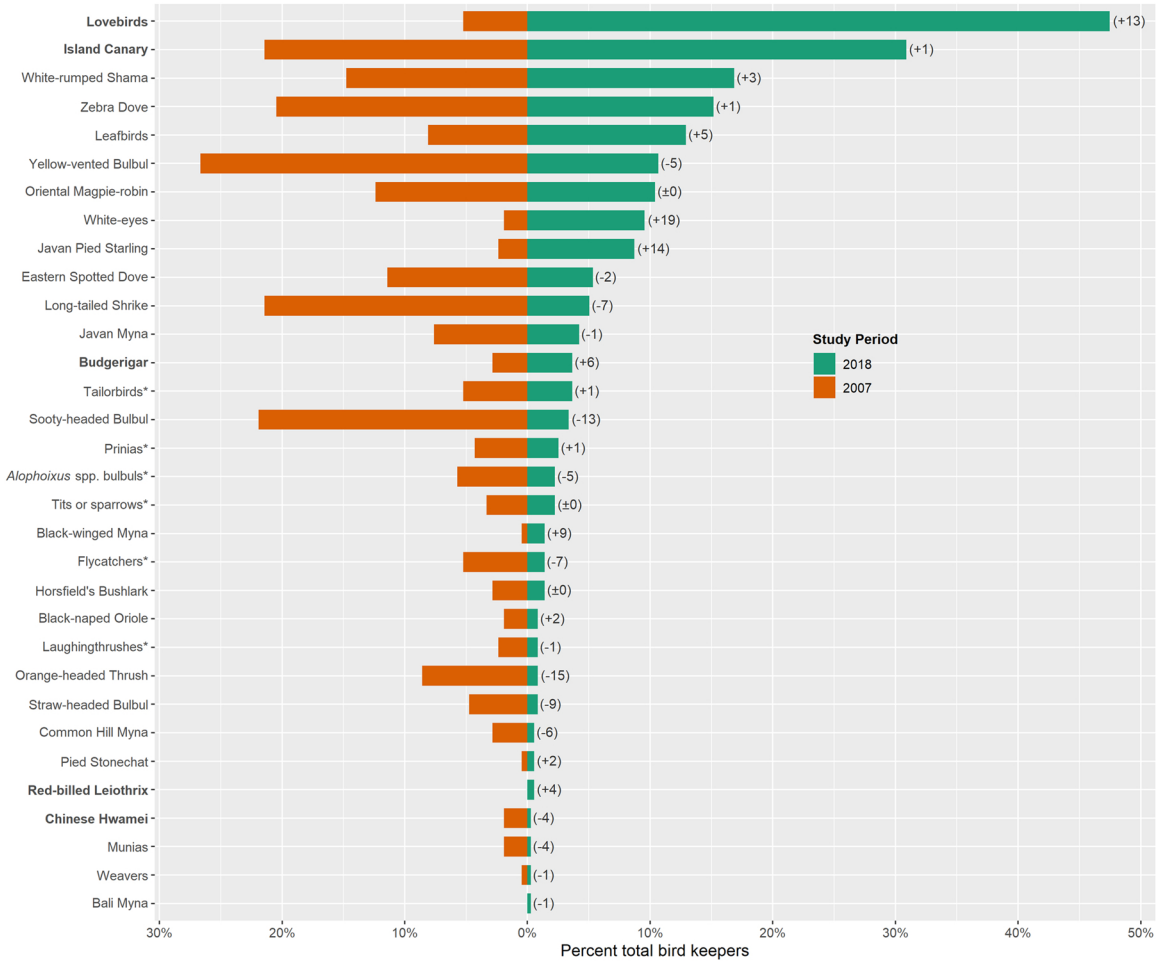

Fig. 2. Comparison of species/taxon composition between 2007 and 2018, ranked by percent ownership of species/taxon in 2018. Changes in rank across surveys is shown in brackets beside percentage ownership in 2018. Non-native taxa are highlighted in bold. * indicates species that have been matched despite different taxonomic classification between the two datasets. Scientific names of species are in Appendix C.

wider range of species, perhaps reflecting availability of species from Java and other Indonesian islands in their large markets (Chng et al., 2015) and higher disposable incomes (UNESCO, 2017). They also kept a higher proportion of non-native birds such as lovebirds and canaries, and were much more likely to enter singing contests, which may be associated with the larger proportion of rural populations employed in low-wage labour-intensive work than urban ones. Conservation interventions aimed at demand reduction or other behavioural change will need to start with an appreciation of these differences (Challender et al., 2014; Olmedo et al., 2018), focusing on the habits of hobby breeders in the eastern half of the island, and the preferences of singing-contest enthusiasts in urban centres in the western half.

A major conservation concern is the decline in ownership of species such as Orange-headed Thrush, Long-tailed Shrike, and some *Pycnonotus* and *Alophoixus* bulbuls. Whether ownership of these taxa has dropped more due to a reduction in availability through declines in wild populations, or something more benign like simple trends in what is fashionable, requires investigation. Previous work found an increase in ownership of *Geokichla* thrush species (including Orange-headed Thrush) between 1999 and 2006 (Jepson and Ladle, 2009) due to their popularity in singing contests, and during the same period they appear to have been trapped to local extinction across Java (Jepson, 2008). Regional trends in ownership of some of these taxa raise the possibility that availability in the wild may be a key factor in predicting presence

in captivity, and that demand shifts to more highly abundant taxa when one source dries up (Eaton et al., 2015). These trends highlight how understanding the popularity of species with individual bird-keepers will be key to predicting which species may be targeted as substitutes in future.

Another major concern is the growth over the last decade in ownership of taxa such as leafbirds and white-eyes, both of which, despite growing fears for wild populations of these taxa (Lee et al., 2016), are yet to become staples of the captive-breeding industry (Nijman et al., 2018). The large numbers of these taxa entering the market reflects the ability of the songbird trade in Java to switch to previously unexploited sources. Recent research on bird-keeping in Sumatra and Kalimantan demonstrates how leafbirds and white-eyes have become popular outside Java and how wild-caught individuals are often more desirable than captive-bred alternatives (Burivalova et al., 2017; Rentschlar et al., 2018). Notable are within-country regional trends in consumer demand for cage-birds, for example the large numbers of munias found in markets in Medan to supply merit releases by the large ethnically Chinese population (Chng et al., 2018), or significant levels of trapping (primarily parrots) observed in Maluku to supply local demand for pets (Cottee-Jones et al., 2014; Tamalane et al., 2019). The importance of Java as the biggest regional source of demand however is demonstrated by the large number of birds from higher-value species supplied by other islands within Indonesia, notably Sumatra (Bušina et al., 2018) and Kalimantan (Rentschlar et al., 2018).

The huge numbers of White-rumped Shamas in households, a species of great commercial value now virtually extirpated from Javan forests, must be supplied through importation of wild birds from outside of Java (Rentschlar et al., 2018), and commercial breeding (Nijman et al., 2018). We know from seizures that thousands of shamas arrive in Java from Indonesia's other Sundaic islands, Malaysia and Thailand (Leupen et al., 2018), and the further spread of Java's pervasive demand for songbirds to adjacent areas of Asia must now be regarded as a real and serious danger to wild populations. The degree to which demand for White-rumped Shamas is being or might be met by commercial breeding is unclear, as it is for other species such as Javan Pied Starling, Bali Myna (*Leucopsar rothschildi*), and Oriental Magpie-robin. The numbers of these high-value species kept and reportedly sourced from commercial breeders indicates that the avicultural community in Indonesia has considerable capacity (Jepson et al., 2011). At present, however, legitimate concerns exist that breeding facilities possess the potential to 'launder' wild birds (Eaton et al., 2015; Rentschlar et al., 2018; Nijman et al., 2018) and even that successful commercial breeding may simply stimulate rather than satisfy demand. It is therefore a matter of urgency to establish whether and how commercial captive breeding of popular native or once-native species could be developed and regulated to replace, rather than add to, Java's current consumption of wild-caught birds.

The great increase in ownership of easy-to-breed non-native species, especially lovebirds, also raises the possibility that higher-volume production of these and other birds could meet indiscriminate demand for cage-birds and song competitors. However, the huge increase in the numbers of non-native birds relative to a still remarkable increase in native birds, suggests that trade in captive-bred non-native species may simply be supplementing rather than supplanting demand for native songbirds. Again, it is critical to investigate the scale and scope of the industry to determine the commercial viability of expanding businesses sustainably to meet the increasing demand. It is particularly important to explore whether sustainably breeding highly sought-after taxa such as leafbirds and white-eyes, which have thus far proved difficult to breed at commercial scales, could realistically reduce pressure on wild populations. Evidence is also urgently needed, through an intensive profiling of consumer behaviour, preferences, and socio-economic circumstance (Drury, 2009; Offord-Woolley, 2017), to inform a conservation response that can induce a genuine and lasting behavioural change in consumption habits and thereby prevent further exacerbation of the Asian Songbird Crisis.

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Appendices. Supplementary data

Supporting material can be found in three appendices: Appendix A - supporting tables and figures; Appendix B – survey questions; Appendix C - full list of bird taxa reportedly owned. Supplementary data to this article can be found online at https://doi.org/10.1016/j.biocon.2019.108237.

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