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Marshall, Harry, Collar, Nigel J, Lees, Alexander C , Moss, Andrew, Yuda, Pramana and Marsden, Stuart J (2020) Spatio-temporal dynamics of consumer demand driving the Asian Songbird Crisis. *Biological Conservation*, 241. p. 108237. ISSN 0006-3207

DOI: <https://doi.org/10.1016/j.biocon.2019.108237>

Publisher: Elsevier BV

Version: Accepted Version

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1 **Title:** Spatio-temporal dynamics of consumer demand driving the Asian Songbird Crisis

2 Published online in Biological Conservation on 20/09/2019

3

4 **DOI:** <https://doi.org/10.1016/j.biocon.2019.108237>

5

6 **Author names and affiliations:**

7 Harry Marshall^a, Nigel Collar^b, Alexander C. Lees^{a,c}, Andrew Moss^c, Pramana Yuda^d, Stuart Marsden^a.

8 ^aSchool of Science & the Environment, Manchester Metropolitan University, Manchester, M1 5GD, UK

9 ^bBirdLife International, The David Attenborough Building, Pembroke St, Cambridge, CB2 3QZ, UK

10 ^cCedar House, Chester Zoo, Upton-by-Chester, Chester, CH2 1LH

11 ^dFakultas Teknobiologi, Kampus II Gedung Thomas Aquinas, Universitas Atma Jaya Yogyakarta, Jalan Babarsari 44,

12 Yogyakarta 55281, Indonesia

13 ^eCornell Lab of Ornithology, Cornell University, Ithaca, USA

14

15 **Author contact details:**

16 Corresponding Author: Harry Marshall,

17 PhD Office E401, John Dalton Building,

18 School of Science & the Environment, Manchester Metropolitan University,

19 Manchester, M1 5GD, UK

20 +44(0)7546881935, harry.marshall@stu.mmu.ac.uk / harry.marshall112@gmail.com

21

22 **Abstract:**

23 Many South-East Asian bird species are in rapid decline due to offtake for the cage-bird trade, a
24 phenomenon driven largely by consumption in Indonesia and labelled the ‘Asian Songbird Crisis’.

25 Interventions aimed at reducing this offtake require an understanding of the spatial and temporal dynamics
26 of the trade. We surveyed the bird-keeping habits of over 3,000 households from 92 urban and rural
27 communities across six provinces on Java, Indonesia, and compared prevalence and patterns of bird keeping
28 with those from surveys undertaken a decade ago. We estimate that one-third of Java’s 36 million
29 households keep 66–84 million cage-birds. Despite over half of all birds owned being non-native species,
30 predominantly lovebirds (*Agapornis* spp.), the majority of bird-keepers (76%) owned native species.

31 Ownership levels were significantly higher in urban than rural areas, and were particularly high in the
32 eastern provinces of the island. Overall levels of bird ownership have increased over the past decade, and
33 species composition has changed. Notably, lovebirds showed a seven-fold increase in popularity while
34 ownership of genera including groups with globally threatened species such as leafbirds (*Chloropsis* spp.)

35 and white-eyes (*Zosterops* spp.) also rose sharply. The volume of some locally threatened birds estimated
36 to be in ownership (e.g., >3 million White-rumped Shama *Kittacincla malabarica*) cannot have been
37 supplied from Java's forests and research on supply from other islands and Java's growing commercial
38 breeding industry is a priority. Determining temporal and spatial patterns of ownership is a crucial first step
39 towards finding solutions to this persistent, pervasive and adaptive threat to the regional avifauna.

40

41 **Keywords**

42 Cage-bird, wildlife trade, threatened species, Java, Indonesia, behavioural change, ownership patterns

43

44 **1. Introduction**

45 Trade in wildlife is a multi-billion-dollar international industry increasingly driven by demand in certain
46 countries for wildlife products from an emerging middle class (Drury, 2009; Davis et al., 2016; Veríssimo
47 and Wan, 2018). Birds are a major component of this trade, identified as a threat to over 3,000 wild species,
48 approaching a third of the global avifauna (Butchart, 2008). Impacts of this trade are especially acute in
49 South-East Asia, where >1000 species of wild birds are traded for various reasons, a level of extraction that
50 has precipitated an 'Asian Songbird Crisis' (Nijman, 2010; Su et al., 2014; Lee et al., 2016; Harris et al.,
51 2017). Indonesia in particular represents a major regional market for cage-birds (Nash, 1993; Nijman, 2010;
52 Chng et al., 2015), with trade significantly affecting at least 26 globally threatened bird species in Indonesia
53 (Birdlife International, 2019).

54 Indonesia's most densely populated island, Java, with a population of over 140 million people, is
55 considered the biggest source of demand for cage-birds within the region (Jepson and Ladle, 2005; Eaton
56 et al., 2015). Keeping and breeding songbirds is a common pastime in Indonesia, with deep cultural roots
57 (Jepson and Ladle, 2005). The potential of the trade to affect wild populations is significant: decade-old
58 estimates indicated that across six cities in Java and Bali alone over two million native songbirds were kept
59 as pets, almost a million of which were likely wild-caught (Jepson and Ladle, 2005, 2009). Moreover, in
60 the last three decades keeping birds to enter them in singing contests has become increasingly popular in
61 Indonesia (Jepson, 2008). Market surveys across Java have found over one hundred native Indonesian
62 species for sale (Profauna, 2009; Chng et al., 2015) and revealed that the supply is now being met from

63 Sumatra, Borneo and Peninsular Malaysia (Harris et al., 2017; Rentschlar et al., 2018). Expansion of the
64 already strong bird-breeding industry in Java has previously been recommended to reduce pressure on wild
65 bird populations (Jepson, 2010; Jepson, Ladle and Sujatnika, 2011), yet in recent years the breeding industry
66 has lobbied for the removal of nationally protected status from widespread household species such as
67 White-rumped Shama (*Kittacincla malabarica*) (ASEAN Post, 2018), highlighting the complexities faced
68 in attempting to address the unsustainable offtake of wild birds. Accordingly, despite efforts from one
69 national singing contest accreditation authority to reduce the number of wild-caught birds in their contests
70 (Jepson et al., 2011), wild populations continue to suffer declines due largely to trapping pressure (Harris
71 et al., 2017; Marthy & Farine, 2018; Birdlife International, 2019).

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

85

86 **2. Methods**

87 ***2.1. Study design***

88 We define a cage-bird as a bird kept or sold as a pet in either households or markets (Su et al., 2014; Chng
89 et al., 2015). This definition encompasses passerine songbirds and other birds that can be entered in singing

90 contests such as lovebirds (*Agapornis* spp.), various doves (Columbiformes) although not feral pigeons
91 (Jepson and Ladle 2005), owls (Strigiformes) (Nijman and Nekaris 2017), woodpeckers (Piciformes), and
92 cuckoos (Cuculiformes) (Chng et al., 2015). Taxonomy follows del Hoyo and Collar (2014) and del Hoyo
93 et al. (2016).

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

109 Within each province, two districts were selected randomly from each quartile; within each district
110 two communities were again selected randomly (see Fig. A.1.). In each community, a target number of
111 surveys to be completed proportional to the community population size was established (20–40 surveys per
112 community). Communities were divided between teams (2–4 interviewers) by neighbourhoods, which were
113 selected randomly. Research was conducted over two four-month periods between January and October
114 2018. Over each period research teams, comprising 6–10 trained Indonesian students and the principal
115 investigator (HM), systematically searched assigned neighbourhoods for potential respondents in the first
116 ten homes encountered. Once a neighbourhood had been fully searched or when at least five surveys were

117 completed, another random number was used to find the next neighbourhood within the village until the
118 target number of surveys was met.

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

136

137 ***2.2. Ethics statement***

138 Research ethical approval was obtained from the Academic Ethics Committee at Manchester Metropolitan
139 University and the Ethical Review Committee at Chester Zoo. A research permit
140 (427/.A/SIP/FRP/E5/Dit.KI/II/2018) was obtained for Indonesia from the Indonesian research authority
141 (RISTEKDIKTI) with the named research partner institution being Universitas Atma Jaya Yogyakarta.
142 Prior to data collection, teams gained permission from the head of the neighbourhood, and agreed on
143 stipulations laid out by the local higher administrative level (i.e. community, district or regency).
144 Interviewers obtained prior informed consent from household members. Interview rejection rates were high

145 (around 40%), more so in urban than rural areas and for the team's non-Javanese interviewers. Commonest
146 reasons for rejection were lack of time or suspicion of a burglary plot. The time and date of the survey were
147 recorded before data were collected, along with the name of interviewer; all data were subsequently
148 anonymized.

149

150 **2.3. Data analysis**

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

164 Overall cage-bird ownership and that of individual taxa (e.g. White-rumped Shama) were
165 extrapolated to the whole of Java by calculating (a) the mean proportion (\pm SE) of households keeping each
166 taxon across communities for each province, and (b) the mean number (\pm SE) of cage-birds owned per
167 household, and then multiplying (a) by the number of households in each province, and (b) by the estimated
168 number of households keeping those taxa. Taxa were then ranked by the estimated number of birds in
169 households. We summarized the number of individuals of each bird species owned, along with the number
170 of households keeping each species. All data on the number of households were obtained from the 2010
171 Indonesian Census (Badan Pusat Statistik, 2010). To identify the most common origin for each species, we
172 calculated the proportion of that taxon reported as 'wild-caught' or 'captive-bred', excluding 'unknown',

173 summarized by the origin that represented the majority. A similar method to that above, without
174 extrapolation, was also used to calculate the mean percentages of bird-owning respondents citing breeding
175 and contest-going as motivations, and the prevalence of keeping the twelve most abundant taxa. Observed
176 species richness and Chao 1 estimation of richness (Souto et al., 2017) were calculated for communities in
177 each province and for urban or rural areas. As the majority of non-native species observed in this study and
178 others (Burivalova et al., 2017) were bred and sourced in captivity, whereas native species found in markets
179 are often sourced from the wild (Chng et al., 2015, 2018) our diversity measures included only species
180 native to Indonesia so as to understand better how bird-keeping affects wild bird populations.

181 Data on cage-bird ownership and taxa recorded from households in Jepson (2009) were obtained,
182 with the lead author's permission, via Oxford University Research Archive (ORA) to examine changes in
183 the prevalence of bird-keeping and the composition of bird taxa owned between 2007 and 2018. The
184 methods employed to collect data in both studies were broadly comparable, but there were some differences
185 regarding sampling strategy and survey methodology: the data collected in Jepson were only collected in
186 urban locations; and Jepson's survey was 'piggybacked' onto other consumer research (see Jepson 2009).
187 As data collected in 2007 were obtained only from a sample of cities in Java and Bali, we used a subset of
188 our data from the same or adjacent urban communities to make the comparison. For the purposes of this
189 study, only data from Jepson's (2009) random sample were used. We examined the difference in total
190 proportion of songbird ownership levels between 2007 and 2018, and calculated the projected population
191 size of native and non-native songbirds using the same method and same number of households as reported
192 in Jepson (2009). We also compared the percentage of people owning different taxa across the two datasets.
193 In this analysis, to ensure congruency between the taxonomy in our study and Jepson's (2009), we grouped
194 certain species together from our dataset (e.g. tailorbirds *Orthotomus* spp., prinias *Prinia* spp., *Alophoixus*
195 bulbul spp., tits *Parus* spp./Java Sparrows *Lonchura oryzivora*, flycatchers *Cyornis* spp., and
196 laughingthrushes *Garrulax* spp.).

197

198

199

200

201 **3. Results**

202 **3.1. Prevalence of bird-keeping**

203 Of 3,042 households surveyed in 92 communities across all six provinces (Figure 1), 958 (31.5%) kept
204 5,967 individual birds belonging to 112 species or species groups (55% non-native and 45% native). Of
205 bird-keeping households, 726 (76%) owned at least one native bird, and 545 (56%) owned a non-native
206 bird. Communities in the eastern provinces of the island (Central Java, DIY, East Java) had significantly
207 higher proportions of households keeping both native (32% vs 15%; $p < 0.001$) and non-native (23% vs
208 12%; $p = 0.003$) birds than those in the western provinces (Banten, DKI, West Java; Fig. 1 and Fig. A.2.
209 for non-native bird ownership). Urban communities had significantly higher proportions of households
210 keeping both native (25% vs 23%; $p = 0.034$) and especially non-native birds (21% vs 14%; $p < 0.001$) than
211 rural ones (for the full GLM outputs see Table A.2.).

212

213 **3.2. Species composition, total volume and extrapolations of ownership**

214 We estimate that $11,973,000 \pm 994,000$ (SE) households kept $74,321,000 \pm 8,490,000$ cage-birds across
215 Java in 2018. This equates to roughly one cage-bird for every two people on the island, or two per
216 household. We estimate that over 30 million lovebirds and around 10 million Island Canaries (*Serinus*
217 *canaria var. domestica*) were being kept on Java in 2018, but that there were also huge numbers of some
218 native songbirds, including >3 million White-rumped Shamans (*Kittacincla malabarica*) and > 2 million
219 Oriental Magpie-robins (*Copsychus saularis*; Table 1). Three species and two genera had higher
220 proportions of individuals reported to be wild-caught than captive-bred, and had estimated ownership levels
221 exceeding one million birds (Table 1). Of all (140) species and genera kept, > 12% are listed as threatened
222 or Near Threatened (Appendix C); of taxa with estimated ownership levels exceeding one million birds,
223 Javan Pied Starling (*Gracupica jalla*) is listed as Critically Endangered and two genera (leafbirds
224 *Chloropsis* spp. & white-eyes *Zosterops* spp.) include species listed as threatened or Near Threatened
225 (Table 1) on the IUCN (International Union for Conservation of Nature) Red List of Threatened Species
226 (IUCN 2019).

227

228 3.3. Patterns of bird ownership across Java

229 We found considerable spatial variation across provinces and gradients of rurality in species composition
230 and abundance, overall taxonomic diversity and motivations for keeping birds (Table 2). The nine most
231 abundant taxa, including eleven species, were doves (Sunda Collared *Streptopelia bitorquata*, Zebra and
232 Eastern Spotted Dove *Spilopelia chinensis*), White-rumped Shama, Oriental Magpie-robin and white-eyes
233 (*Zosterops* spp.), Yellow-vented Bulbul (*Pycnonotus goiavier*), leafbirds (*Chloropsis* spp.), Javan Pied
234 Starling (*Gracupica jalla*), Sooty-headed Bulbul (*Pycnonotus aurigaster*) and Long-tailed Shrike (*Lanius*
235 *schach*) (Table 2). Captive breeding of birds was more common in the eastern provinces, while ownership
236 associated with singing contests was more common in the western provinces, and lower in rural areas than
237 in urban areas across all provinces. Estimated total species richness of birds kept was highest in Yogyakarta
238 and Jakarta. Jakarta had the highest levels of non-native bird ownership, but the locally threatened White-
239 rumped Shama, a highly prized favourite of singing competitions, was also especially common (Table 2).

240

241 3.4. Decadal changes in ownership

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

251

252 4. Discussion

253 Investigating the broad-scale patterns of the trade is crucial to understand the impact on species and the
254 ecological services they provide, and to inform interventions to reduce this impact either through demand
255 reduction (Olmedo et al., 2018; Veríssimo and Wan, 2018) or supply management (Jepson and Ladle, 2009;

256 Nijman et al., 2018). This study examined the spatial variability and temporal dynamics of consumer
257 demand in Java both to highlight the scale of the threat it poses to the regional avifauna and as an evidence
258 base that can inform future interventions aimed at increasing the sustainability of songbird-keeping in Java.

259 We estimate that some 66–83 million cage-birds are now kept in captivity on Java - one bird for
260 every two of the island's human population. While the majority of these birds are captive bred non-native
261 species, the projected number of native songbirds kept in some of Java's largest urban centres has more
262 than trebled over the last decade. Given that less than 12,000 km² of Java's forest remains (Prasetyo et al.,
263 2011) and that little of Java's non-forested land remains suitable for many bird species due to both intense
264 land-use management (Higginbottom et al., 2019) and bird-trapping (Ng et al., 2017; Nijman et al., 2018),
265 we suggest that the number of birds held in cages might approach or actually exceed the number of birds
266 left in the wild on the island. The scale of demand for cage-birds has pushed more than a dozen species to
267 the brink of extinction on Java and beyond (BirdLife International, 2019), and many species affected by
268 trade which were once common and widespread, such as Java Sparrow and White-rumped Shama, have
269 now become increasingly difficult to find (Eaton et al., 2015). Even so, despite significant drops in wild
270 bird populations (Harris et al., 2016; Sykes, 2017), bird ownership levels have increased over the past
271 decade.

272 There was significant variation in multiple bird ownership metrics both across provinces and between
273 urban and rural communities. Overall ownership was higher in Javanese-dominated eastern Java, where
274 both bird-breeding and the keeping of ornamental species such as Yellow-vented Bulbul were much more
275 common. In western Java, bird-keeping was more associated with singing contests, with species such as
276 White-rumped Shama and leafbirds more commonly kept. Even more striking were differences between
277 Java's rural populations and its urban centres. Urban communities were more likely to keep birds, and kept
278 a wider range of species, perhaps reflecting availability of species from Java and other Indonesian islands
279 in their large markets (Chng et al., 2015) and higher disposable incomes (UNESCO, 2017). They also kept
280 a higher proportion of non-native birds such as lovebirds and canaries, and were much more likely to enter
281 singing contests, which may be associated with the larger proportion of rural populations employed in low-
282 wage labour-intensive work than urban ones. Conservation interventions aimed at demand reduction or

283 other behavioural change will need to start with an appreciation of these differences (Challender et al.,
284 2014; Olmedo et al., 2018), focusing on the habits of hobby breeders in the eastern half of the island, and
285 the preferences of singing-contest enthusiasts in urban centres in the western half.

286 A major conservation concern is the decline in ownership of species such as Orange-headed Thrush,
287 Long-tailed Shrike, and some *Pycnonotus* and *Alophoixus* bulbuls. Whether ownership of these taxa has
288 declined more due to a reduction in availability through declines in wild populations, or something more
289 benign like simple trends in what is fashionable, requires investigation. Previous work found an increase in
290 ownership of *Geokichla* thrush species (including Orange-headed Thrush) between 1999 and 2006 (Jepson
291 and Ladle, 2009) due to their popularity in singing contests, and during the same period they appear to have
292 been trapped to local extinction across Java (Jepson, 2008). Regional trends in ownership of some of these
293 taxa raise the possibility that availability in the wild may be a key factor in predicting presence in captivity,
294 and that demand shifts to more highly abundant taxa when one source dries up (Eaton et al., 2015). These
295 trends highlight how understanding the popularity of species with individual bird-keepers will be key to
296 predicting which species may be targeted as substitutes in future.

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

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

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

338

339 **Supplementary data**

340 Supporting material can be found in three appendices: Appendix A - supporting tables and figures;
341 Appendix B – survey questions; Appendix C - full list of bird taxa reportedly owned.

342

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Tables

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	<i>Agapornis</i> spp.	-	386	2293	NN	33,479,000 (5,957,000)
2	Island Canary	<i>Serinus canaria</i>	-	253	675	NN	9,702,000 (2,467,000)
3	Dove spp.	<i>Streptopelia</i> / <i>Spilopelia</i> / <i>Geopelia</i> spp.	LC	223	824	CB	8,045,000 (1,272,000)
4	White-rumped Shama	<i>Kittacincla malabarica</i>	LC	133	294	CB	3,386,000 (707,000)
5	Budgerigar	<i>Melopsittacus undulatus</i>	-	34	209	NN	1,694,000 (788,000)
6	Oriental Magpie-robin	<i>Copsychus saularis</i>	LC	116	186	CB	2,457,000 (371,000)
7	White-eyes	<i>Zosterops</i> spp.	^c	83	174	WC	1,859,000 (427,000)
8	Yellow-vented Bulbul	<i>Pycnonotus goiavier</i>	LC	120	208	WC	1,644,000 (206,000)
9	leafbirds	<i>Chloropsis</i> spp.	^d	92	123	WC	1,596,000 (211,000)
10	Javan Pied Starling	<i>Gracupica jalla</i>	CR	85	125	CB	1,144,000 (143,000)
11	Sooty-headed Bulbul	<i>Pycnonotus aurigaster</i>	LC	55	75	WC	1,028,000 (170,000)
12	Long-tailed Shrike	<i>Lanius schach</i>	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), *Z. montanus* (LC), *Z. atricapilla* (LC), *Z. flavus* (VU), *Heleia javanica* (LC).

^d Leafbird species: *Chloropsis venusta* (NT), *C. sonnerati* (VU), *C. moluccensis* (LC), *C. cyanopogon* (NT).

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

Province	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.*	White-rumped Shama	Oriental Magpie-robin	White-eyes**	Yellow-vented Bulbul	Leafbirds***	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

* Dove species include Sunda Collared *Streptopelia bitorquata*, Zebra and Spotted Doves.

** White-eye species: *Zosterops palpebrosus* (LC), *Z. montanus* (LC), *Z. atricapilla* (LC), *Z. flavus* (VU), *Heleia javanica* (LC).

*** Leafbird species: *Chloropsis venusta* (NT), *C. sonnerati* (VU), *C. moluccensis* (LC), *C. cyanopogon* (NT).

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 native non-native	n	Keeping songbirds	Projected number of songbirds 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 9,177	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

Figure legends

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.

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.

Figures

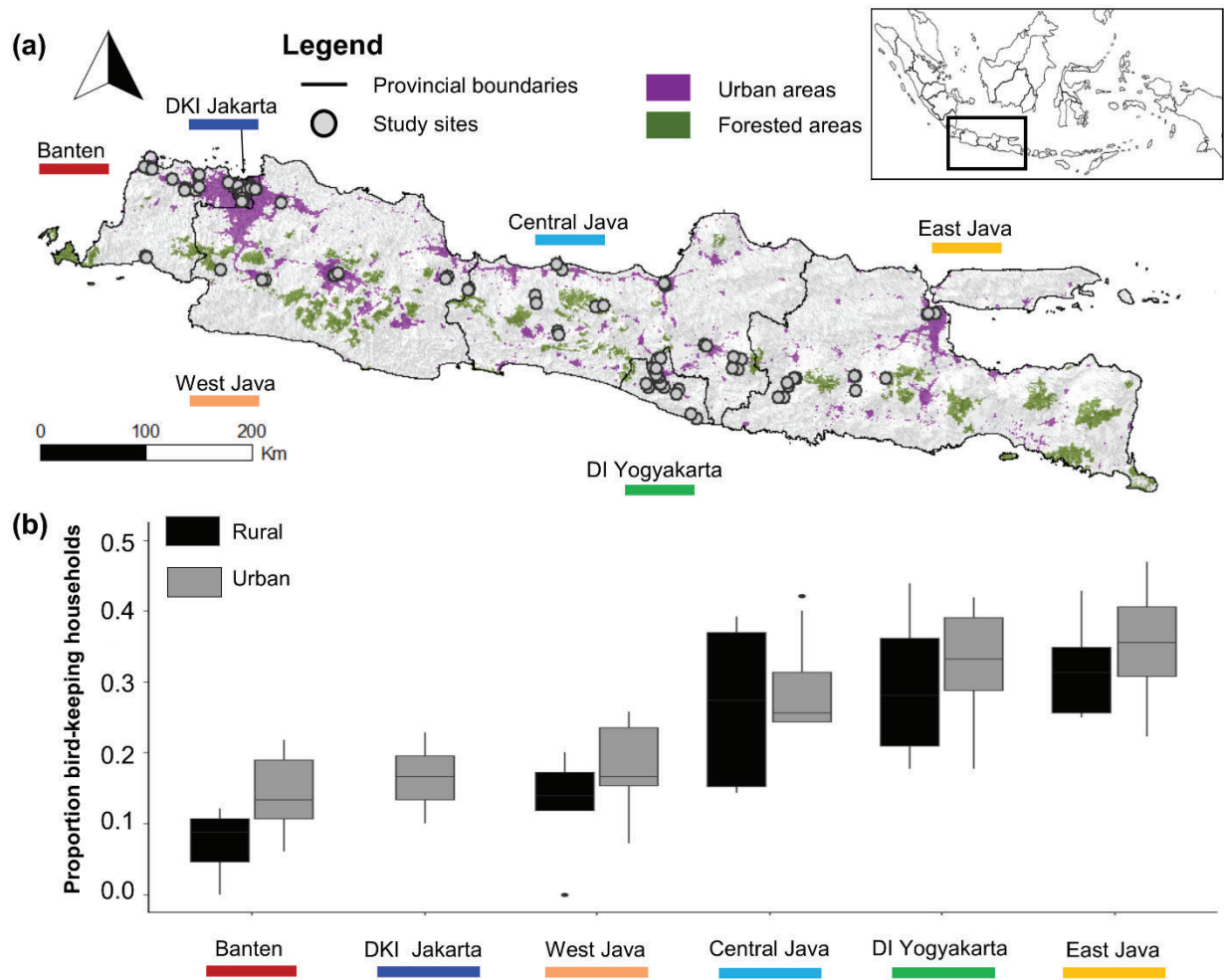


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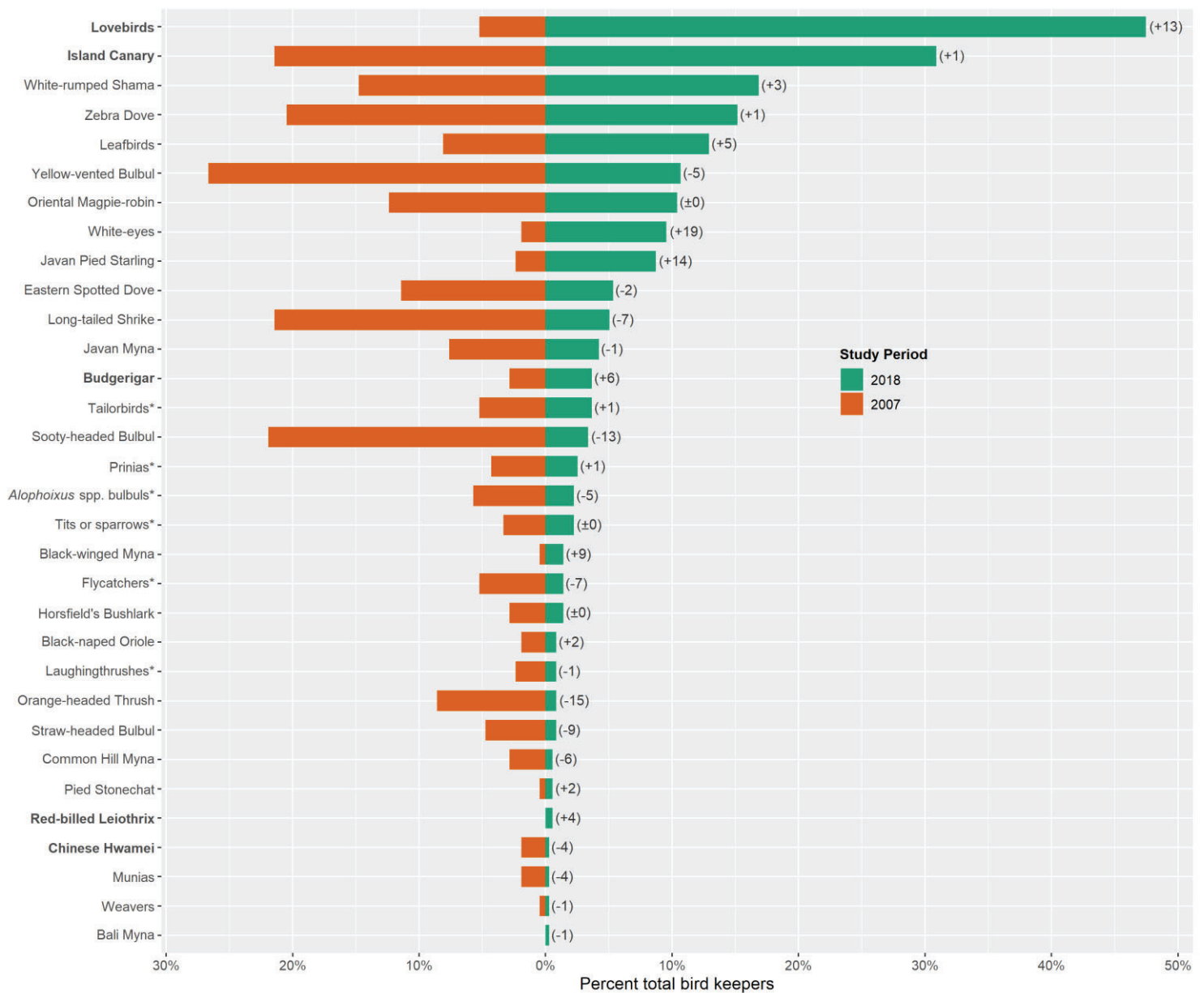


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