

# A distance sampling survey of the Critically Endangered Straw-headed Bulbul *Pycnonotus zeylanicus* in Singapore

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## Summary

The Straw-headed Bulbul *Pycnonotus zeylanicus* is one of South-East Asia's most threatened songbirds due to relentless demand for the regional cage-bird trade. The species was recently uplisted from 'Endangered' to 'Critically Endangered' only two years after its previous uplisting. Intriguingly, populations in highly urbanised Singapore appear relatively secure. However, the last Singaporean density estimates, derived from traditional census methods, were obtained nearly two decades ago in 2001. A recent population estimate in 2016 was derived from the census work in 2001 coupled with relative abundance indices from population trends. We thus performed systematic field surveys using the distance sampling method, estimating  $573 \pm 185$  individuals nationwide, with a break-down of  $217 \pm 81$  on the main island of Singapore and  $356 \pm 104$  birds on the satellite of Pulau Ubin. Taken together, the total population estimate reported here comprises 22.9–57.3% of the global wild population, underscoring the importance of Singapore as a stronghold for the species. In spite of its apparently secure status in Singapore, the species remains susceptible to local and foreign trapping pressures. Based on our assessment, we propose a number of local and regional conservation measures to ensure the continued survival of populations in Singapore.

**Keywords:** songbird crisis, population assessment, South-East Asia, passerine, point count

## Introduction

South-East Asia is known to be a region rich in biodiversity (Myers *et al.* 2000, Myers 2003, Mittermeier *et al.* 2004). However, it is also known for one of the highest rates of faunal extirpations and forest loss (Sodhi *et al.* 2004, 2010, Barlow *et al.* 2018). Overexploitation of biodiversity for the wildlife trade is thought to be one of the main drivers for species loss (Nijman 2010, Maxwell *et al.* 2016, Symes *et al.* 2019). The caged bird trade in particular has received increased scientific and governmental attention in recent years due to its role in the endangerment and extinction of multiple avian species (Eaton *et al.* 2015).

Listed as 'Critically Endangered' on the IUCN Red List, the Straw-headed Bulbul *Pycnonotus zeylanicus* (Figure 1) is a highly sought-after songbird that is trapped chiefly for its distinct and



Figure 1. A Straw-headed Bulbul *Pycnonotus zeylanicus* in Singapore (Photo by: WXC).

melodious song (Shepherd *et al.* 2013, Chng *et al.* 2016, Yong *et al.* 2017). Relentless trapping throughout its range has led to severe population declines (Eaton *et al.* 2015, Harris *et al.* 2017, Bergin *et al.* 2018) that are thought to have exceeded 80% in the last three generations (BirdLife International 2018). As a result of these declines, the species was expeditiously uplisted from 'Endangered' to 'Critically Endangered' in 2018 within a short span of two years after having been uplisted from 'Vulnerable' to 'Endangered' in 2016 on the IUCN Red List.

The Straw-headed Bulbul is a Sundaic lowland species that was formerly common throughout South-East Asia (BirdLife International 2001, Wells 2006, Robson 2015, Eaton *et al.* 2016) but has since experienced range-wide extirpations and can scarcely be found in the wild now (Nash 1993, Eaton *et al.* 2015). The species is thought to be long extirpated from Thailand (Wells 2006, Fishpool *et al.* 2018), and is most certainly extinct on Java (van Balen 1999), with populations in Sumatra likely to follow suit (Eaton *et al.* 2015). In Kalimantan (Borneo), records of the species have been increasingly scarce since the mid-1990s, with site-level extirpations recorded at various sites (Brickle *et al.* 2010, Fischer *et al.* 2016). This reduction in distribution is echoed by concomitant increases in market price recorded in recent years (Shepherd *et al.* 2013, Chng *et al.* 2015, Eaton *et al.* 2015, Harris *et al.* 2015, Bergin *et al.* 2018, Rentschlar *et al.* 2018). Rising market values persist to the present day, with sale prices going as high as USD\$700 per individual in Sumatra (see Chng *et al.* 2018). Remaining populations on Borneo are highly sought after by trappers, who are cognisant of the species' increasing rarity and market price (Fischer *et al.* 2016, Rentschlar *et al.* 2018), and populations in Peninsular Malaysia face imminent extirpation if mitigation measures are not taken (Eaton *et al.* 2015).

In stark contrast to population reductions faced in the rest of the species' range, populations in tiny Singapore appear stable, secure, and in recent years even on the increase (Yong *et al.* 2017). The species was assessed as nationally endangered more than a decade ago in the 2008 Singapore Red Data assessment (Davison *et al.* 2008). Across Singapore, the species is known to inhabit the

edge of secondary and fragmented forests (Lim and Lim 2009, Robson 2015). Despite the global importance of the Singaporean population for the species' survival, there exists a dearth of published up-to-date information on its national population numbers and status.

Thus far, population assessments of the species have been conducted across Singapore using three approaches: (1) "look-see" quadrat counts with playback across forest patches on the main island of Singapore in 2001 (Tan 2001), (2) standardised counts and pair mapping on the offshore satellite of Pulau Ubin in 2001 (Ho 2001), and (3) a recent study (Yong *et al.* 2017) reporting modelled population estimates of the species in 2016 based on unpublished historical estimates from 2001 (Ho 2001, Tan 2001) and multi-year citizen science data (time-series count data) from 2001 to 2015 (e.g. Lim 2009, 2016, Lim and Lim 2009, Lim and Yong 2013). However, an assessment of the population in Singapore involving a systematic approach has yet to be implemented.

Distance sampling is employed extensively as a reliable approach to abundance estimation in highly heterogeneous environments (Ruelle *et al.* 2003, Camp *et al.* 2009, Quinten *et al.* 2010, Subedi *et al.* 2018, Bombaci and Pejchar 2019). It is capable of producing population density estimates without the need for complete detection (Buckland *et al.* 2001). Studies involving highly-threatened avian species like the 'Critically Endangered' Grenada Dove *Leptotila wellsi* (Rivera *et al.* 2015), Azores Bullfinch *Pyrrhula murina* (Ceia *et al.* 2011) and Citron-crested Cockatoo *Cacatua citrinocristata* (Cahill *et al.* 2006) are textbook examples of the use of distance sampling to monitor populations. Here we report on population estimates of the Straw-headed Bulbul in Singapore obtained via a point count distance sampling approach. Based on distance sampling results, and given the Singaporean population's global importance, we then propose appropriate local and regional conservation actions that will hopefully safeguard the survival of the species in the wild.

## Methods

### Study area

The Republic of Singapore is an equatorial island city-state situated at the tip of the Malay Peninsula, approximately 137 km from the equator (Figure 2). The study was conducted on the main island of Singapore (hereafter Singapore Island; 103°8'E, 1°29'N) and on one of its nearby offshore satellites, Pulau Ubin (103°8'E, 1°41'N). Singapore Island and Pulau Ubin have a total land area of 72,420 ha (Singapore Land Authority 2018) and 1,019 ha, respectively (National Parks Board 2018).

Having undergone extensive urbanisation, over 95% of the original forest cover of Singapore was cleared for agriculture and urban development up until the 1980s (Corlett, 1992). Nevertheless, substantial tracts of secondary forests persist (Lim 2009, Yee *et al.* 2011, Gaw *et al.* 2019), most notably on the western end (also known as the Western Catchment), which is reserved for water catchments and military use. The largest tract of remnant forest is situated in the centre of Singapore, most of which is protected within Bukit Timah and Central Catchment nature reserves. This forest tract houses remnant patches of older lowland dipterocarp and freshwater swamp forests within a matrix of younger secondary forests. Of the country's 60 satellite islands, Pulau Ubin (1,019 ha) and Tekong Besar (2,440 ha) are the two largest (Figure 2). The former is designated as a recreational site, while the latter is reserved exclusively for military activities. Both islands have low levels of development and consist mostly of secondary and mangrove forests, along with regrown plantations (Ho 2001, Lim 2009).

### Survey design

Fieldwork was conducted on both Singapore Island and Pulau Ubin over a six-month period, between August 2018 and January 2019. The Straw-headed Bulbul is thought to breed throughout

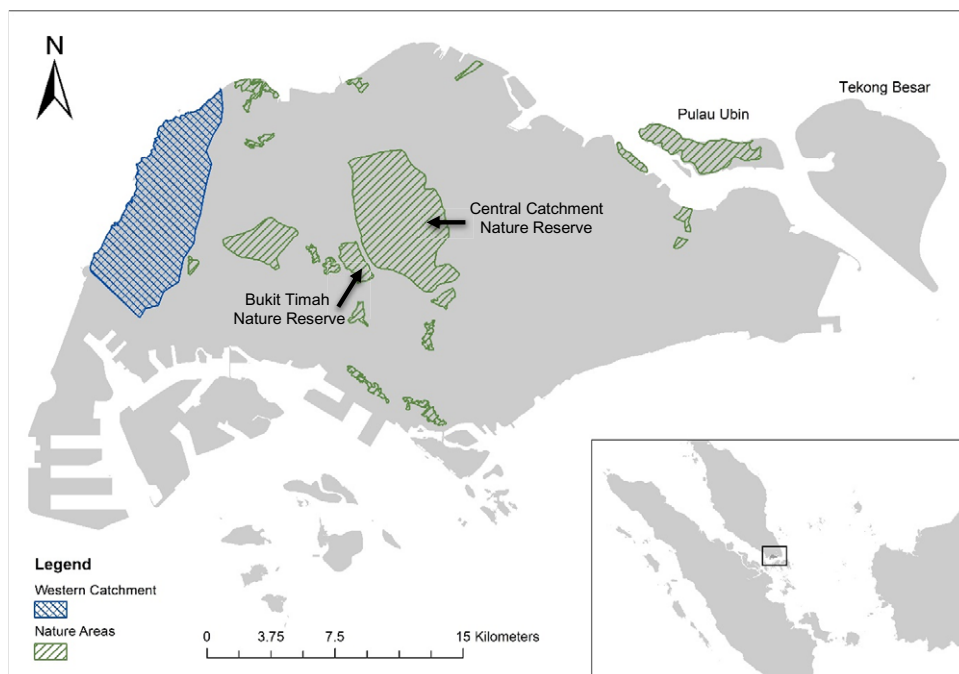


Figure 2. Map of Singapore and its offshore islands, with surveyed areas demarcated, and an inset of the Southeast Asia region. The cross-hatched area represents the Western Catchment forest, which was inaccessible, and thus not surveyed during the study. Diagonally hatched areas indicate accessible nature areas that were identified and surveyed during this study.

the year and is thus vocal year-round (Fishpool *et al.* 2018). We assumed a closed population, which is reasonable given a lack of recent field records in the neighbouring state of Johor (Peninsular Malaysia) (Chiok *et al.* 2019). The species is noted to be tolerant to human disturbance (Fishpool *et al.* 2018) and has been observed to inhabit a range of environments across Singapore, from parks to secondary forest (Chng *et al.* 2016). Previous mapping attempts of its Singaporean distribution (Ho 2001, Tan 2001, Lim and Lim 2009, Yong *et al.* 2017) allowed us to survey suitable habitats for known and potential populations, so as to obtain accurate population estimates.

Potential survey sites were demarcated using ArcGIS Desktop ver. 10.4 (ESRI 2015), with reference to Google Earth satellite imagery (Google Earth Pro ver. 7.3.2.; Google 2018) and Singapore's landscape classification information (Yee *et al.* 2011, 2016). Suitable survey sites (hereafter referred to as 'nature areas') were selected based on the following criteria due to logistical, time and accessibility constraints: 1. Nature area of at least 35 ha; 2. At least 10 ha of contiguous (unbroken) forest present within the nature area.

The above criteria narrowed our selection of nature areas to a list of locations thought to be suitable for the Straw-headed Bulbul. Areas with extensive urban development, such as residential housing, industrial and commercial zones were eliminated, leaving localities with forests patches and forest edges. All accessible localities were surveyed in the aforementioned areas (Figure 2). The Western Catchment forest patch (Figure 2) is reserved for military use was not accessible during this study.

A regular 600 x 600 m grid pattern was overlaid on the map of Singapore (Government of Singapore 2017). Nature areas were then intersected with the grid to obtain the final selection of areas to be surveyed. In total, 151 plots (of 36 ha grids) were demarcated on Singapore Island and

25 plots on Pulau Ubin. We subsequently surveyed a subset of the nature areas identified. To ensure adequate representation of nature areas, the number of plots sampled per nature area was proportional to its size, accessibility and time constraints permitting. Nature areas of at least 35 ha would thus constitute one sampling plot, while those larger in size would have proportionately more plots that were randomly sampled (see Figure 3). For instance, Pulau Ubin, with a total size of 1,019 ha, had seven out of its 25 plots surveyed.

A total of 51 plots (44 out of 151 on Singapore Island, and seven out of 25 on Pulau Ubin) were surveyed. Eight survey points were placed at random within each of the selected plots. Plots and survey points were surveyed at random to avoid any bias that may arise through the sequential surveying of adjacent plots. Ground-truthing was conducted on-site for all survey points, and points situated in inaccessible or restricted areas were adjusted to the nearest accessible location. The survey effort amounted to 408 points, whereby each point was visited once (352 points on Singapore Island and 56 points on Pulau Ubin), amounting to approximately 68 survey hours.

In this study, we share the same concerns about trapping as outlined by previous authors (Shepherd *et al.* 2013, Chng *et al.* 2016, Yong *et al.* 2017), and therefore do not present exact locality and presence information (i.e. names of locations surveyed) pertaining to the species.

### Distance sampling protocol

We employed a point count distance sampling survey technique (Bibby *et al.* 2000, Buckland *et al.* 2001, 2012), where a single observer (WXC) conducted all the point counts, thereby reducing

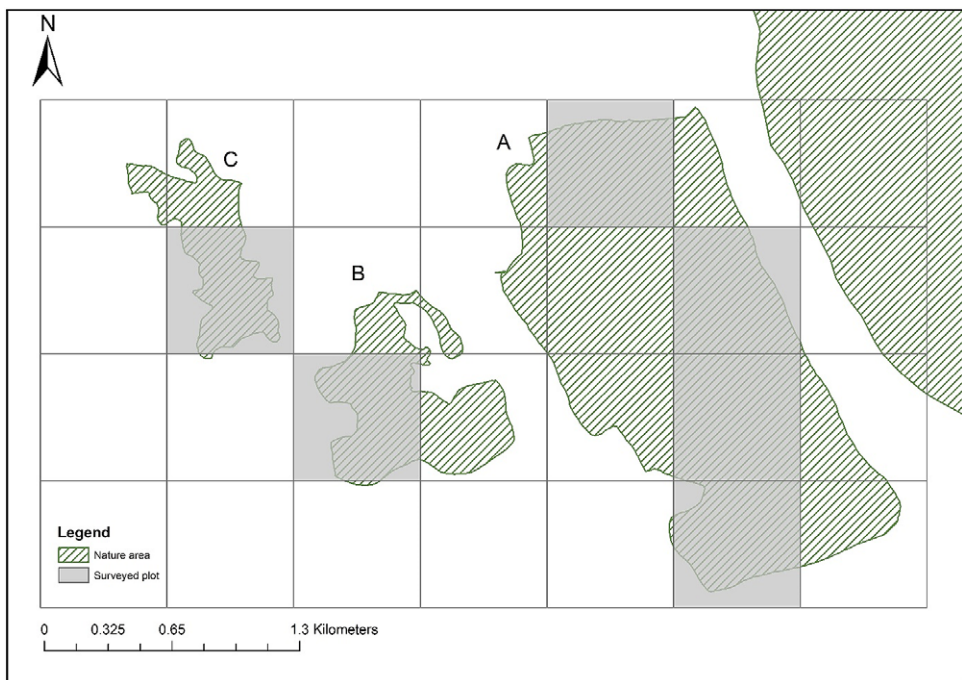


Figure 3. Map showing the 600 × 600 m grid overlaid on demarcated nature areas, with greyed areas indicating number of plots surveyed per nature area. (A) Nature area of c.276 ha with four plots surveyed. (B) Nature area of c.54 ha with one plot surveyed. (C) Nature area of c.36 ha with one plot surveyed. Surveyed plots are shown for illustration purposes and may not be the actual location.

observer bias (Farmer *et al.* 2012). A GPS unit (GARMIN GPSMAP 64S) was used to verify and locate the randomly placed points. A pair of 10 x 42 binoculars (Nikon Monarch 3) and a laser rangefinder ( $\pm 1$  m error; Nikon Forestry Pro) were used to facilitate accurate distance measurements. Point counts were conducted in non-rainy weather, either in the morning (07h00–10h30) or afternoon (16h00–19h30 hours). A settling-in period was not implemented prior to point counts (Lee and Marsden 2008). The survey duration of 10 minutes for each point count was deemed to heighten chances of detecting calling individuals visually. Fly-bys or moving individuals were excluded from the data unless their original (stationary) locations could be determined during or after the point count (Bibby *et al.* 2000).

Distance measurements larger than 300 m were truncated to eliminate outliers that provide little information for estimates of density functions (Buckland *et al.* 2001). Measurements were continuous and binned into intervals of 25 m, from 0 to 300 m.

### Population estimates

All statistical analyses were carried out using the statistical software R ver. 3.5.2 (R Core Team 2018). Population density and abundance were estimated using the distance sampling function *distsamp* within the *unmarked* R package (Fiske and Chandler 2011). Data for Singapore Island and Pulau Ubin were analysed separately based on Pulau Ubin's status as an offshore satellite, and its lack of significant urban development compared to highly urbanised Singapore Island. We did not conduct post-stratification of habitats as the majority of areas surveyed on both islands consisted of secondary forest.

Four detection functions (half-normal, uniform, hazard rate and negative exponential) were fitted to respective models for Singapore Island and Pulau Ubin. The hazard-rate detection function was found to be the most suitable for both islands, based on Akaike Information Criteria (AIC) values (Akaike 1973, Buckland 2001). Based on the top-ranked model according to the AIC, density estimates for each island were computed. These density estimates were subsequently extrapolated to obtain population estimates across the demarcated nature areas (Figure 2) in Singapore Island (151 plots totalling 5,436 ha) and Pulau Ubin (25 plots totalling 900 ha), respectively. Population estimates for the Straw-headed Bulbul are reported with  $\pm$  standard errors (SE).

## Results

The surveyed plots covered a total of 1,584 ha on Singapore Island and 252 ha on Pulau Ubin. In general, Pulau Ubin had both a higher encounter rate and a higher density estimate than Singapore Island. In total 36 detections were made within 300 m point count centres across 352 points on Singapore Island, with another 35 detections across 56 survey points located on Pulau Ubin (Figure S1 in the online supplementary material). Density estimates were  $0.0400 \pm 0.0149$  and  $0.396 \pm 0.116$  per hectare for Singapore Island and Pulau Ubin, respectively. Extrapolated population estimates for the Straw-headed Bulbul were  $217 \pm 81$  birds for Singapore Island, and  $356 \pm 104$  for Pulau Ubin (Table 1). Overall, we consider these estimates to be conservative due to the inability to survey restricted areas that may harbour populations of the species. Most notably, the Western Catchment forest patch (c.3,250 ha; Figure 2) is known to harbour populations of Straw-headed Bulbul (Lim 2009, Yong *et al.* 2017).

## Discussion

Our implementation of distance sampling has allowed for a rigorous assessment of Straw-headed Bulbul population size in Singapore, putting the total estimate at over 500 individuals. The use of distance sampling permitted the computation of density estimates without the need to calculate abundance and area, nor the detection of all individuals within the area. That said, the study area

Table 1. Current and historical population estimates for the Straw-headed Bulbul on Singapore Island and Pulau Ubin; as well as their proportion compared to global estimates by the IUCN Red List.

Site	Estimated population number		
	2001 (Ho 2001, Tan 2001)	2016 (Yong et al. 2017)	2019 (current study)
Pulau Ubin	64.0	110.2	356 ± 104
Singapore Island	84.6 ± 8.15	91.9	217 ± 81
Republic of Singapore*	148.6	202.1	573 ± 185
IUCN Threat Status			
Global estimates according to IUCN Red List	Vulnerable 15,000–30,000	Endangered 1,000–2,499	Critically Endangered 1,000–2,499
Singapore population's percentage of global population (%)	0.5–1.0	8.1–20.2	22.9–57.3

\* Estimates here exclude inaccessible areas such as military sites and state land (e.g. Western Catchment; refer to Fig. 1), which were not surveyed in this study.

and methodologies of previous studies (Ho 2001, Tan 2001, Yong *et al.* 2017) have differed greatly, meaning that estimates are not directly comparable.

### Population estimates in Singapore and its implications

Our estimate of 573 ± 185 birds was greater in number than the estimate of 202 in 2016 by Yong *et al.* (2017), providing updated baseline estimates for the species in Singapore. The stark contrast in estimates (Table 1) could be explained by the use of different methodologies. Estimates reported by Yong *et al.* (2017) were obtained via estimates derived from traditional census methods (Ho 2001, Tan 2001), which had been subject to inadequate detection and imprecision (Gregory *et al.* 2004).

Distance sampling, as implemented in this study, accounts for variations in detection with the use of fitted detection probabilities, at the same time allowing for population densities to be computed without the need for complete detections (Buckland *et al.* 2001). Distance sampling has its limitations: its effective implementation crucially relies on the fulfilment of multiple core assumptions (Marsden 1999, Barraclough 2000, Bart *et al.* 2004, Lanctot *et al.* 2008), all of which were met during the implementation of this research. For instance, our number of total detections was well within the recommended threshold of reliability for distance sampling results, and the use of a range finder ensured accurate distance measurements.

Taken together, the total population estimate of 573 ± 185 Straw-headed Bubluls comprises 22.9–57.3% of the global population based on the current estimate of 1,000–2,499 individuals (BirdLife International 2018). Differences in methodologies aside, our results echo those of Yong *et al.* (2017), underscoring the importance of Singapore's population as a global stronghold (Table 1) against the backdrop of the species' extirpation across most of its Sundaic range (Eaton *et al.* 2015).

Trade-driven declines of South-East Asian songbird populations have received greater recent attention (Duckworth *et al.* 2012, Eaton *et al.* 2015, Harris *et al.* 2015, Chng *et al.* 2018, Leupen *et al.* 2018, Rentschlar *et al.* 2018). The need for accurate population estimates to facilitate the implementation of conservation plans has been emphasised widely (Lee *et al.* 2016, Harris *et al.* 2017), as they constitute one of the cornerstones for IUCN Red List assessments (IUCN 2001). Not only do up-to-date baseline estimates provide information for status assessments of the species locally, they also allow for changes in population size to be monitored—permitting the evaluation of potential impacts of habitat loss and trade activity (Buckland *et al.* 2008).

### Conservation implications

Our field surveys indicated a population size for the Critically Endangered Straw-headed Bulbul in Singapore in excess of 500 individuals. This population size may be comparable to the national population size of the entire Republic of Indonesia, given steep population declines there and in neighbouring Malaysia (Chiok *et al.* 2019). While the Straw-headed Bulbul population in Singapore appears to be secure (Table 1), its local presence should not be taken for granted. The increasing importance of Singapore's population warrants enhanced conservation efforts. As such, pre-emptive measures should be taken to address the likely trade shifts that are imminent with the decline of the species across most of its range. In light of the threats faced by the Straw-headed Bulbul, we propose the following recommendations (without reiterating those made by Yong *et al.* 2017) to enhance chances for the long-term survival of this species in the wild:

1. We call for the input of increased resources to support the national Singapore working group of Straw-headed Bulbul conservation that has recently been founded by relevant stakeholders (see Sin *et al.* 2019) to develop a species action plan with the aim to ensure the continued survival of the Straw-headed Bulbul in Singapore. A species-specific monitoring plan (e.g. using distance sampling)—ideally including the survey of restricted areas such as the Western Catchment—should be implemented to obtain improved population estimates of the Straw-headed Bulbul in Singapore. Alternatively, point count data from existing localities (established via citizen science efforts) could also be used to conduct an occupancy analysis for the species.
2. Enhanced regulations and enforcement across Singapore, including legislative improvements, are urgently needed. It has been noted that there is room for improvement in current wildlife protection laws in Singapore (Tan 2017, Hong 2018, Quek 2018, Sim 2018). The illegal trapping of Straw-headed Bulbuls continues to occur locally on both Singapore Island and Pulau Ubin, and the species is sold in local pet shops and online marketplaces (Eaton *et al.* 2017, Chiok 2019). Therefore, while current surveillance and enforcement efforts have kept local populations safe, it is recommended that the authorities continue to be vigilant of poachers. Regular and frequent ranger patrols have been shown to be an effective form of deterrence for trappers, and if implemented here, could further enhance the protection of the Straw-headed Bulbul and Singapore's biodiversity (Hilborn *et al.* 2006, Challender *et al.* 2014, Cooney *et al.* 2017).

There is also a need for continued and active monitoring of both physical and online shops in Singapore. Such monitoring efforts are established methods, where both physical (Nash 1993, Chng *et al.* 2015, 2018, Eaton *et al.* 2017, Bergin *et al.* 2018, Rentschlar *et al.* 2018) and online surveillance (Krishnasamy and Stoner 2016, Indenbaum 2018, Martin *et al.* 2018, Phassaradomsak and Krishnasamy 2018, Sy 2018) have provided insights that would otherwise be overlooked, particularly for non-CITES listed species (Janssen and Shepherd 2018, Janssen and Leupen 2019). Regular monitoring provides data on trade volumes and price fluctuations, which can be proxy indicators of a species' threat status in the wild (Harris *et al.* 2015, Shepherd *et al.* 2016, Sung and Fung 2018, Nijman *et al.* 2018).

3. In spite of its Critically Endangered status, the Straw-headed Bulbul is currently listed on Appendix II in the CITES appendices. With Singapore being the global stronghold for the species and a global hub for the wildlife trade, we advocate for the Straw-headed Bulbul to be uplisted to Appendix I of CITES. Appendix I-listed species would be subject to stringent regulations, where any import or export of the species require the provision of documents certifying that the bird was acquired through legal means. This would improve traceability and accountability with regard to the trade of the species. Moreover, international trade bans resulting from CITES Appendix listings have been shown to exert positive effects on species protection within gazetted protected areas (Hilborn *et al.* 2006).



### Future research

Further research focusing on the genomics of Straw-headed Bulbul populations in Singapore should be also conducted (e.g. Tang *et al.* 2016, Ng *et al.* 2017). It would be pertinent to assess if there is sufficient genetic diversity to sustain local populations in the long term.

### Supplementary Materials

To view supplementary material for this article, please visit <http://dx.doi.org/10.1017/S095927092000060X>.

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