Wildlife trade and the establishment of invasive alien species in Indonesia: management, policy, and regulation of the commercial sale of songbirds

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Abstract In Southeast Asia, mynas (genus Acridotheres) are amongst the most invasive bird species. Information is largely lacking as to where they have established themselves. The spread of invasive, non-native mynas is partially or largely driven by the massive trade in these species as songbirds. While preventing unintentional introductions early is the most effective management option, these species continue to be traded in bird markets throughout the region. We focus on the trade of native and non-native species of mynas, and the establishment of non-native mynas on the Indonesian islands of Java, Bali, and Lombok.

Between 2016 and 2019, through field surveys and use of citizen science data (e.g., Burungnesia, iNaturalist, birding reports), we assessed where non-native mynas have been recorded in the wild on these three islands; through bird market surveys we established in which cities these birds are traded. We recorded common myna in Yogyakarta, one of our three survey areas. Combining all records, the areas where alien invasive mynas are established are Greater Jakarta (common and jungle myna), Yogyakarta (common myna), Bali (common and bank myna) and Lombok (common and Javan myna). Two-thirds of the records come from farmlands, home gardens and urbanised areas. In the bird markets, we recorded ~23,000 mynas of five species for sale, with Greater Jakarta, Bali and Lombok standing out as areas with high numbers of potentially invasive alien species offered for sale. Restrictions on the sale of wild-caught birds are not adhered to. Well-intended policies concerning the breeding and sale of legally protected species, whereby 10% of the stock is bred to be released in the wild, exacerbate the risk of the establishment of non-native species. We surmise that one of the most effective ways to reduce the risk of the accidental or deliberate release of potentially invasive alien mynas (and indeed other birds) into the wild is for governments and conservationists to work more closely with the retailers who hold the key to informing and educating consumers.
Introduction

Policies aimed at eradicating invasive alien species can be extremely costly, are often effective only in isolated areas or in the early stages of invasion and may negatively impact other species in the ecological community (Carrete and Tella 2008). Preventing unintentional introductions by recognizing potential invaders early is therefore likely to be a more effective management option (Kolar and Lodge 2001; Edelaar and Tella 2012; Reaser et al. 2020). With respect to birds, amongst the best studied taxa in invasive biology, it has been argued and demonstrated empirically, that in terms of effective management, proposals to ban the trade in wild-caught birds could help the spread of invasions already underway and to prevent future ones (Carrete and Tella 2008). Wildlife trade, both legal and illegal, has facilitated the introduction of species to new regions, where they compete with native species for resources, may destroy crops and damage infrastructure such as dams and ultimately may alter whole ecosystems (Pyšek et al. 2020). The international trade in wildlife has intensified in recent decades (Symes et al. 2018) and this is especially true for the trade in birds in Southeast Asia (Shepherd 2006; Leupen et al. 2020). While much of the focus on the trade in birds is on the negative effects trade has on populations of imperilled species (Van Balen and Nijman 2004; Eaton et al. 2015; Harris et al. 2017; Nijman et al. 2018), several studies explicitly addressed how this trade facilitates the introduction of invasive alien species (Blackburn et al. 2009; Iqbal et al. 2014; Jackson et al. 2015; Reino et al. 2017; Vall-llosera and Cassey 2017; Souviron-Priego et al. 2018; Lockwood et al. 2019; Du et al. 2022), many of which are of less conservation concern.

When considering the potential for successful alien species invasion, i.e., long-term establishment, it is important to consider not only the biological characteristics of the alien species but also the environmental conditions of the area where it may become established. Large parts of Southeast Asia offer excellent conditions for invasive alien bird species to establish themselves: (1) habitats are anthropogenically disturbed (e.g., Van Balen 1988); (2) with many species having allopatric distributions, climate matches closely with the original habitat of the potentially alien species; (3) because of extirpation, extinction, or excessive trapping species diversity is lowered thus creating vacancies for potential invasive alien species. Finally, the likelihood of successful establishment of an invasive alien species almost certainly is linked in part to the introduction effort (i.e., the number of releases or individuals released at each location) (Blackburn and Duncan 2001; Du et al. 2022). *Ceteris paribus*, those species that are traded in larger numbers outside their native range, will result in a larger introduction effort, either through deliberate releases or through accidental escapes.

The common myna *Acridotheres tristis*, a songbird that ranges in Asia including mainland Southeast Asia and that has been introduced in many parts of the world, is one of three bird species included on the list of ‘100 most invasive species’ (Lowe et al. 2000). Yap and Sodhi (2004) recognised two additional species of myna as among the 16 most invasive bird species in South-east Asia. The first of these is the Javan myna *A. javanicus*, a species native to the Indonesian islands of Java and Bali that has been introduced via the cage bird trade into Singapore and from there expanded into West Malaysia (Arazmi et al. 2022). The second is the crested myna *A. cristatellus* from China and Indochina that has been introduced into West Malaysia and the northern Philippines, partially as a biological pest control but also through the cage bird trade. Mynas in general have high reproductive rates and relative short generation times. They are long-lived and have high dispersal rates; within their native range they occupy a broad niche (habitat, diet, nest site selection) (Eaton et al. 2016).

The trade in birds in Indonesia is heavily regulated, at least on paper (Nijman et al. 2018, 2021a, 2021b). Over 100 native species are listed as protected under government regulation No 20/MenLHK/SetJen/Kum.1/6/2018 and wild-caught individuals cannot be legally traded (Apriyani et al. 2018). These include black-winged, grey-backed and grey-rumped myna (here considered one species, see below). Second generation captive-bred offspring of these protected species can be traded but only when accompanied by appropriate paperwork (Nijman et al. 2018). Wild-caught individuals of other native species can only be harvested (and traded) in limited numbers from specific regions (e.g., provinces), which are determined...
annually at a meeting organised by the Ministry of Forestry. For mynas, the 2019 quotas were: 4500 Javan myna from Sumatra (provinces of Jambi, Riau and North Sumatra only), 100 Javan myna from Kalimantan (province of South Kalimantan only), and 3900 common myna A. tristis from Sumatra (Jambi, Riau and North Sumatra only). For any of the other mynas that occur in Indonesia there are no capture quotas. To the best of our knowledge, there are no provisions in the law to prevent or restrict the import and sale of non-native mynas.

We here aim to report on the trade in eight species of myna on the Indonesian islands of Java, Bali, and Lombok, with two species being native to two or three of these islands and six species that are non-native to this region. We assess which of these species, if any, have been observed in the wild on these islands, how many are observed within their native range and how many outside, and we discuss the policies that Indonesia has in place for preventing or minimising the risk of the establishment of potentially invasive alien species.

Methods

Evidence of invasive mynas on Java, Bali and Lombok

Six species of myna are listed on the Global Register of Introduced and Invasive Species (www.griis.org), including the three singled out by Yap and Sodhi (2004); none of them is listed as being introduced or as invasive in Indonesia. Combining this information with records of mynas in trade within our study region (e.g., Basuni and Setiyani 1989; Bell and Seibels 1990; Chng and Eaton 2015; Iqbal 2015; Chng et al. 2018; Nijman et al. 2021a) we focussed on black-winged myna A. melanopterus (native to the entire study region), Javan myna (non-native to Lombok), crested myna, common myna, great myna A. grandis, bank myna A. ginginianus, jungle myna A. fuscus and pale-bellied myna A. cinereus (all non-native to the entire study region). Following Sadananandan et al. (2020) we now consider grey-backed myna A. tertius and grey-rumped myna A. tricolor to be black-winged mynas (contra Nijman et al. 2021a).

To establish whether any of these mynas had indeed been recorded in Java, Bali, and Lombok outside their native range, we conducted observations at three sites on Java and obtained data from the Burungnesia app. (Winnasis et al. 2018; Squires et al. 2021), the Handbook of Birds of the World (HBW) Alife website (www.hbw.com), iNaturalist (www.org), and online birding reports. The three field sites where we made observations over the three years (August 2016 to June 2019) were in the Garut regency in West Java (mostly in upland regions), Tenanggung regency in Central Java (mostly in lowland regions) and Sleman regency in the special district of Yogyakarta (mostly in urban regions). Burungnesia is a free app that allows bird-watchers and ornithologists to identify and upload information on and photographs of birds they observe in the field; these uploads are accompanied by locality data (latitude, longitude) and habitat data (Winnasis et al. 2018). For each species the HBW life website, a global map displays aggregated data of recordings from online websites (Caretto 2014); while the map does not display exact localities (because of sensitivity of these data for some of the rarer species) for the purpose of this study it presents data at a high enough resolution. iNaturalist gives geographic details and ranks the observation in terms of quality (“Research Grade”) (Van Horn et al. 2018); we only included those that were approved. We consulted 20 online bird reports for one, two or three of the islands, and searched for records of mynas (often named starlings) outside their native range. When available, data on the type of habitat in which the birds were observed were recorded. Given that the records in Burungnesia, HBW Life, iNaturalist and birding reports are unlikely to be independent, we pooled data from these four sources to obtain an overall picture of invasiveness.

Commercial captive breeding facilities

In 2018, we visited several facilities in Klaten and Yogyakarta, both in the central part of Java, which breed mynas and other starlings for the songbird trade (Nijman et al. 2021b), including those facilities that breed legally protected species. We observed what species were kept, and which ones were bred commercially. With the owners and employees, we discussed the policies and practicalities of the trade in
myenas, including the policy of the mandatory release of 10% of the offspring of legally protected species. Note that at the time of the visit, the black-winged myenas were considered three separate legally protected species, and each would qualify for the 10% release rule.

Bird market surveys

We surveyed bird markets on Java, Bali and Lombok, Indonesia, for a total of 172 times, from August 2016 to June 2019. The first author has visited these bird markets repeatedly since the early-1990s and is familiar with their layout, characteristics, and trade dynamics, allowing us to include a representative sample. Bird markets are open to the public without the need for entry tickets or other controls. Most of them are open every day from early morning to early evening, but some are only open on specific days of the 5-day Javanese calendar (e.g., Wage, Pon). Traders offer a wide range of wild bird species for sale, including native species that can be traded in limited numbers, native species that are legally protected and can only be traded when specific conditions are met, and non-native species that were imported into the country or that were bred in captivity. We have surveyed many of these bird markets (Shepherd et al. 2020; Nijman et al. 2021a,b) and here we focus on a relatively small number of bird markets (14) that were surveyed intensively over this period (at least five times, but on average more than twelve times). For each bird market, surveyors visited each individual stall of shop and recorded the species and the number of individuals for sale. A survey could last from around two hours for some of the smallest bird markets (e.g., Mawar in Garut) to a full day for the largest (e.g., Pramuka in Jakarta). Prices were obtained by requesting them from traders and by observing myenas being sold in the bird markets. All were quoted in Indonesian Rupiah. We did not purchase any birds or other wildlife.

Analysis

For analysis we only included surveys that were at least a month apart. We anticipated that myenas observed in the various bird markets are different individuals. Hence, we take it that birds do not move between shops, between markets or between cities; no birds were returned to the market and offered for resale; and all were sold within one month (c.f. Nijman et al. 2018).

Prices, in Indonesian rupiah, were corrected for inflation based on the Consumer Price Index to April 2019 using an online inflation calculator. These inflation corrected prices were then converted to USD using the OANDA currency exchange database (www.oanda.com) again using the value for April 2019. To put the asking prices into perspective in terms of consumer spending power, we compared mean prices with the annual government-set minimum wage for the district capital of Jakarta for 2019. These minimum wages differ by province and Jakarta’s are the highest in the country, and up to 50% higher than other parts of our study region.

The research forms part of the Little Fireface Project that is underpinned by a Memorandum of Understanding between Universitas Gadjah Mada and Oxford Brookes University. The Indonesian Ministry of Research and Technology (2016–2019) granted permission to conduct our research, and the work adhered to the legal requirements of Indonesia. Our Indonesian and United Kingdom organisations did not require institutional permission for observational research in bird markets. Our work was, however, added to Oxford Brookes University’s Register of Activities Involving Animals (2016–2019). Discussions with traders followed the ethical guidelines proposed by the Association of Social Anthropologists of the UK and Commonwealth. All translations from Bahasa Indonesia, Bahasa Jawa or Bahasa Sunda to English are our own.

Results

Establishment of myenas as invasive alien species

We did not observe any invasive alien myenas in Garut or Temanggung regencies, but we did observe common myena on the campus grounds of Universitas Gadjah Mada and in Demang in the Sleman regency of Yogyakarta. The different datasets (HWB Life, iNaturalist, Burungnesia and birding reports) were consistent in what species were observed where. Common myena has been recorded in the Greater Jakarta area (north Jakarta, Bekasi, Depok, west to Cilegon), Yogyakarta, Greater Surabaya and Malang in central East
Java, easternmost Java roughly between Bondowoso and Banyuwangi in East Java, and central, southwest and southeast Bali. Javan myna has been recorded in north Lombok and Nusa Penida, an island between Bali and Lombok. Jungle myna has been recorded in Bogor, in West Java. Bank myna has been observed in Bali (Denpasar). For the other species no records are lodged on the HLB life website, Burungnesia or iNaturalist, suggesting no or very few observations. Combined these data suggest that the Jakarta-Bogor area in western Java, Yogyakarta, Bali, and Lombok are areas where invasive alien mynas have established themselves (Fig. 1).

For those recorded where we have an accurate description of the type of habitat in which the myna was seen (i.e., mainly the records from Burungnesia and the bird reports) it was clear that most were seen in open and disturbed habitat types. A total of 20 records (12.5%) were observed in different types of closed forest, 30 (18.8%) in open or disturbed forest types, 53 (33.1%) in farmland or gardens and 57 (35.6%) in urban areas.

Mynas in captive breeding facilities

Klaten in central Java is the centre for the captive breeding of mynas and other starlings. There are over a thousand breeders in the village and its wider surroundings (including parts of Yogyakarta), although not all are fully dependent on just breeding birds for their livelihood. The most popular birds that are bred commercially are Javan pied starlings *Gracupica jalla*, black-winged myna, Javan myna, and, in smaller numbers, Bali mynas *Leucopsar rothschildi*. Assuming for a breeder to be commercially viable it needs a stock of at least 10 pairs we estimate that at least 20,000 mynas are kept at any one time. While most of the breeders of Bali mynas were familiar with the regulation that 10% of the offspring of legally protected species were to be used for release back into the wild few did provide offspring to be released. Fewer breeders seemed to be aware that the same rules applied to black-winged mynas (at the time of our visits the Indonesian government considered these three species). Following our discussions, accidental release of non-native mynas or of native mynas outside their natural distribution range (including where the different types of black-winged myna might get released) was clearly not something that breeders were concerned about.

Mynas in trade

We recorded over 23,000 mynas of five species, i.e., 16,751 Javan myna, 5121 common myna, 1158 black-winged myna, 271 crested myna and 7 bank myna. The highest mean numbers recorded per survey were ~500 to 600 for Javan myna, 150 to 200 for common myna, but below 20 for crested and black-winged myna. We did not record any Jungle mynas or pale-bellied mynas. Traders indicated that the most frequently recorded species were sourced locally and were a combination of captive-bred and wild-caught individuals (and thus harvested from Java and/or

Fig. 1 Java, Bali and Lombok with cities where bird markets were surveyed from August 2016 to June 2019 and areas where alien invasive mynas have been observed in grey. Cities with a disproportionate large number of potentially alien invasive mynas for sale are highlighted

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Bali), with Klaten and Yogyakarta often mentioned as the source for captive-bred birds (Table 1).

Cities that stood out because of their high number of invasive alien mynas offered for sale were Jakarta and Surakarta on Java and Mataram on Lombok. The proportion of invasive alien mynas for sale was particularly high (> 25%) in Jakarta, Cirebon, Semarang, Yogyakarta, all on Java, and Mataram on Lombok (Fig. 2).

Mynas could be bought for anything between a US$3 and US$130; the price depended on the species, age and singing ability. We found markedly higher asking prices for black-winged myna than for the native unprotected Javan myna or the non-native common myna and crested myna (Fig. 3). Overall, even the most expensive mynas could be bought for less than half a month’s recommended minimum wage, making these birds affordable for a large proportion of Indonesian society. The Javan, common and crested mynas were cheap and are affordable to most people in Indonesia.

Table 1 Markets surveyed for mynas (Acridotheres spp) between August 2016 and July 2019, showing mean number and total number in brackets, with surveys at least a month apart

| Market, city       | Surveys | A. grandis | A. fuscus | A. cinereus | A. ginnianus | A. tristis | A. cristatellus | A. javanicus | A. melanopterus |
|--------------------|---------|------------|-----------|-------------|--------------|------------|-----------------|--------------|----------------|
| Barito, Jakarta    | 13      | 0          | 0         | 0           | 0            | 2.9 (38)   | 0.7 (9)         | 15.2 (197)   | 0.3 (4)        |
| Jatinegara, Jakarta| 10      | 0          | 0         | 0           | 0            | 33.7 (337) | 1.1 (11)        | 60.8 (608)   | 1.9 (19)       |
| Pramuka, Jakarta   | 12      | 0          | 0         | 0           | 0.5 (6)      | 195.3 (2343)| 11.1 (133)     | 516.3 (6195) | 15.3 (184)     |
| Sukahaji, Bandung  | 18      | 0          | 0         | 0           | 0            | 24.6 (443) | 3.7 (66)        | 64.3 (1158)  | 20.4 (367)     |
| Kerkhof, Garut     | 32      | 0          | 0         | 0           | 0            | 11.7 (374) | 0.6 (20)        | 32.5 (1041)  | 4.6 (148)      |
| Mawar, Garut       | 26      | 0          | 0         | 0           | 0.1 (1)      | 5.7 (149)  | 0.3 (7)         | 8.2 (212)    | 5.2 (135)      |
| Cikurubuk, Tasikmalaya | 17    | 0          | 0         | 0           | 0            | 8.8 (150)  | 0.1 (1)         | 31.9 (543)   | 3.7 (63)       |
| Plered, Cirebon    | 13      | 0          | 0         | 0           | 0            | 24.8 (322) | 0.5 (7)         | 111.0 (1443) | 7.9 (103)      |
| Karimata, Semarang | 6       | 0          | 0         | 0           | 0            | 17.5 (105) | 2.2 (13)        | 34.0 (204)   | 7.8 (47)       |
| Pasty, Yogyakarta  | 5       | 0          | 0         | 0           | 0            | 23.4 (117) | 0.8 (4)         | 66.0 (330)   | 3.4 (17)       |
| Depok, Surakarta   | 5       | 0          | 0         | 0           | 0            | 142.0 (710)| 0               | 605.8 (3029) | 0.4 (2)        |
| Beringkit, Denpasar| 5       | 0          | 0         | 0           | 0            | 4.2 (21)  | 0               | 46.2 (231)   | 0.8 (4)        |
| Satria, Denpasar   | 5       | 0          | 0         | 0           | 0            | 0         | 0               | 231.6 (1158) | 4.6 (23)       |
| Sundu, Mataram     | 5       | 0          | 0         | 0           | 0            | 2.4 (12)  | 0               | 80.4 (402)   | 8.4 (42)       |
| Total within range | n.a     | n.a        | n.a       | n.a         | n.a          | n.a       | n.a             | 16,349       | 1158           |
| Total outside range| 0       | 0          | 0         | 0           | 7            | 5121      | 271             | 402          | n.a            |

In italics are the numbers observed in areas outside the species’ native range

n.a. not applicable
Discussion

Potential for the establishment of invasive alien species

Disturbed habitats, agricultural land and cities are often prime areas where invasive alien birds manage to establish a stronghold (Blackburn et al. 2009; Hernández-Brito et al. 2014; Su et al. 2016; Cohen et al. 2022). The landscape of Java, Bali and Lombok is largely anthropogenic and little undisturbed woodlands or forest remains (Van Balen 1988), thus greatly improving the environmental conditions for the establishment of invasive alien mynas. In their review of invasive bird species in Southeast Asia, Yap and Sodhi (2004) presented data on three species of myna as invasive alien species (Java, common and crested). They however did not include Java, Bali, or Lombok as areas where they had been recorded as outside their range, nor as areas where the birds had established themselves as invasive alien species. We demonstrated that several species of myna have been recorded as invasive alien species on Java (common, black-winged, jungle myna), Bali (common and Javan myna) and Lombok (Javan myna). The regions where these species were recorded were mostly anthropogenically disturbed, with a lowered bird species richness and were climatically matched with the regions where these species would have ranged naturally. Yap and Sodhi (2004) noted that most long-distance introductions of non-native species to new areas are the direct or indirect results of human activities. Social and economic factors are often as critical as biological factors in the introduction, and establishment of invasive alien species. Activities such as logging and grazing further enhance establishment of these species by creating optimal habitat for colonization. While the biological attributes of mynas give them a
high potential as invasive alien species, the culture of bird keeping and the changing natural environment on Java, Bali and Lombok made them conducive for successful establishment (see also Iqbal et al. 2013 for a discussion on the situation in Indonesian Borneo).

Mynas that are native to Java, Bali, and Lombok were consistently present in the bird markets, as were ones that were not native to the region, in large enough numbers (23,000 during 172 bird market surveys) to be of concern. The keeping of mynas has a long history and for instance Basuni and Setiyani (1989) reported that Javan myna was the most traded bird in Jakarta’s Pramuka bird market in the 1980s, with hundreds of them sold every month. This results in a high risk of repeat deliberate or accidental introduction. Access to disposable income or household income are factors in explaining what birds are kept as pets (Jepson and Ladle 2011; Marshall et al. 2020). The asking prices for some of these mynas are very low and even the more expensive species are still affordable for a large part of Indonesian society, again increasing the risks of accidental or deliberate releases compared to more expensive species. These low prices also make mynas candidates for deliberate releases, either to celebrate special days such as the International Day of Forests, as a religious mercy release, or, in places like Bali or Yogyakarta where well-meaning foreign tourists show compassion to individual birds by buying and releasing them.

Release of non-native mynas as part of government protected species policy

In the last ten years the trade in certain protected bird species has been legalised, provided that the individuals that are sold are at least second-generation offspring and the facility that breeds the birds has obtained permission from the regional branch of the Forestry Department (see Nijman et al. 2018 for details). As such, black-winged, grey-rumped mynas, and grey-backed mynas, and their hybrids, are bred in substantial numbers. Following article 71 of Government Regulation No 19 of 2005 facilities that are breeding protected species have to ensure that 10% of the offspring is returned to the wild. To the best of our knowledge, there are no provisions on how breeders are to execute these reintroductions (or when or where). Owners and managers of the breeding facilities we visited did indicate that in the case of mynas, the target of 10% was not met in any of the years they had been operating. While it was difficult to establish how many mynas were released, and where, probably at most 1% was released at the times we conducted...
our surveys. With 1000 s of mynas being bred each year, potentially dozens of mynas of various species are released to comply with government regulations. Equally worrying was that breeders indicated that their stock included hybrids raising the possibilities that these are released as well.

The Indonesian authorities occasionally confiscate mynas, both species that are legally protected and species for which there are harvest quotas (Haryanto 2016; Inanulhaq 2017; Fanini 2018). Habitually these birds are released nearest to the area where they were confiscated or nearest to the offices of the arresting authorities, and this may include areas are outside the natural distribution range of these species (Nijman et al. 2018, 2021a).

National level strategies dealing with invasive alien songbirds

Indonesia has a harvest quota from specific provinces for a limited number of bird species; species that have not been allocated a quota cannot be traded commercially. In recent years these quotas have only been allocated to three or four provinces in Sumatra and one in Kalimantan for the Javan myna and for three provinces in Sumatra for the common myna. This should preclude any harvest of mynas from Java, Bali or Lombok; we found many mynas in the bird markets and traders indicated that at least a proportion of them were locally sourced. At present Indonesia’s import of birds, and restrictions to this import, are mostly discussed in the context of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (Mamoen 2021). CITES has considered invasive alien species (specifically in its Regulation 13.10) and it recommends Parties to consult with appropriate bodies when considering the import of potentially invasive species. CITES also urges strong cooperation between those responsible for implementing CITES and those responsible for implementing the Convention of Biological Diversity. But by its very nature, CITES almost exclusively deals with international trade (Wijnstekers 2003), and domestic trade and trade in non-listed species falls outside its remit. For the prevention of the spread of invasive alien mynas, none of which are listed on any of the CITES appendices, in Indonesia or elsewhere, CITES is largely irrelevant.

Through the ratification of several agreements, Indonesia has committed itself to the prevention of the spread of invasive alien species outside their native ranges in Indonesia. Already in 1985 it adopted the ASEAN Agreement on the Conservation of Nature and Natural Resources, and this requires Parties to regulate and, as appropriate, prohibit alien species introductions. Similar agreements are included in the Convention of Biological Diversity whereby Indonesia has agreed to, as far as possible and as appropriate, prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats, or species. It also agreed to put measures in place to manage pathways to prevent their introduction and establishment. To implement this plan, in 2015 Indonesia published its National Strategy and Management Action Plan for Invasive Alien Species (Strategi Nasional dan Arahan Rencana Aksi Pengelolaan Jenis Asing Invasif di Indonesia) (Yuwo et al. 2015). Some parts of this action plan are indeed appropriate for the management of all invasive alien species, including mynas. It is noteworthy that birds, and the substantial bird trade, are not singled out as potentially problematic. The focus instead is largely on plants and aquatic animals and overall, it does little to inform policies on how to best mitigate the risk of the introduction of potentially invasive alien bird species. Furthermore, as argued by Cohen et al. (2022) for the Mediterranean countries, it is vital that Indonesia and its neighbours (firstly Malaysia and Singapore but this could be extended to Brunei Darussalam, East Timor, Papua New Guinea and Australia) properly engage in international reciprocal transfer of information and develop regional, cross-border, mitigation strategies as these are essential for the successful control of invasive mynas.

Management of mynas as invasive alien species

At present there is a disconnect in the oversight for the trade in invasive alien birds such as mynas and their monitoring and removal from the wild. Multiple governmental departments (sometimes at different administrative levels) bear responsibility. At the central level there are the Ministry of Environment and Forestry (Kementerian Lingkungan Hidup dan Kehutanan), with at its regional level partner, the natural resource management agencies (Balai Konservasi Sumber Daya Alam), the Ministry of
Agriculture (Kementerian Pertanian) and the Ministry of Trade (Kementerian Perdagangan). At the local level regents (Bupati) and mayors (Walikota) share the responsibilities with central government agencies. How these management responsibilities are shared between the various (local and national) government departments is unclear and, worse, often conflicting.

One overlooked aspect of the management of potentially invasive alien species in Indonesia are the retailers (Nijman and Nekaris 2017; Rentschlar et al. 2018; Miller et al. 2019), i.e., in the case of the trade in mynas the vendors in the bird markets. Vendors, and bird market operators, have to be made aware of the risks that certain bird species have when introduced into the wild. Training and certification of bird traders and vendors is necessary to identify and properly handle high-risk species (and we include mynas in this category). Ultimately, professionalization of the songbird trade not only improves the relationship between the local public authorities (such as the local natural resource management agencies) and private vendors but also has the potential to enroll the bird shop owner as a familiar, established, personal contact for the pet-owning public. Retailers already are a frequent and trusted source of information for songbird owners (Rentschlar et al. 2018). An involved, engaged bird shop owner with real public obligations and tasks that can extend beyond their narrow shop operations may have the best potential to educate the public and to help them to comply with protocols that can prevent escapes or even to respond to incipient populations that have established themselves outside their native ranges (cf. Perry and Farmer, 2011).

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Data availability All data are included in the text.

Declarations

Conflict of interest No potential conflict of interest was reported by the authors.

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References

Apriyani L, Ar FY, Erwandi M (2018) Comparison of wildlife protection law between Indonesia and the United States. Hasanuddin Law Rev 4:181–193

Arazmi FN, Ismail NA, Daud UNS, Abidin KZ, Nor SM, Mansor MS (2022) Spread of the invasive Javan myna along an urban–suburban gradient in Peninsular Malaysia. Urban Ecosyst 1–8

Basuni S, Setiyanegi G (1989) Studi perdagangan burung di pasar Pramuka, Jakarta dan teknik penangkapan burung di alam. Media Konservasi 2:9–18

Bell KJ, Seibels R (1990) A visit to some Indonesian zoos and bird markets. Avicultur Mag 96:50–54

Blackburn TM, Duncan RP (2001) Determinants of establishment success in introduced birds. Nature 414:195–197

Blackburn TM, Lockwood J, Cassey P (2009) Avian invasions: the ecology and evolution of exotic birds. Oxford University Press, Oxford

Caretto CM (2014) HBW Alive: handbook of the birds of the world alive. Current Rev Acad Libraries 52:286–288

Carrete M, Tella J (2008) Wild-bird trade and exotic invasions: a new link of conservation concern? Frontiers Ecol Environ 6:207–211

Chng SC, Eaton JA (2015) In the market for extinction: central and East Java. TRAFFIC, Petaling Jaya

Chng SC, Shepherd CR, Eaton JA (2018) In the market for extinction: birds for sale at selected outlets in Sumatra. TRAFFIC Bull 30:15–22

Cohen TM, Hauber ME, Akriotis T, Crochet PA, Karris G, Kirschel AN, Khoury F, Menchetti M, Mori E, Per E, Reino
Wildlife trade and the establishment of invasive alien species in Indonesia: management, policy,…

L, Saavedra S, Santana J, Dor J (2022) Accelerated avian invasion into the Mediterranean region endangers biodiversity and mandates international collaboration. J Appl Ecol. https://doi.org/10.1111/1365-2664.14150

Du Y, Yang Z, Xi Y, Zhang Z, Gu D, Fan L, Yang L, Tu W, Zeng Y, Xin Y, Liu X (2022) High risks with opportunities of religious release resulted biological invasions in China. Current Biol. https://doi.org/10.2139/ssrn.4047250

Eaton JA, Shepherd CR, Rheindt FE, Harris JB, Van Balen S, Wilcove DS, Collar NJ (2015) Trade-driven extinctions and near-extinctions of avian taxa in Sundaic Indonesia. Forktail 31:1–2

Eaton JA, van Balen B, Brickle NW, Rheindt FE (2016) Birds of the Indonesian archipelago. Lynx, Barcelona

Edehaar P, Tella JL (2012) Managing non-native species: don’t wait until their impacts are proven. Ibis 154:635

Ewel JJ (1986) Invasibility: lessons from south Florida. In: Ecological invasions. Springer, New York, pp 214–230

Fanini A (2018) Pria Banyuwangi ini ditangkap jual jalak suren white-vented myna A. javanicus in Kalimantan. Kukila 18:22–26

Harris JB, Tingley MW, Hua F, Yong DL, Adeney JM, Lee TM, Marthy W, Prawiradilaga DM, Sekercioglu CH, Winarni N, Wilcove DS (2017) Measuring the impact of the pet trade on Indonesian birds. Conserv Biol 31:394–405

Haryanto R (2016) Polisi ungkap kasus perdagangan satwa ilegal. Detik News, 5 October 2016

Hernández-Brito D, Carrete M, Popa-Lisseanu AG, Ibáñez C, Tella JL (2014) Crowding in the city: losing and winning competitors of an invasive bird. PLoS ONE 9(6):100593

Ilanulhaq A (2017) Penjual yang tawarkan 13 Jalak Putih ini ditangkap, begini imbuan polisi kepada pencinta burung. Tribun Jateng, 15 March 2017

Iqbal M, Setyawan B, Johannis HS, Lasmana F (2013) The occurrence of common myna Acridotheres tristis and white-vented myna A. javanicus in Kalimantan. Kukila 17:26–29

Iqbal M, Noske RA, Hermawan B, Istanto D, Arfi M (2014) The first wild common mynas Acridotheres tristis in Java: colonists or aviary escapees? Kukila 18:22–26

Jackson H, Strubbe D, Tollington S, Prys-Jones R, Matthysen E, Groombridge JJ (2015) Ancestral origins and invasion pathways in a globally invasive bird correlate with climate and influences from bird trade. Mol Ecol 24:4269–4285

Jepson P, Ladle RJ (2011) Assessing market-based conservation governance approaches: a socio-economic profile of Indonesian markets for wild birds. Oryx 45:482–491

Kolar CS, Lodge DM (2001) Progress in invasion biology. Trends Ecol Evol 16:199–204

Leuven BT, Gomez L, Shepherd CR, Nekaris KA, Imron MA, Nijman V (2020) Thirty years of trade data suggests population declines in a once common songbird in Indonesia. Europ J Wildlife Res 66:1–11

Lockwood JL, Welbourne DJ, Romagos CM, Cassey P, Mandrak NE, Strecker A, Leung B, Stringham OC, Udell B, Episcopio-Sturgeon DJ, Trusty MF (2019) When pets become pests: the role of the exotic pet trade in producing invasive vertebrate animals. Front Ecol Environ 17:323–330

Low S, Browne M, Boudjelas S, De Poorter M (2000)100 of the world’s worst invasive alien species: a selection from the global invasive species database. Invasive Species Specialist Group, Auckland

Mamoen SH (2021) Analyzing the implementation of Article III of The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in Indonesia Doctoral dissertation. Universitas Gadjah Mada, Yogyakarta

Marshall H, Collar NJ, Lees AC, Moss A, Yuda P, Marsden SJ (2020) Characterizing bird-keeping user-groups on Java reveals distinct behaviours, profiles and potential for change. People Nature 2:877–888

Miller AE, Gary D, Ansyah J, Sagita N, Munifhati K, Adirahmanta SN (2019) Socioeconomic characteristics of songbird shop owners in West Kalimantan. Indonesia Trop Conserv Sc 12:1940082919889510

Nijman V, Langgeng A, Birot H, Imron MA, Nekaris KAI (2018) Wildlife trade, captive breeding and the imminent extinction of a songbird. Global Ecol Conserv 15:00425

Nijman V, Campera M, Imron MA, Ardiansyah A, Langgeng A, Dewi T, Hedger K, Hendrik R, Nekaris K (2021a) The role of the songbird trade as an anthropogenic vector in the spread of invasive non-native mynas in Indonesia. Life 11:814

Nijman V, Campera M, Ardiansyah A, Balestri M, Bizri HR, Budiahi B, Dewi T, Hedger K, Hendrik R, Imron MA, Langgeng A, Nekaris KAI (2021b) Large-scale trade in a songbird that is extinct in the wild. Diversity 13:238

Perry G, Farmer M (2011) Reducing the risk of biological invasion by creating incentives for pet sellers and owners to do the right thing. J Herpetol 45:134–142

Pysek P, Hulme PE, Simberloff D, Bacher S, Blackburn TM, Carlton JT, Dawson W, Essl F, Foxcroft LC, Genovesi P, Jeschke JM (2020) Scientists’ warning on invasive alien species. Biol Rev 95:1511–1534

Reaser JK, Burgiel SW, Kirkby J, Brantley KA, Veatch SD, Burgos-Rodríguez J (2020) The early detection of and rapid response (EDRR) to invasive species: a conceptual framework and federal capacities assessment. Biol Invasions 22:1–19

Reino L, Figueira R, Beja P, Araújo MB, Capinha C, Strubbe D (2017) Networks of global bird invasion altered by regional trade ban. Sci Adv 3:1700783

Rentschlar KA, Miller AE, Lauck KS, Martinez-Alier J, Bobby, Mullihat, Kartikawati (2018) A silent morning: the songbird trade in Kalimantan, Indonesia. Trop Conserv Sc 11:1940082917753909

Sadanaandan KR, Low GW, Sridharan S, Gwee CY, Ng EY, Yuda P, Prawiradilaga DM, Lee JG, Tritto A, Rheindt FE (2020) The conservation value of admixed phenotypes in a critically endangered species complex. Sci Rep 10:1–16

Shepherd CR (2006) The bird trade in Medan, North Sumatra: an overview. BirdingASIA 5:16–24

Shepherd CR, Leuven BT, Siriwat P, Nijman V (2020) International wildlife trade, avian influenza, organised crime and the effectiveness of CITES: The Chinese hwamei as a case study. Global Ecol Conserv 23:01185
Souviron-Priego L, Muñoz AR, Olivero J, Vargas JM, Fa JE (2018) The legal international wildlife trade favours invasive species establishment: the monk and ring-necked parakeets in Spain. Ardeola 65:233–246

Squires TM, Yuda P, Akbar PG, Collar NJ, Devenish C, Taufigurrahman I, Wibowo WK, Winarni NL, Yanuar A, Marsden SJ (2021) Citizen science rapidly delivers extensive distribution data for birds in a key tropical biodiversity area. Global Ecol Conserv 28:01680

Su S, Cassey P, Blackburn TM (2016) The wildlife pet trade as a driver of introduction and establishment in alien birds in Taiwan. Biol Invasions 18:215–229

Symes WS, McGrath FL, Rao M, Carrasco LR (2018) The gravity of wildlife trade. Biol Conserv 218:268–276

Vall-llosera M, Cassey P (2017) Leaky doors: private captivity as a prominent source of bird introductions in Australia. PLoS ONE 12:0172851

Van Balen S (1988) Forest fragmentation and the survival of forest birds in Indonesia: a preliminary report. Proc Sem Nachkontakt DAAD 115–165

Van Balen SB, Nijman V (2004) Biology and conservation of pink-headed fruit-dove Ptilinopus porphyreus. Bird Conserv Intern14:139–152

Van Horn G, Mac Aodha O, Song Y, Cui Y, Sun C, Shepard A, Adam H, Perona P, Belongie S (2018) The iNaturalist species classification and detection dataset. Proc IEEE Conf Computer Vision Pattern Recogn 2018:8769–8778

Wijnstekers W (2003) The evolution of CITES. CITES Secretariat, Geneva

Yap CA, Sodhi NS (2004) Southeast Asian invasive birds: ecology, impact and management. Ornithol Sc 3:57–67

Yuwono A, Awang SA, Harpini B, Prasmadji N (2015) Strategi Nasional dan Arahan Rencana Aksi Pengelolaan Jenis Asing Invasif di Indonesia. Ministry of Environment and Forestry, Jakarta

Winnasis S, Hakim L, Imron MA (2018) The utilization of Burungnesia to detect citizen scientist participation preference in birding sites observation in Java Island. J Indonesian Tour Dev St 6:49–54

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