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# Controlling trapping, overgrazing and invasive vegetation are key to saving Java's last population of the Black-winged Myna

#### 3 ABSTRACT

4 The Black-winged Myna (Acridotheres melanopterus) is a Critically Endangered passerine 5 endemic to the islands of Java and Bali, Indonesia. Illegal trapping to supply the cage-bird trade 6 has led to its near-total extinction, with the global population estimated to number fewer than 7 100 individuals. We estimated the current range and population size of the species at Baluran 8 National Park, which supports Java's last known population, and used species distribution 9 modelling to evaluate potential suitability of currently unoccupied areas across the park to 10 identify priorities for management intervention. We estimate that the Black-winged Myna population numbers 179 individuals (95% CI: 111–288; density: 14.3 ± 3.5 individuals km<sup>-2</sup>) and 11 12 that its current range is 12.3 km<sup>2</sup>. Our model indicated that some 72 km<sup>2</sup> of the park (30% of total 13 area) has potentially suitable habitat for the species, and we infer that the principal cause for the 14 disparity between its current and potential range is trapping, compounded by savanna loss and 15 degradation due to illegal domestic cattle grazing and the spread of invasive thorny acacia 16 (Vachellia nilotica). The partial clearance of acacia in recent years appears to have assisted a 17 modest population recovery by the myna. Its further population growth and range expansion in 18 Baluran depends on effective management of illegal poaching, further clearance of acacia, and 19 easing domestic cattle grazing pressure on areas of savanna, particularly through engagement 20 with communities living inside the park. Any actions that increase the size of the Black-winged 21 Myna population are likely to benefit other threatened savanna-dependent wildlife in the park, 22 notably banteng (Bos javanicus) and Green Peafowl (Pavo muticus). While our models and 23 recommendations may be applicable to other protected areas in Java, and indeed other 24 threatened myna species, trapping and habitat change may have site-specific dimensions, 25 especially outside of protected areas, and thus demand local bespoke solutions.

26

*Keywords*: Black-winged Myna (*Acridotheres melanopterus*); Asian songbird crisis; Critically
 Endangered; Indonesia; Java; Baluran;

29

## 30 LAY SUMMARY

- The Black-winged Myna, confined to Java and Bali in Indonesia, is threatened with extinction
   due to illegal trapping for the cage-bird trade. Baluran National Park supports the last known
   population on Java.
- We estimated the number of mynas in the park, mapped where they occur, and assessed their
   habitat to determine how much of it is currently unoccupied.
- There are around 180 Black-winged Mynas in the park, indicating recent population growth.
   However, they occupy <20% of the potentially suitable habitat, restricting further population</li>
   growth.
- Trapping is the foremost factor holding back the mynas, but overgrazing by domestic
   livestock and invasion by thorny acacia negatively affect the potentially suitable habitat.
- Thorny acacia eradication must continue. Working with the human communities living in the
   park is key to alleviating the grazing pressure and addressing the trapping issue.
- 43

## 44 ABSTRAK (BAHASA INDONESIA)

45 Jalak putih (Acridotheres melanopterus) adalah burung berkicau endemik di pulau Jawa dan Bali, 46 Indonesia, yang berstatus Kritis. Selama beberapa dekade terakhir, penangkapan ilegal untuk 47 memasok perdagangan burung dalam sangkar telah menyebabkan kepunahan dengan populasi 48 global diperkirakan berjumlah kurang dari 100 individu. Kami melakukan estimasi sebaran dan 49 ukuran populasi spesies saat ini di Taman Nasional Baluran, yang mendukung populasi liar 50 terakhir yang diketahui di Jawa, serta menggunakan pemodelan distribusi spesies untuk 51 mengevaluasi potensi kesesuaian area yang tidak ditempati Jalak putih di seluruh Taman 52 Nasional untuk mengidentifikasi prioritas intervensi pengelolaan. Estimasi populasi Jalak putih 53 di TN Baluran berjumlah 179 individu (95% CI: 111–288; kepadatan: 14,3 ± 3,5 individu km<sup>-2</sup>) dan sebarannya saat ini adalah 12.3 km<sup>2</sup>. Pemodelan kesesuaian habitat menunjukkan bahwa 54 sekitar 72 km<sup>2</sup> dari taman nasional (30% dari total luas) berpotensi sesuai untuk spesies 55

56 tersebut, dengan kesimpulan bahwa penyebab utama perbedaan antara sebaran saat ini dan 57 potensi sebaran adalah penangkapan, ditambah dengan degradasi dan hilangnya savana akibat 58 penggembalaan sapi lokal ilegal serta penyebaran akasia berduri yang invasif (Vachellia nilotica). 59 Namun, pembukaan sebagian akasia berduri tampaknya telah membantu pemulihan populasi secara sederhana. Pertumbuhan populasi dan perluasan sebaran jalak putih di Baluran, 60 61 tergantung pada pengelolaan perburuan liar yang efektif, pengurangan akasia berduri yang terus 62 berlanjut, serta mengurangi tekanan penggembalaan ternak lokal di daerah savanna terutama 63 melalui keterlibatan masyarakat yang tinggal di dalam kawasan. Setiap tindakan untuk 64 meningkatkan jumlah Jalak putih, kemungkinan besar akan menguntungkan satwa liar lain yang 65 berstatus terancam dan bergantung pada savana di dalam kawasan, terutama banteng (Bos 66 javanicus) dan merak hijau (Pavo muticus). Sementara model dan rekomendasi ini mungkin bersifat umum dalam penerapannya pada kawasan lindung lainnya di Jawa, serta spesies Jalak 67 68 lainnya yang terancam, namun masalah penangkapan dan perubahan habitat yang terjadi 69 bersamaan mungkin bersifat spesifik lokasi, terutama di luar kawasan konservasi, dan mungkin 70 pada gilirannya menuntut solusi lokal yang tepat.

71

#### 72 INTRODUCTION

73 Biological diversity is being eroded at an unprecedented rate and wildlife trade is a main 74 underlying cause, contributing to enormous declines in species abundance, loss of ecosystem 75 function, and increased risks to human health through zoonotic diseases (Pimm et al. 2014, Dirzo 76 et al. 2014, Benítez-López et al. 2017, Aguirre et al. 2020). Nearly a fifth of all extant vertebrate 77 species are traded, mostly in and from the tropics, with birds and mammals being 78 disproportionately affected (Wyler and Sheikh 2008, Barber-Meyer 2010, Scheffers et al. 2019). 79 Southeast Asia, one of the most biodiverse regions on earth, has among the highest proportion of 80 threatened species for most higher classes of animals (Myers et al. 2000, Sodhi et al. 2010, Hughes 81 2017). Throughout the region, the trade in wild-caught songbirds—prized for their vocal ability, 82 plumage, rarity and cultural significance—is having a massive effect on wild populations (Nijman

83 2010, Lee et al. 2016, Symes et al. 2018, Indraswari et al. 2020). The resulting 'Asian Songbird 84 Crisis' has left many species facing extinction, while for many others the damage trade has 85 wrought on their populations is still poorly understood due to insufficient monitoring (Eaton et 86 al. 2015, Shepherd and Cassey 2017, Bergin et al. 2018, Marshall et al. 2020). Indonesia, 87 particularly its most populous island of Java, is widely regarded as the epicenter of the bird trade 88 in Southeast Asia, with millions of birds sold annually at markets irrespective of their legal status 89 and an estimated 70 million cage-birds kept in one-third of Java's 36 million households (Chng 90 and Eaton 2016, Harris et al. 2017, Marshall et al. 2020). Almost half of Indonesia's 64 globally 91 threatened songbirds (order Passeriformes) are threatened primarily by trade, and most of them 92 occur on Java (IUCN 2021).

93 There are several patterns of decline exhibited by species under heavy pressure from 94 habitat loss and trapping: some show dampened population densities across their range 95 (Laaksonen and Lehikoinen 2013) while others collapse into just a few strongholds (Abram et al. 96 2015, Annorbah et al. 2016). The role of formally protected areas in the conservation of 97 endangered wildlife is also varied, ranging from absolutely critical (Prakash et al. 2019, Ghosh-98 Harihar et al. 2019) to relatively secondary (Agardy et al. 2003, Kamp et al. 2015). A number of 99 conservation strategies may be useful for songbirds in Indonesia. Some species, such as the Bali 100 Myna (Leucopsar rothschildi), survive almost exclusively in formally protected areas (Jepson 101 2016) but other species survive in refuges outside of protected areas (Kurniandaru 2008, Yong et al. 2018). The latter, which may fall under the umbrella of 'other effective area-based 102 103 conservation measures' (OECMs; Jonas et al. 2014), can include temples and other culturally 104 important sites, small islands, tourist facilities and privately guarded sites, where work with local 105 communities/authorities underpins the maintenance of socio-ecological conditions that support 106 the survival of key species, intentionally or otherwise (Negi 2010, Li et al. 2014, Dolman et al. 107 2021).

The Black-winged Myna (*Acridotheres melanopterus*), endemic to the Indonesian islands
of Java, Bali and Madura, now primarily survives in formally protected areas, but was once

110 widespread in the lowlands, predominantly savannas and cultivated areas up to 1,200 m in West 111 Java and reportedly 2,400 m in East Java (Feare & Craig 1998; Collar et al. 2001). It has been 112 present in both domestic and international trade for decades, despite its protection under 113 Indonesian law since 1979 (Minister of Agriculture, Decree no. 757/Kpts/Um/12/1979). It is, 114 however, domestic trade that is largely responsible for the precipitous decline of the wild 115 population, which began in the 1960s but was most pronounced in the 1990s, and the sharp 116 decline in numbers traded in the 2000s gave a clear indication that wild populations were 117 vanishing because of trapping (Collar et al. 2001, 2012; Eaton et al. 2015, Shepherd et al. 2016, 118 Nijman et al. 2018).

119 Although small numbers may persist in recently unsurveyed areas including some nature 120 reserves, the only known wild population of Black-winged Myna left on Java occurs in Baluran 121 National Park, East Java (Winnasis et al. 2020, eBird 2021), while a small number persist at two 122 sites in Bali, with 35 birds at Bali Barat National Park (Brillianti et al. 2019) and 12 at another 123 unspecified site (Eaton et al. 2015). The small number of birds known from two sites near Jakarta, 124 Java (Eaton et al. 2015) are unlikely to persist (TMS pers. obs.). At Baluran, the population has 125 been extremely low over the past decade: the largest flocks observed in 2009 and 2010 numbered 126 25 and 12 individuals, respectively (Winnasis et al. 2011, Eaton et al. 2015), although in 2016 a 127 flock of 37 was recorded (BirdLife International 2021). Accordingly, the global population size of 128 wild Black-winged Mynas is considered to be below 100 individuals, probably around 85. This 129 circumstance indicates a clear and urgent need to carry out a thorough ecological assessment of 130 the species to inform its conservation management strategy (Lee et al. 2016). We therefore 131 sought to (1) document its current distribution and estimate its population size within Baluran 132 National Park; (2) use species distribution modelling to identify potentially suitable areas that 133 should be prioritized for appropriate management; and (3) identify the barriers to population 134 expansion in different parts of the park and recommend interventions that can break these down.

135

#### 136 METHODS

#### 137 Study area

Baluran National Park (BNP; 7°50'S 114°22'E) is situated on the north-eastern tip of Java, with a 138 139 land area of 264 km<sup>2</sup> (Figure 1). It was first established as Baluran Game Reserve in 1937 by the 140 Dutch colonial government owing to the large mammals found there—banteng (Bos javanicus), 141 Javan rusa (Rusa timorensis), feral water buffalo (Bubanus bubanus), dhole (Cuon alpinus), Javan 142 leopard (Panthera pardus melas) and the now extinct Javan tiger (Panthera tigris sondaica) 143 (Whitten et al. 1996). The park is in one of the driest parts of Java, receiving <1,500 mm of rainfall 144 a year, most falling between December and February (Winnasis et al. 2011); a pronounced May-145 October dry season, in combination with fire and herbivory, maintains the savanna-like landscape 146 in the north and east of the park (Pennington et al. 2018). Mount Baluran (1,247 m), a dormant 147 volcano, dominates the center of the park and is cloaked in tropical evergreen and dry deciduous 148 forest.

149 The residents of Karang Tekok village to the north-west and Wonorejo village to the 150 south-east have always utilized BNP to trap and hunt wildlife and to collect wood, seeds, fodder, 151 honey and tamarind fruit (Tamarindus indica), and they also start fires both accidentally and 152 deliberately (Whitten et al. 1996, Sabarno 2002). Overall, hunting and trapping still represent the 153 greatest threat to wildlife in BNP: the Green Peafowl (Pavo muticus), an Endangered species, has 154 declined at BNP, partly because adults and chicks are trapped and sold either alive as pets or dead 155 as food (Winnasis et al. 2011). At least 23 other bird species are known to have been trapped 156 within BNP, mostly alive using mist-nets (Winnasis et al. 2011), and hunters have been 157 prosecuted for poaching East Javan langurs (Trachypithecus auratus), a globally Vulnerable 158 species (Nijman 2020). Five guard posts control the main entry points and regular patrols are 159 conducted, but a public road bisects the west side and the park's long coastline offers great ease 160 of access from the sea.

161 The savanna in the north of BNP has been significantly altered since 1975, when a 162 commercial license was awarded to replace native trees with an agati or turi (Sesbania 163 grandiflora) plantation, a pulpwood species used in paper production (Pudyatmoko et al. 2018). 164 The plantation workers have remained in the park despite the license expiring in 2000, and now 165 graze herds of cattle across the savanna and grow crops along the coast (Wianti 2014). More 166 cattle kept by residents of Karang Tekok village on the park's boundary also enter the northern 167 savanna to graze daily (Prijono 2014). In total, almost four thousand cattle and over a thousand 168 goats subsist on the northern savanna (Prijono 2014, Pudyatmoko 2017). The park's savanna is 169 also threatened by the spread of thorny acacia (Vachellia nilotica), which was planted at Bekol in 170 1969 to prevent fire from spreading into teak (Tectona grandis) plantations (Sutomo et al. 2016).

### 171 Classifying the park's habitats

172 We generated a contemporary land-cover map for BNP based on cloud-free LANDSAT 8 imagery 173 (30 m resolution) from October 2018. Some recent burns on the image were removed using 174 neighbor-based interpolation. Training data were obtained using field data collected in 175 September–November 2018 by classifying land-cover types visually with descriptions employed 176 in previous land-cover maps (Supplementary Material Table S1), and by Google Earth image 177 interpretation, which was used to increase the sample size of the smallest classes to address the 178 potential training data imbalance (Millard and Richardson 2015). We selected the following nine land-cover types for the classification, modified from the latest BNP land-cover map (Baluran 179 180 National Park 2008) and using relevant descriptions (Supplementary Material Table S1): open 181 savanna, savanna woodland, dry deciduous woodland/shrubland, dry deciduous forest, thorny 182 acacia scrub, teak plantation, tropical evergreen forest, beach forest, and mangrove forest. The 183 difficult terrain on Mount Baluran made field data collection impossible there, but the tropical 184 evergreen forest on its slopes could be delimited from Google Earth images and was therefore 185 included in the training data.

186 Training data were used to build a random forest (RF) classification model (Breiman 2001). 187 The environmental variables we used were bands 1–7 of the LANDSAT 8 imagery; normalized 188 difference vegetation index (NDVI); the Global Land Analysis and Discovery (GLAD) laboratory's 189 Global Forest Canopy Height 2019 product (Potapov et al. 2021); wetness, brightness and 190 greenness indices; and topography (elevation, slope and aspect) calculated from the Shuttle 191 Radar Topography Mission (SRTM) digital elevation model with 30 m resolution (van Zyl 2001). 192 Analysis was carried out in R (R Core Team 2020) using packages 'raster' v3.3.13 (Hijmans 2020), 193 'randomForest' v.4.6.14 (Breiman 2001) and 'sf' v0.9-7 (Pebesma 2018). As a dimension 194 reduction procedure, we ran the RF classification 25 times and recorded the five most important 195 variables for each iteration. A Spearman's rank correlation analysis was then used to measure 196 pair-wise correlations and if any of the five most important variables were highly correlated ( $r_s >$ 197 0.90) with lower-ranked variables, the latter were removed (Millard and Richardson 2015). The 198 model was tuned by selecting the number of trees to grow and variables sampled at each split 199 that minimized the out-of-bag error rate. The final RF classifier grew 1,000 trees and two 200 variables were randomly sampled at each split.

## 201 *Population size and range estimation*

202 To estimate the current range of the Black-winged Myna in BNP we included all records from line 203 transect sampling and incidental observations during the fieldwork period from March 2018 to 204 March 2019, as well as one observation by a proficient local birdwatcher (Heru Fitriadi) and 19 205 observations by experienced members of the Copenhagen Zoo project staff at BNP, who carried 206 out a survey in November 2017. We removed six outlying records from the current range estimate 207 (see Figure 1) because they were over 4 km from the main cluster of observations, and were never 208 of more than two birds which, given the sociality of mynas, suggests they were exploratory 209 movements by dispersing birds. Moreover, we visited the area of these sightings monthly during 210 the fieldwork period and only recorded mynas on two occasions, indicating that the southern area 211 of the park did not form part of the species' home range. We constructed a minimum convex polygon around the remaining occurrences (Burgman and Fox 2003) in R with a 200-m buffer toprovide a final range estimate.

214 Based on the pre-existing land-cover map a total of 36 distance sampling line transects 215 with a combined length of 73.5 km were run across BNP to sample each land-cover type except 216 for tropical rainforest, which we considered unsuitable for Black-winged Mynas (Collar et al. 217 2001). Line transects were distributed following a stratified sampling approach (Buckland 2004), 218 whereby more transects were located in the east of the park to focus survey effort on the area 219 expected to contain most of the Black-winged Myna population (Winnasis et al. 2011). Within 220 what were classified as open habitat types (open savanna and savanna woodland) line transects 221 were assigned randomly; in woodland (classified as closed habitat), transects followed narrow 222 tracks made by humans or large mammals, as attempts to penetrate the dense understory, 223 especially during the wet season, risked disturbing the target species before detection (Buckland 224 2001). Line transects outside our estimated Black-winged Myna range were excluded from the 225 distance analysis and subsequent population density estimate because no encounters were 226 recorded on any of these. Most transects were walked in both wet and dry seasons, but eight were 227 only walked in the dry season. Twenty-one transects with a combined length of 29.1 km (mean 228 length: 1.4 km) were included in the final analysis, giving a total effort of 50.6 km (Figure 1).



230

Figure 1. Baluran National Park, East Java, showing the location of all line transects, of which
 those in green were included in the Black-winged Myna population density analysis because they
 were inside the species' estimated range (green dashed line).

234

235 Distance sampling was undertaken at the end of the wet season and beginning of the dry 236 season from March 28 to May 30, 2018 (hereafter referred to as wet season sampling because in 237 May the vegetation is still lush and the understory dense), and in the dry season from October 5 238 to November 21, 2018. Sampling was conducted between 06h00 and 12h00 by one of two 239 experienced observers (TMS, PGA) following the standard protocol for line-transect distance sampling (Buckland 2001, Buckland et al. 2008). We walked transects at  $\sim$ 1.5 km h<sup>-1</sup> and each 240 241 was preceded by a 200-m 'burn in'-the first section of a transect (not included in its reported length) which is walked but encountered birds are not recorded in an attempt to equalize the 242

243 effects of observer disturbance across the transect (Buckland 2004). Birds seen only in flight were ignored, but those seen taking off or landing (i.e. using the habitat) were recorded. We used laser 244 245 rangefinders (Hawke LRF 400) to measure distances and targeted the nearest visible object when 246 no clear line of sight was available (Buckland et al. 2008). Distance sampling analysis followed 247 standard methods (Buckland 2001) and was carried out in R (R Core Team 2020) using package 248 'Distance' v1.0.2 (Miller et al. 2019). Detection data were right-truncated at 135 m after 249 discarding the furthest 5% of detections from the transect. Group sizes for aural-only detections 250 were replaced by the average of all groups of known size. We generated a two-level open vs. 251 enclosed habitat covariate for the detection function. The final model for the detection function 252 was selected based on minimum Akaike Information Criterion (AIC) and after confirming that the 253 detection function curve fitted the observed data (Supplementary Material Table S2 and Figure 254 S1).

## 255 Estimating habitat suitability

We used species distribution modelling (SDM) to estimate the habitat suitability for Black-winged Myna within each 30 m pixel across BNP (Araújo and Guisan 2006). Three environmental covariates were used in the models: an NDVI layer generated from LANDSAT 8 imagery; the landcover classification raster covering the park (Figure 2); and a habitat openness layer, for which each pixel represented the proportion of open vs. enclosed habitat pixels in the 0.56 km<sup>2</sup> (25 × 25 pixels) surrounding the target pixel. Black-winged Myna occurrences (n = 339) were filtered to include just one per pixel, resulting in 291 pixels containing presences across the raster layer.

We used R packages 'raster' v3.3-13 and 'biomod2' v3.4.6 (Thuiller et al. 2020) to model Black-winged Myna distribution. During the data formatting procedure in biomod2, we set the number of pseudo-absences (PAs) to 5,000 and created five sets of PAs (biomod2 generated a total of 24,122 unique PAs) using the 'disk' algorithm with the minimum distance to presences set to 75 m (Chefaoui and Lobo 2008, Thuiller et al. 2020). We ran three different SDM algorithms available in biomod2 on the five presence/PAs datasets: generalized linear model (GLM), 269 generalized additive model (GAM), and maximum entropy (MaxEnt). Models were calibrated 270 using 80% of the data and the remainder were used to evaluate model performance. Every 271 algorithm was run five times with each PA dataset (total number of runs for each algorithm = 25). SDM algorithms were evaluated using area under the curve (AUC) values calculated in 272 273 biomod2. All of the algorithms performed well (AUC > 0.80) and were used to produce full models 274 without data partitioning. Variable importance values on a scale from 0 to 1 were calculated for 275 each algorithm, higher values indicating greater influence in the model. We then aggregated the 276 models by algorithm and generated algorithm-specific projections of habitat suitability across 277 BNP in order to calculate algorithm-specific model averages, which were used to evaluate how 278 well individual algorithms discriminated between presences and PAs based on Tjur's R<sup>2</sup> (Tjur 279 2009).

For the final output, an ensemble of the projections was generated with the SDM algorithms using mean-weighting based on the algorithms' AUC value. This raster map provided raw suitability values for each pixel in BNP on a scale of increasing suitability from 0 to 1. We generated a binary raster of unsuitable and suitable habitat using a threshold value, which was the minimum suitability value at a pixel including a Black-winged Myna presence after excluding the lowest 10th percentile of suitability values from pixels with presences. Final maps from the analysis were generated using QGIS v3.10.3.

287

#### 288 RESULTS

Black-winged Mynas were recorded a total of 339 times during fieldwork, with all but six records in the Bekol, Balanan and Bama areas in the east of the park (Figures 2, 4). Based on the occurrence data gathered, we estimate that the current range for Black-winged Myna covers 12.3 km<sup>2</sup> (<5% of the park's area). The land-cover types with most occurrences were open savanna (37.8%), followed by savanna woodland and dry deciduous woodland/shrubland (both 20.6%), thorny acacia scrub (19.8%; but see the discussion), beach forest (0.9%) and dry deciduous forest (0.3%); the full land-cover classification map is shown in Figure 2. Of the outlying occurrences
excluded from the range estimation, three were in savanna 4 km south of Bekol, and three were
near the cultivated land adjacent to Wonorejo village, 6 km south of the current range. The largest
groups recorded were seen gathering before dusk, with the highest record being of 97 individuals
on 26 September 2018, when birds flew to roost in ten groups (maximum single group size = 25
individuals).

301



Figure 2. (A) Land-cover classification for Baluran National Park; and (B) all Black-winged Myna
occurrences (magenta circles) recorded and the occupied range (black dashed line) overlaid on
land-cover types. The extent of (B) is shown by the red dashed line in (A).

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Black-winged Mynas (median group size = 2) were detected on 56 occasions during linetransect distance sampling over the wet (n = 30) and dry (n = 26) seasons. The average encounter rate was  $2.9 \pm 0.7$  individuals km<sup>-1</sup>, with the highest encounter rate in savanna woodland followed by open savanna, and the lowest in dry deciduous woodland/shrubland and thorny acacia scrub; birds were not detected in the other land-cover types during line-transect distance sampling (Table 1). Detection probabilities were described best by a uniform key function with one cosine adjustment term (Supplementary Material Table S2 and Figure S1). Population density was highest in savanna woodland (34.4 individuals km<sup>-2</sup>, 95% CI: 13.5–88.0) and lowest in dry deciduous woodland/shrubland (10.9, 95% CI: 4.6–25.9), and the overall population density in the current range was 14.3 individuals km<sup>-2</sup> (95% CI: 8.8–23.1) (Table 1). We estimate the overall population size to be 179 individuals (95% CI: 111–288).

318

Table 1. Estimated Black-winged Myna population density and abundance within its estimated range for each land-cover type in which birds were detected during line-transect distance sampling.

	A 1.1.1	Encounter		
Land-cover type	Area within	rate	Density	Abundance
	current	Tute	individuals (95%	individuals (95%
		individuals		CD
	range (km²)	km⁻¹ ± SE	CIJ	CIJ
		= 0.2		
Savanna woodland	0.8	5.8 ± 2.7	34.4 (13.5–88.0)	28 (11–70)
Open savanna	2.1	3.6 ± 1.8	21.0 (7.8–57.0)	44 (16–120)
Dry deciduous				
woodland/shrubland	5.3	$1.9 \pm 0.8$	10.9 (4.6–25.9)	58 (24–137)
Thorny acacia scrub	4.1	$2.0 \pm 0.8$	12.0 (5.6–25.6)	49 (23–105)
Total/overall	12.3	2.9 ± 0.7	14.3 (8.8–23.1)	179 (111–288)

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All the SDM algorithms performed well based on AUC values (Table 2). The Tjur's R<sup>2</sup> values for all three algorithms were similar and showed a high level of discrimination between pixels with occurrences and pseudo-absences. Variable importance values for models produced by each algorithm showed that land-cover type had the greatest influence in models produced by all algorithms (Supplementary Material Table S3), and relative differences in variable importance for the models produced by GAM and GLM were similar. The influence of land-cover type and
habitat edge was similar in the MaxEnt model, while NDVI had a relatively small influence.

330

Table 2. Calculated AUC, sensitivity, specificity and Tjur's R<sup>2</sup> values of SDM algorithms used to estimate Black-winged Myna habitat suitability. Values of AUC, sensitivity and specificity are averages ± SD across the five different datasets included, each comprising Black-winged Myna presences (n = 291) and 5,000 pseudo-absences. Tjur's R<sup>2</sup> values were calculated from model averages for each SDM algorithm after projecting the models across the raster surface for the study area. The highest values for each metric are shown in bold.

SDM algorithm	AUC	Sensitivity	Specificity	Tjur's R <sup>2</sup>
GLM	0.88 ± 0.02	86.9 ± 6.43	76.3 ± 6.95	0.46
GAM	$0.87 \pm 0.01$	89.3 ± 5.13	72.4 ± 6.58	0.48
MaxEnt	$0.87 \pm 0.02$	87.5 ± 5.27	73.4 ± 6.75	0.46

337

338 The final ensemble model had a Tjur's R<sup>2</sup> value of 0.47 and discriminated well between 339 areas we expected to be suitable (savanna-type land-covers) and unsuitable (closed-canopy 340 areas) for Black-winged Myna. Large areas of potentially suitable habitat (values of >0.6) are 341 predicted across the north of the park, where open savanna and savanna woodland dominate, 342 while there are smaller areas of suitable habitat surrounding the savanna in the south-east of the 343 park (Figure 3). The central areas of large open savannas are deemed less suitable than the edges. 344 The areas of highest suitability adjoining the current range of Black-winged Myna are distributed 345 to the north and north-west.

346



Figure 3. Baluran National Park habitat suitability map for Black-winged Myna, with values on a
scale of increasing suitability from 0 to 1. Magenta circles show the actual Black-winged Myna
occurrences that were used in species distribution modelling.

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We then delimited the potentially suitable area for Black-winged Myna across BNP from the suitability raster using the calculated threshold (Figure 4). This final output indicated that there are an estimated 72.1 km<sup>2</sup> of potentially suitable habitat for Black-winged Mynas, mainly to the north-west of the current range and mostly within open savanna and savanna woodland. Of the potentially suitable habitat, 89% lies within 5 km of the coast at elevations below 300 m. Much

of the potentially suitable area is close to the roads and settlements that occur in the north of BNP.

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360 **Figure 4.** Baluran National Park, showing predicted suitable habitat for Black-winged Mynas that

- is currently occupied and unoccupied.
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## 363 DISCUSSION

The once widespread but now Critically Endangered Black-winged Myna has been extirpated from localities throughout its range on Java and Bali after decades of overexploitation for the cage-bird trade (Eaton et al. 2015, Shepherd et al. 2016, Nijman et al. 2018). This first comprehensive assessment of its status at Baluran National Park, the home of the only known 368 wild population on Java, reveals that fewer than 200 individuals are confined to 12.3 km<sup>2</sup> of 369 savanna and shrubland in the east of the park, an area six times smaller than the 72.1 km<sup>2</sup> of 370 potentially suitable habitat identified by our species distribution model. While some of the 371 potentially suitable habitat is located on Mount Baluran at higher elevations than the species 372 currently occurs at in the park, it is within the species' historically reported altitudinal range of 373 0-2,400 m (Collar et al. 2001). Although formal population assessments have not been published, 374 a comparison of our population estimate with the maximum flock size of 37 birds recorded in 375 2016 (BirdLife International 2021) suggests that there may have been recent population growth. 376 Our model delineates areas where management for Black-winged Mynas should be prioritized, 377 and if conditions could be improved across the entire potentially suitable habitat, with a 378 population density matching the average estimated for its current range, BNP might be able to 379 support a population in excess of 1,000 Black-winged Mynas. However, there remain at least 380 three significant barriers to such population recovery-trapping, overgrazing and invasive 381 thorny acacia.

382 There are, however, several difficulties associated with building distributional models for 383 species with small remnant populations that were once widespread and have declined due to 384 multiple and concurrent factors. These difficulties may help to explain why the species is 385 currently not occupying habitat identified by our model as suitable. First, it is possible that part 386 of the population occupies suboptimal habitat constituting a demographic 'sink', where mortality 387 exceeds productivity (Howe et al. 1991), in which case our model may have considered 388 suboptimal habitat suitable for the species. Second, characterizing trapping pressure is difficult 389 and direct indices are seldom available (but see Biddle et al. 2021). Metrics of remoteness 390 (distance from roads or human settlements) may explain, to some degree, such anthropogenic 391 pressures at a large scale (Benítez-López et al. 2017, Shaney et al. 2017, Symes et al. 2018), but 392 fail to account for spatially discrete forms of anthropogenic protection that benefit some species 393 such as guarding (Demerdzhiev et al. 2014); tourism, as on Komodo (Reuleaux et al. 2020); 394 community-based conservation (Watson et al. 2007); and special land status such as sacred 395 groves (Plieninger et al. 2020). The mynas at BNP appear to benefit from a combination of 396 guarding and tourism (or even research) activities, for which spatial data reflecting the 397 complexity of the situation were not available. Third, the myna population in BNP is clumped, so 398 projecting this distribution onto other parts of the—albeit relatively small—park needs to be 399 done with care, as habitat and other relationships may not hold in other areas. This caveat extends 400 to other protected areas in East Java (e.g., Meru Betiri and Alas Purwo National Parks), and 401 especially to non-protected areas, where habitat associations and trapping pressures may be 402 different. In fact, the lack of studies when the species was still common means that its true habitat 403 preferences remain uncertain, but they may have included a wider range of habitats than those 404 present in BNP, although probably not closed-canopy woodland. Nevertheless, the model built for 405 Baluran is a starting point for use in other protected areas in East Java, and the habitat 406 associations resemble those of the nearby remnant populations of Black-winged Myna around 407 Bali Barat National Park (TMS pers. obs.).

408 The most likely constraint on the size of the myna population in BNP is trapping for the 409 domestic pet trade. Black-winged Mynas have been heavily trapped and traded over four or five 410 decades for cage-bird markets across Java (Collar et al. 2001, Shepherd et al. 2016, Nijman et al. 411 2018); such is their value that seven years ago 151 individuals were stolen in a highly organized 412 raid on a well-guarded conservation breeding center (Tritto and Sözer 2014). Recently, mynas 413 explicitly identified as trapped in Baluran have been openly advertised for sale online (Bruslund 414 et al. 2021). Evidence from our study suggests that the species persists only in the small area 415 where we found them because birds there are afforded protection against trapping. This likely 416 comes from three sources: the heavy park staff presence at Bekol, which houses an office, 417 conservation breeding enclosure and guard post; tourist activity, which is centered around Bekol and Bama and which saw visitors rise from 39,874 in 2013 to 245,901 in 2020 (Padmanaba et al. 418 419 2017; BNP unpublished data); and the presence of park staff, contract workers and the 420 Copenhagen Zoo project team performing savanna restoration at Balanan. Elsewhere in the park trappers may be less constrained, owing to the much less frequent presence of guards andtourists.

423 A second constraint on Black-winged Mynas at BNP is savanna degradation and disturbance resulting from the 5,000 domestic livestock grazing and browsing some 56 km<sup>2</sup> of 424 425 the park's northern savannas (Pudyatmoko 2017), representing 21% of the park's total area. Just 426 over half of the 4,000 cattle and all of the goats are kept by inhabitants of the settlements along 427 BNP's northern coast from Labuhan Merak to Simacan, with the remainder kept by residents of 428 Karang Tekok village (Pudyatmoko 2017). Most of the livestock belong to a few members of the 429 local elite and are loaned to keepers under a *gaduh* system, whereby owners take the profit from 430 cattle sold for slaughter and keepers retain calves born on pasture, with a ten-fold difference in 431 annual profit in favor of owners (Wianti 2014, Pudyatmoko et al. 2018). Low-intensity grazing 432 can be beneficial for many starlings and mynas because it maintains a low sward height (Fuller 433 et al. 2013), providing birds with access to surface and topsoil invertebrates (Heldbjerg et al. 434 2016, van Balen and Collar 2021), while manure increases food availability by promoting plant 435 and invertebrate abundance and diversity (McNaughton 1985, Steinauer and Collins 1995, 436 Plantureux et al. 2005). Indeed, like other Acridotheres, Black-winged Mynas commonly associate 437 with large herbivores, feeding on invertebrates from the ground they disturb (Collar et al. 2001). 438 However, the current high intensity of grazing by domestic livestock in the northern savannas of 439 BNP probably greatly exceeds former natural levels based on the maximum recent population 440 sizes for the entire park of water buffalo (1,293 in 1984; Suhadi 2009) and banteng (267 in 2000; 441 Winnasis et al. 2011), and the graziers who accompany livestock are a source of disturbance to 442 wildlife (Pudyatmoko 2017). The resulting soil impoverishment (Dormaar and Willms 1998, 443 Villamil et al. 2001) and atrophied biodiversity (Olff and Ritchie 1998, Dhaou et al. 2010) 444 associated with intensive grazing seriously reduces the habitat suitability for Black-winged Myna 445 and other savanna-dependent wildlife.

That the recent clearance of thorny acacia within the Bekol area has coincided with an apparent population upturn of Black-winged Mynas (our population estimate of around 179 448 individuals is substantially higher than the maximum flock sizes reported in the 2010s) suggests 449 that thorny acacia is a poor habitat for the species, despite the relatively high usage registered in 450 our results, caused by birds perching in acacias fringing open foraging areas. Thorny acacia 451 spreads rapidly, replacing savanna with impenetrable thickets and reducing the food available to 452 savanna-dependent wildlife (Kriticos et al. 1999, Dhileepan 2009, Zahra et al. 2020). Dense stands 453 had engulfed the savanna at Bekol, Balanan and Kramat by 1993, covering an estimated 12 km<sup>2</sup> 454 (Schuurmans 1993 in Setiabudi et al. 2013), and despite restoration attempts since 1985, with 455 some of Bekol savanna successfully cleared (Zahra et al. 2020), by 2014 the overall acacia cover 456 had increased (Sutomo et al. 2020). Since 2016, thorny acacia clearance at Balanan has restored 457 3.6 km<sup>2</sup> of grassland (Copenhagen Zoo 2021), which has been used by Black-winged Mynas, 458 including for breeding (TMS pers. obs.). Our habitat classification indicated that there are at least 459 another 12 km<sup>2</sup> of thorny acacia within BNP in monospecific stands, most of which are close to 460 the current Black-winged Myna range and Simacan settlement (Figure 4); efforts to clear this are 461 therefore a priority and could double the habitat immediately available to the species.

462 If birds (re)colonize this area, guard patrols must of course follow. Such protection could 463 be supported by the mapping of nesting and particularly roosting areas, which are probably 464 where most trapping is done; well-protected nest-boxes could be deployed to encourage 465 dispersing birds, as practiced in early reintroduction attempts (Tritto 2014), particularly as the 466 myna's natural cavity nest sites may have been reduced in number by the removal of dead trees 467 for fuelwood near settlements (TMS pers. obs.). Patrolling also needs to target beaches, land 468 access points, and the northern settlements where mynas and Baluran's other key species are 469 suspected of being smuggled out of the park (Winnasis et al. 2011).

A crucial underpinning of any conservation management of Black-winged Mynas will be engagement with the park's human communities, especially those at Simacan and along BNP's northern coast. Such work has been instrumental in protecting species facing similar anthropogenic pressures elsewhere: the Philippine Cockatoo (*Cacatua haematuropygia*) was trapped almost to extinction until a conservation program trained and employed ex-trappers as 475 wardens and involved local communities in wildlife monitoring (Widmann et al. 2006). 476 Communities living inside BNP could likewise be recruited to support a nestbox and monitoring 477 scheme for Baluran's mynas in a type of payment for ecosystem services arrangement (Ferraro 2011). In 2016 BNP established a 20 km<sup>2</sup> 'special use zone' in a bid to settle a long-standing 478 479 dispute over the communities' land rights (Mulyana et al. 2010, Wianti 2014, Pudyatmoko et al. 480 2018), which suggests that local goodwill might allow such a project to be implemented. 481 Nevertheless, further negotiations are essential to achieve a significant but equitable reduction 482 in grazing pressure in the 56 km<sup>2</sup> of highly degraded northern savanna, for example, by keeping 483 cattle in enclosures and providing alternative livelihoods (Pudyatmoko et al. 2018).

484 Protected areas are understandably the first option considered when seeking to preserve 485 species, because they provide a pre-existing legal, geographical, organizational and social 486 framework for the endeavor, and often also because they are the last places where the species of 487 concern survive. With the western form of Black-winged Myna, nominate melanopterus, 488 apparently extinct in the wild and the Bali form *tertius* not known to number more than 35 inside 489 Bali Barat National Park, Baluran National Park represents by far the most important opportunity 490 to save the Black-winged Myna from the trapping pressure that is driving it to extinction. The 491 cases of the Javan Pied Starling (Gracupica jalla), now almost certainly extinct in the wild (van 492 Balen and Collar 2021), and the Bali Myna, once thought extinct in the wild and now surviving 493 only through intensely managed reintroductions (Jepson 2016), serve as examples of what the 494 near future could hold for the Black-winged Myna without effective action.

495 At Baluran, there is scope to increase its small population by habitat restoration and 496 enhancement, elevated protective vigilance and strong community engagement, building on 497 established models trialed elsewhere in the world. Nevertheless, open-country starlings and 498 mynas tend to make medium-distance movements to forage and explore (Bruun and Smith 2003, 499 Minderman et al. 2010, Astudillo et al. 2019), so protected areas cannot be expected to harbor 500 them indefinitely. In the longer term, therefore, such species, especially if under pressure from 501 trapping, will have to be conserved by management strategies that embrace adaptation and 502 improvisation, taking advantage of the various types of security provided by mining or 503 geothermal operations (Randriamamonjy et al. 2015, Devenish et al. 2021), religious sites 504 (Colding and Folke 1997), tourist resorts (Moritz et al. 2017) and organic farming, all of which 505 may to some extent be leveraged to create appropriate socio-ecological conditions to allow them 506 to survive within working landscapes. Other interventions proposed for exploited wider-ranging 507 species include demand reduction (Burivalova et al. 2017, Marshall et al. 2020), commercial 508 breeding (Jepson et al. 2011) and better enforcement of trade laws (Nijman 2010), and all of these 509 measures could be applied in the case of the Black-winged Myna, whose recovery in Baluran could 510 also be abetted by supplementations of captive-bred birds. What can be achieved at Baluran in 511 the next decade may therefore point the way for many species recoveries, not just of threatened 512 songbirds and not just in protected areas, across Indonesia and indeed the world.

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## 514 LITERATURE CITED

- Abram, N. K., E. Meijaard, J. A. Wells, M. Ancrenaz, A.-S. Pellier, R. K. Runting, D. Gaveau, S. Wich,
  Nardiyono, A. Tjiu, A. Nurcahyo, and K. Mengersen (2015). Mapping perceptions of
  species' threats and population trends to inform conservation efforts: the Bornean
  orangutan case study. Diversity and Distributions 21:487–499.
- Agardy, T., P. Bridgewater, M. P. Crosby, J. Day, P. K. Dayton, R. Kenchington, D. Laffoley, P.
  McConney, P. A. Murray, J. E. Parks, and L. Peau (2003). Dangerous targets? Unresolved
  issues and ideological clashes around marine protected areas. Aquatic Conservation:
  Marine and Freshwater Ecosystems 13:353–367.
- Aguirre, A. A., R. Catherina, H. Frye, and L. Shelley (2020). Illicit wildlife trade, wet markets, and
   COVID-19: preventing future pandemics. World Medical & Health Policy 12:256–265.
- Annorbah, N. N. D., N. J. Collar, and S. J. Marsden (2016). Trade and habitat change virtually
   eliminate the Grey Parrot *Psittacus erithacus* from Ghana. Ibis 158:82–91.
- Araújo, M. B., and A. Guisan (2006). Five (or so) challenges for species distribution modelling.
  Journal of Biogeography 33:1677–1688.
- Astudillo, P. X., D. G. Schabo, D. C. Siddons, and N. Farwig (2019). Patch-matrix movements of birds
   in the páramo landscape of the southern Andes of Ecuador. Emu Austral Ornithology
   119:53–60.
- van Balen, S. (Bas), and N. J. Collar (2021). The vanishing act: a history and natural history of the
   Javan Pied Starling *Gracupica jalla*. Ardea 109:41–54.

- 534 Baluran National Park (2008). Peta penutupan lahan kawasan Taman Nasional Baluran.
- Barber-Meyer, S. M. (2010). Dealing with the clandestine nature of wildlife-trade market surveys.
   Conservation Biology 24:918–923.
- Benítez-López, A., R. Alkemade, A. M. Schipper, D. J. Ingram, P. A. Verweij, J. A. J. Eikelboom, and
  M. A. J. Huijbregts (2017). The impact of hunting on tropical mammal and bird
  populations. Science 356:180–183.
- Bergin, D., S. C. L. Chng, J. A. Eaton, and C. R. Shepherd (2018). The final straw? An overview of
  Straw-headed Bulbul *Pycnonotus zeylanicus* trade in Indonesia. Bird Conservation
  International 28:126–132.
- 543Biddle, R., I. Solis-Ponce, M. Jones, M. Pilgrim, and S. Marsden (2021). Parrot ownership and544capture in coastal Ecuador: developing a trapping pressure index. Diversity 13:15.
- 545BirdLifeInternational(2021).Speciesfactsheet:Acridotherestricolor.546http://datazone.birdlife.org.
- 547 Breiman, L. (2001). Random Forests. Machine Learning 45:5–32.
- 548 Brillianti, D. H., J. B. Hernowo, and L. B. Prasetyo (2019). Perkembangan populasi jalak putih
  549 (*Sturnus melanopterus* Daudin 1800) di Taman Nasional Bali Barat. Jurnal Pengelolaan
  550 Sumberdaya Alam dan Lingkungan 9:97–105.
- Bruslund, S., B. Leupen, K. Indraswari, and C. R. Shepherd (2021). Online trade records of Grey backed Myna *Acridotheres tricolor* may indicate poaching practices in Baluran National
   Park, East Java, Indonesia. BirdingASIA 35:102–105.
- Bruun, M., and H. G. Smith (2003). Landscape composition affects habitat use and foraging flight
   distances in breeding European starlings. Biological Conservation 114:179–187.
- 556 Buckland, S. T. (2001). Introduction to distance sampling. Oxford University Press, Oxford, UK.
- 557 Buckland, S. T. (2004). Advanced distance sampling. Oxford University Press, Oxford, UK.
- Buckland, S. T., S. J. Marsden, and R. E. Green (2008). Estimating bird abundance: making methods
   work. Bird Conservation International 18:S91–S108.
- Burgman, M. A., and J. C. Fox (2003). Bias in species range estimates from minimum convex
   polygons: implications for conservation and options for improved planning. Animal
   Conservation 6:19–28.
- Burivalova, Z., T. M. Lee, F. Hua, J. S. H. Lee, D. M. Prawiradilaga, and D. S. Wilcove (2017).
  Understanding consumer preferences and demography in order to reduce the domestic
  trade in wild-caught birds. Biological Conservation 209:423–431.
- 566 Chefaoui, R. M., and J. M. Lobo (2008). Assessing the effects of pseudo-absences on predictive
   567 distribution model performance. Ecological Modelling 210:478–486.
- 568 Chng, S. C. L., and J. A. Eaton (2016). In the market for extinction: Eastern and Central Java.
   569 TRAFFIC, Selangor, Malaysia.
- 570 Colding, J., and C. Folke (1997). The relations among threatened species, their protection, and
   571 taboos. Conservation Ecology 1.

- 572 Collar, N. J., A. V. Andreev, S. Chan, M. J. Crosby, S. Subramanya, and J. A. Tobias (Editors) (2001).
  573 Threatened birds of Asia: The BirdLife International Red Data Book. BirdLife
  574 International, Cambridge, UK.
- 575 Collar, N. J., L. Gardner, D. F. Jeggo, B. Marcordes, A. Owen, T. Pagel, T. Pes, A. Vaidl, R. Wilkinson,
  576 and R. Wirth (2012). Conservation breeding and the most threatened birds in Asia.
  577 BirdingASIA 18:50–57.
- 578 Copenhagen Zoo (2021). Konservasi satwaliar di Taman Nasional Baluran: laporan capaian
  579 program kerjasama Januari 2015-Desember 2020. Copenhagen Zoo (Baluran National
  580 Park Project), Java, Indonesia.
- Demerdzhiev, D., S. Stoychev, D. Dobrev, S. Spasov, and N. Terziev (2014). Conservation measures
   undertaken to improve the population status of eastern imperial eagle (*Aquila heliaca*) in
   Bulgaria. Slovak Raptor Journal 8:27–39.
- Devenish, C., A. R. Junaid, R. Saryanthi, S. (B) van Balen, F. Kaprawi, G. C. Aprianto, R. Stanley, O.
  Poole, A. Owen, N. J. Collar, and S. J. Marsden (2021). Biological richness of Gunung Slamet,
  Central Java, and the need for its protection. Oryx in press.
- 587 Dhaou, S. O., F. Abdallah, A. O. Belgacem, and M. Chaieb (2010). The protection effects on floristic
   588 diversity in a North African pseudo-savanna. Pakistan Journal of Botany 42:1501–1510.
- 589 Dhileepan, K. (2009). Acacia nilotica ssp. indica (L.) Willd. ex Del. (Mimosaceae). In Weed
  590 biological control with arthropods in the tropics: towards sustainability. Cambridge
  591 University Press, Cambridge, UK, pp. 17–37.
- Dirzo, R., H. S. Young, M. Galetti, G. Ceballos, N. J. B. Isaac, and B. Collen (2014). Defaunation in the
   Anthropocene. Science 345:401–406.
- Dolman, P. M., K. M. Scotland, R. J. Burnside, and N. J. Collar (2021). Sustainable hunting and the
   conservation of the threatened houbara bustards. Journal for Nature Conservation
   61:126000.
- 597 Dormaar, J. F., and W. D. Willms (1998). Effect of forty-four years of grazing on fescue grassland
   598 soils. Journal of Range Management 51:122–126.
- Eaton, J. A., C. R. Shepherd, F. E. Rheindt, J. B. C. Harris, S. (B) van Balen, D. S. Wilcove, and N. J.
   Collar (2015). Trade-driven extinctions and near-extinctions of avian taxa in Sundaic
   Indonesia. Forktail 31:1–12.
- 602 eBird (2021). eBird: An online database of bird distribution and abundance [web application].
   603 eBird, Cornell Lab of Ornithology, Ithaca, New York. http://www.ebird.org.
- Feare, C., and A. Craig (1998). Starlings and mynas. Helm, London.
- Ferraro, P. J. (2011). The future of payments for environmental services. Conservation Biology
  25:1134–1138.
- 607 Ghosh-Harihar, M., R. An, R. Athreya, U. Borthakur, P. Chanchani, D. Chetry, A. Datta, A. Harihar, K.
  608 K. Karanth, D. Mariyam, D. Mohan, et al. (2019). Protected areas and biodiversity
  609 conservation in India. Biological Conservation 237:114–124.
- Harris, J. B. C., M. W. Tingley, F. Hua, D. L. Yong, J. M. Adeney, T. M. Lee, W. Marthy, D. M.
  Prawiradilaga, C. H. Şekercioğlu, Suyadi, N. Winarni, and D. S. Wilcove (2017). Measuring

- the impact of the pet trade on Indonesian birds: bird declines from pet trade.Conservation Biology 31:394–405.
- Heldbjerg, H., A. D. Fox, G. Levin, and T. Nyegaard (2016). The decline of the Starling *Sturnus vulgaris* in Denmark is related to changes in grassland extent and intensity of cattle
   grazing. Agriculture, Ecosystems & Environment 230:24–31.
- Hijmans, R. J. (2020). raster: Geographic data analysis and modeling. https://CRAN.R project.org/package=raster.
- Howe, R. W., G. J. Davis, and V. Mosca (1991). The demographic significance of 'sink' populations.
  Biological Conservation 57:239–255.
- Hughes, A. C. (2017). Understanding the drivers of Southeast Asian biodiversity loss. Ecosphere
  8:e01624.
- Indraswari, K., R. S. Friedman, R. Noske, C. R. Shepherd, D. Biggs, C. Susilawati, and C. Wilson
  (2020). It's in the news: characterising Indonesia's wild bird trade network from mediareported seizure incidents. Biological Conservation 243:108431.
- IUCN (2021). The IUCN Red List of Threatened Species. IUCN Red List of Threatened Species.
   https://www.iucnredlist.org/en.
- Jepson, P., R. J. Ladle, and Sujatnika (2011). Assessing market-based conservation governance
   approaches: a socio-economic profile of Indonesian markets for wild birds. Oryx 45:482–
   491.
- Jepson, P. R. (2016). Saving a species threatened by trade: a network study of Bali starling
   *Leucopsar rothschildi* conservation. Oryx 50:480–488.
- Jonas, H. D., V. Barbuto, Jonas, A. Kothari, and F. Nelson (2014). New steps of change: looking
   beyond protected areas to consider other effective area-based conservation measures.
   Parks 20:111–128.
- Kamp, J., S. Oppel, A. A. Ananin, Y. A. Durnev, S. N. Gashev, N. Hölzel, A. L. Mishchenko, J. Pessa, S.
  M. Smirenski, E. G. Strelnikov, S. Timonen, et al. (2015). Global population collapse in a
  superabundant migratory bird and illegal trapping in China. Conservation Biology
  29:1684–1694.
- Kriticos, D., J. Brown, I. Radford, and M. Nicholas (1999). Plant population ecology and biological
   control: *Acacia nilotica* as a case study. Biological Control 16:230–239.
- Kurniandaru, S. (2008). Providing nest boxes for Java sparrows *Padda oryzivora* in response to
  nest site loss due to building restoration and an earthquake, Prambanan Temple, Java,
  Indonesia. Conservation Evidence 5:62–68.
- Laaksonen, T., and A. Lehikoinen (2013). Population trends in boreal birds: Continuing declines
  in agricultural, northern, and long-distance migrant species. Biological Conservation
  168:99–107.
- Lee, J. G. H., S. C. L. Chng, and J. A. Eaton (Editors) (2016). Conservation strategy for Southeast
  Asian songbirds in trade. Recommendations from the first Asian Songbird Trade Crisis
  Summit 2015 held in Jurong Bird Park, Singapore 27-29 September 2015. Wildlife
  Reserves Singapore/TRAFFIC.

- Li, J., D. Wang, H. Yin, D. Zhaxi, Z. Jiagong, G. B. Schaller, C. Mishra, T. M. Mccarthy, H. Wang, L. Wu,
  L. Xiao, et al. (2014). Role of Tibetan Buddhist Monasteries in Snow Leopard Conservation.
  Conservation Biology 28:87–94.
- Marshall, H., N. J. Collar, A. C. Lees, A. Moss, P. Yuda, and S. J. Marsden (2020). Spatio-temporal
   dynamics of consumer demand driving the Asian Songbird Crisis. Biological Conservation
   241:108237.
- McNaughton, S. J. (1985). Ecology of a grazing ecosystem: the Serengeti. Ecological Monographs
   55:260–294.
- Millard, K., and M. Richardson (2015). On the importance of training data sample selection in
   random forest image classification: a case study in peatland ecosystem mapping. Remote
   Sensing 7:8489–8515.
- Miller, D. L., E. Rexstad, L. Thomas, L. Marshall, and J. L. Laake (2019). Distance sampling in R.
  Journal of Statistical Software 89:1–28.
- Minderman, J., J. M. Reid, M. Hughes, M. J. H. Denny, S. Hogg, P. G. H. Evans, and M. J. Whittingham
  (2010). Novel environment exploration and home range size in starlings *Sturnus vulgaris*.
  Behavioral Ecology 21:1321–1329.
- Moritz, C., F. Ducarme, M. J. Sweet, M. D. Fox, B. Zgliczynski, N. Ibrahim, A. Basheer, K. A. Furby, Z.
  R. Caldwell, C. Pisapia, G. Grimsditch, and A. Abdulla (2017). The "resort effect": can tourist
  islands act as refuges for coral reef species? Diversity and Distributions 23:1301–1312.
- Mulyana, A., M. Moeliono, P. Minnigh, Y. Indriatmoko, G. Limberg, N. A. Utomo, R. Iwan,
  Saparuddin, and Hamzah (2010). Establishing special use zones in national parks: can it
  break the conservation deadlock in Indonesia? Center for International Forestry Research
  (CIFOR).
- Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. A. B. da Fonseca, and J. Kent (2000). Biodiversity
   hotspots for conservation priorities. Nature 403:853–858.
- Negi, C. (2010). The institution of taboo and the local resource management and conservation
  surrounding sacred natural sites in Uttakahand, Central Himalaya. International Journal
  of Biodiversity and Conservation 2:186–195.
- Nijman, V. (2010). An overview of international wildlife trade from Southeast Asia. Biodiversity
   and Conservation 19:1101–1114.
- Nijman, V. (2020). IUCN Red List of Threatened Species: *Trachypithecus auratus*. IUCN Red List of
   Threatened Species.
- Nijman, V., A. Langgeng, H. Birot, M. A. Imron, and K. A. I. Nekaris (2018). Wildlife trade, captive
   breeding and the imminent extinction of a songbird. Global Ecology and Conservation 15.
   https://doi.org/10.1016/j.gecco.2018.e00425.
- 687 Olff, H., and M. E. Ritchie (1998). Effects of herbivores on grassland plant diversity. Trends in
   688 Ecology & Evolution 13:261–265.
- Padmanaba, M., K. W. Tomlinson, A. C. Hughes, and R. T. Corlett (2017). Alien plant invasions of
   protected areas in Java, Indonesia. Scientific Reports 7:1–11.

- 691 Pebesma, E. (2018). Simple features for R: standardized support for spatial vector data. The R
  692 Journal 10:439-446.
- Pennington, R. T., C. E. R. Lehmann, and L. M. Rowland (2018). Tropical savannas and dry forests.
   Current Biology 28:R541–R545.
- Pimm, S. L., C. N. Jenkins, R. Abell, T. M. Brooks, J. L. Gittleman, L. N. Joppa, P. H. Raven, C. M.
  Roberts, and J. O. Sexton (2014). The biodiversity of species and their rates of extinction,
  distribution, and protection. Science 344:1246752.
- Plantureux, S., A. Peeters, and D. McCracken (2005). Biodiversity in intensive grasslands: effect of
   management, improvement and challenges. Agronomy Research 3:153–164.
- Plieninger, T., C. Quintas-Soriano, M. Torralba, K. M. Samani, and Z. Shakeri (2020). Social dynamics of values, taboos and perceived threats around sacred groves in Kurdistan, Iran.
   People and Nature 2:1237–1250.
- Potapov, P., X. Li, A. Hernandez-Serna, A. Tyukavina, M. C. Hansen, A. Kommareddy, A. Pickens, S.
  Turubanova, H. Tang, C. E. Silva, J. Armston, et al. (2021). Mapping global forest canopy
  height through integration of GEDI and Landsat data. Remote Sensing of Environment
  253:112165.
- Prakash, V., T. H. Galligan, S. S. Chakraborty, R. Dave, M. D. Kulkarni, N. Prakash, R. N. Shringarpure,
   S. P. Ranade, and R. E. Green (2019). Recent changes in populations of Critically
   Endangered *Gyps* vultures in India. Bird Conservation International 29:55–70.
- 710Prijono,A.(2014).DilemaBaluran.NationalGeographicIndonesia.711https://nationalgeographic.grid.id/read/13278631/dilema-baluran?page=all.
- Pudyatmoko, S. (2017). Free-ranging livestock influence species richness, occupancy, and daily
   behaviour of wild mammalian species in Baluran National Park, Indonesia. Mammalian
   Biology 86:33-41.
- Pudyatmoko, S., A. Budiman, and S. Kristiansen (2018). Towards sustainable coexistence: people
   and wild mammals in Baluran National Park, Indonesia. Forest Policy and Economics
   90:151–159.
- R Core Team (2020). R: a language and environment for statistical computing. R Foundation for
   Statistical Computing, Vienna, Austria. https://www.r-project.org/.
- Randriamamonjy, V. C., A. Keane, H. J. Razafimanahaka, R. K. B. Jenkins, and J. P. G. Jones (2015).
  Consumption of bushmeat around a major mine, and matched communities, in
  Madagascar. Biological Conservation 186:35–43.
- Reuleaux, A., B. A. Siregar, N. J. Collar, M. R. Panggur, A. Mardiastuti, M. J. Jones, and S. J. Marsden
   (2020). Protected by dragons: Density surface modeling confirms large population of the
   critically endangered Yellow-crested Cockatoo on Komodo Island. The Condor
   122:duaa042.
- Sabarno, M. Y. (2002). Savana Taman Nasional Baluran. Biodiversitas 3:207–212.
- Scheffers, B. R., B. F. Oliveira, I. Lamb, and D. P. Edwards (2019). Global wildlife trade across the
   tree of life. Science 366:71–76.

- Setiabudi, S. Tjitrosoedirdjo, S. S. Tjitrosoedirdjo, I. Mawardi, and S. Bachri (2013). Invasion of
   *Acacia nilotica* into savannas inside Baluran National Park, East Java, Indonesia. Bandung,
   Indonesia.
- Shaney, K., A. Hamidy, M. Walsh, E. Arida, A. Arimbi, and E. Smith (2017). Impacts of
  anthropogenic pressures on the contemporary biogeography of threatened crocodilians
  in Indonesia. Oryx 53:1–12.
- Shepherd, C. R., and P. Cassey (2017). Songbird trade crisis in Southeast Asia leads to the
   formation of IUCN SSC Asian Songbird Trade Specialist Group. Journal of Indonesian
   Natural History 5:3–5.
- Shepherd, C. R., V. Nijman, K. Krishnasamy, J. A. Eaton, and S. C. L. Chng (2016). Illegal trade
  pushing the Critically Endangered Black-winged Myna *Acridotheres melanopterus*towards imminent extinction. Bird Conservation International 26:147–153.
- Sodhi, N. S., L. P. Koh, R. Clements, T. C. Wanger, J. K. Hill, K. C. Hamer, Y. Clough, T. Tscharntke, M.
   R. C. Posa, and T. M. Lee (2010). Conserving Southeast Asian forest biodiversity in human modified landscapes. Biological Conservation 143:2375–2384.
- Steinauer, E. M., and S. L. Collins (1995). Effects of urine deposition on small-scale patch structure
   in prairie vegetation. Ecology 76:1195–1205.
- Suhadi, S. (2009). Population dynamics of banteng, buffalo and deer in Bekol savannah, Baluran
  National Park. Biodiversitas, Journal of Biological Diversity 10:139–145.
- Sutomo, E. van Etten, and R. Iryadi (2020). Use of Landsat imagery to map spread of the invasive
   alien species *Acacia nilotica* in Baluran National Park, Indonesia. Biotropia 27:88–96.
- Sutomo, E. van Etten, and L. Wahab (2016). Proof of *Acacia nilotica* stand expansion in Bekol
   Savanna, Baluran National Park, East Java, Indonesia through remote sensing and field
   observations. Biodiversitas 17:96–101.
- Symes, W. S., D. P. Edwards, J. Miettinen, F. E. Rheindt, and L. R. Carrasco (2018). Combined
   impacts of deforestation and wildlife trade on tropical biodiversity are severely
   underestimated. Nature Communications 9:4052.
- Thuiller, W., D. Georges, R. Engler, and F. Breiner (2020). Ensemble platform for species
   distribution modeling. https://CRAN.R-project.org/package=biomod2.
- Tjur, T. (2009). Coefficients of determination in logistic regression models—a new proposal: the coefficient of discrimination. The American Statistician 63:366–372.
- Tritto, A. (2014). Wiedereinbürgerungsprogramm für den Schwarzflügelstar. ZGAP Mitteilungen
   30:11–13.
- Tritto, A., and R. Sözer (2014). Bird thieves in Java show that Indonesian wildlife crime knows no
   boundaries. Journal of Indonesian Natural History 2:11–12.
- Villamil, M. B., N. M. Amiotti, and N. Peinemann (2001). Soil degradation related to overgrazing in
   the semi-arid southern Caldenal area of Argentina. Soil Science 166:441–452.
- Watson, R. T., J. Rabearivony, and R. Thorstrom (2007). Community-based wetland conservation
   protects endangered species in Madagascar: lessons from science and conservation.
   Banwa 4:83–97.

- Whitten, T., R. E. Soeriaatmadja, and S. A. Afiff (1996). Ecology of Java & Bali. Periplus Editions,
  Singapore.
- Wianti, K. F. (2014). Land tenure conflict in the middle of Africa van Java (Baluran National Park).
   Procedia Environmental Sciences 20:459–467.
- Widmann, P., I. D. L. Widmann, S. H. Diaz, D. V. van den Beukel, and R. Cruz (2006). Potentials and
  limitations of community-based parrot conservation projects—the example of the
  Philippine Cockatoo Conservation Program. 6th International Parrot Convention. pp. 27–
  30.
- Winnasis, S., Sutadi, A. Toha, and R. Noske (2011). Birds of Baluran National Park. Baluran
  National Park, East Java, Indonesia.
- Winnasis, S., P. Yuda, M. A. Imron, M. Iqbal, Rudyanto, and H. A. Wahyudi (Editors) (2020). Atlas
   Burung Indonesia: wujud karya peneliti amatir dalam memetakan burung nusantara.
   Yayasan Atlas Burung Indonesia, Batu, Indonesia.
- Wyler, L. S., and P. A. Sheikh (2008). International illegal trade in wildlife: threats and U.S. policy.
   Congressional Research Service, Washington DC, United States.
- Yong, D. L., K. S. Lim, K. C. Lim, T. Tan, S. Teo, and H. C. Ho (2018). Significance of the globally
   threatened Straw-headed Bulbul Pycnonotus zeylanicus populations in Singapore: a last
   straw for the species? Bird Conservation International 28:133–144.
- Zahra, S., R. Hofstetter, K. Waring, and C. Gehring (2020). Review: the invasion of *Acacia nilotica* in Baluran National Park, Indonesia, and potential future control strategies. Biodiversitas
   21. https://doi.org/10.13057/biodiv/d210115.
- van Zyl, J. (2001). The Shuttle Radar Topography Mission (SRTM): a breakthrough in remote
   sensing of topography. Acta Astronautica 48:559–565.

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