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Contributed Paper

Measuring the impact of the pet trade on Indonesian birds

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Abstract: *The trade in wild animals involves one-third of the world's bird species and thousands of other vertebrate species. Although a few species are imperiled as a result of the wildlife trade, the lack of field studies makes it difficult to gauge how serious a threat it is to biodiversity. We used data on changes in bird abundances across space and time and information from trapper interviews to evaluate the effects of trapping wild birds for the pet trade in Sumatra, Indonesia. To analyze changes in bird abundance over time, we used data gathered over 14 years of repeated bird surveys in a 900-ha forest in southern Sumatra. In northern Sumatra, we surveyed birds along a gradient of trapping accessibility, from the edge of roads to 5 km into the forest interior. We interviewed 49 bird trappers in northern Sumatra to learn which species they targeted and how far they went into the forest to trap. We used prices from Sumatran bird markets as a proxy for demand and, therefore, trapping pressure. Market price was a significant predictor of species declines over time in southern Sumatra (e.g., given a market price increase of approximately $50, the log change in abundance per year decreased by 0.06 on average). This result indicates a link between the market-based pet trade and community-wide species declines. In northern Sumatra, price and change in abundance were not related to remoteness (distance from the nearest road). However, based on our field surveys, high-value species were rare or absent across this region. The median maximum distance trappers went into the forest each day was 5.0 km. This suggests that trapping has depleted bird populations across our remoteness gradient. We found that less than half of Sumatra's remaining forests are >5 km from a major road. Our results suggest that trapping for the pet trade threatens birds in Sumatra. Given the popularity of pet birds across Southeast Asia, additional studies are urgently needed to determine the extent and magnitude of the threat posed by the pet trade.*

Keywords: decline, overexploitation, Sumatra, trapping, wild population, wildlife trade

Medición del Impacto del Mercado de Mascotas sobre las Aves de Indonesia

Resumen: *El mercado de animales silvestres involucra a un tercio de las especies de aves del mundo y a miles de otras especies de vertebrados. Aunque algunas especies se encuentran en peligro como resultado del*

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mercado de vida silvestre, la falta de estudios de campo complica la estimación de cuán seria es esta amenaza para la biodiversidad. Utilizamos datos sobre los cambios en la abundancia de aves a través del espacio y el tiempo y la información de entrevistas de trampeadores para evaluar los efectos del trampeo de aves silvestres para el mercado de mascotas en Sumatra, Indonesia. Para analizar los cambios en la abundancia de aves a lo largo del tiempo utilizamos los datos recolectados durante 14 años de censos repetidos de aves en un bosque de 900-ha en el sur de Sumatra. En el norte de Sumatra, censamos aves a lo largo de un gradiente de accesibilidad para el trampeo, desde las orillas de las carreteras hasta 5 km dentro del interior del bosque. Entrevistamos a 49 trampeadores de aves en el norte de Sumatra para aprender cuáles especies son sus objetivos y cuán lejos se adentraron en el bosque para atraparlas. Utilizamos los precios de los mercados de aves de Sumatra como sustitutos para la demanda y, por lo tanto, de la presión de trampeo. El precio del mercado fue un pronosticador significativo de la declinación de las especies a lo largo del tiempo en el sur de Sumatra (p. ej.: dado un incremento en el precio del mercado de aproximadamente $50, el cambio en el registro de abundancia por año disminuyó en un promedio de 0.06). Este resultado indica una conexión entre el mercado de mascotas basado en la venta y las declinaciones de especies a nivel de la comunidad. En el norte de Sumatra, el precio y el cambio en la abundancia no estuvieron relacionados con la distancia desde la carretera más cercana. Sin embargo, con base en nuestros censos en el campo, las especies de alto valor fueron raras o estuvieron ausentes en esta región. La distancia máxima media que los trampeadores se adentraron en el bosque cada día fue de 0.5 km. Esto sugiere que el trampeo ha mermado a las poblaciones de aves a través de nuestro gradiente de la distancia a la carretera más cercana. Encontramos que menos de la mitad de los bosques que permanecen en Sumatra están a >5 km de una carretera principal. Nuestros resultados sugieren que el trampeo para el mercado de mascotas amenaza a las aves en Sumatra. Dada la popularidad de las aves mascotas en el sureste asiático, se necesitan urgentemente estudios adicionales para determinar la extensión y la magnitud de la amenaza generada por el mercado de mascotas.

Palabras Clave: declinación, mercado de vida silvestre, población silvestre, sobre-explotación, Sumatra, trampeo

Introduction

The trade in wild animals is worth billions of dollars annually (Wilson-Wilde 2010) and encompasses one-third of the world's bird species and thousands of reptile, amphibian, mammal, and fish species (e.g., Schlaepfer et al. 2005; Butchart 2008; Nijman 2010; Raghavan et al. 2013). A small number of species have been added to the International Union for Conservation of Nature Red List of imperiled species due to trapping for the pet trade (e.g., Spix's Macaw [*Cyanopsitta spixii*] in South America; Bali Myna [*Lecopsar rothschildi*], greater slow loris [*Nycticebus coucang*], and red line torpedo barb [*Sahyadria denisonii*] in Asia; and radiated tortoise [*Astrochelys radiata*] in Madagascar) (Collar et al. 1992; IUCN 2015), but they constitute severe cases involving well-studied species. Scientists have not assessed the impact of the pet trade on wild populations for the vast majority of vertebrates sold in markets.

Southeast Asia is a global hotspot for the wild bird trade; >1000 species are sold (J. B. C. H., personal observation) for pets, song competitions, religious animal release, traditional medicine, and food (e.g., McClure & Chaiyaphun 1971; Jepson 2008; Chng et al. 2015; Su et al. 2015). Indonesia is the largest importer and exporter of wild birds in Asia (Nash 1993). Indonesian bird trappers use mist nets, bird lime (an adhesive made from tree sap), snares, and traps baited with decoy birds to catch target species (Shepherd et al. 2004), and mist nets appear to be increasingly popular (J. B. C. H., et al., personal observation). The deep cultural roots of bird keeping in Indonesia have contributed to the country's active bird trade, whereas human population growth and the rise of bird-song competitions have intensified the pressure on Indonesia's wild birds (Jepson 2010). For example, the highly prized Straw-headed Bulbul (*Pycnonotus zeylanicus*) has been extirpated from Java, has not been seen in Sumatra since 2009, and is in steep decline in Indonesian Borneo (Shepherd et al. 2013; BirdLife International 2015; Eaton et al. 2015). Many wild birds of multiple species sold in Javan markets are now sourced from Sumatra because trapping has depleted Javanese bird populations (Jepson & Ladle 2009; Shepherd 2012).

In Sumatra and Java, the ubiquity of trapping, including inside national parks, complicates efforts to assess the impact of the bird trade on wild populations. Possible ways forward are to analyze time series of systematic survey data, which are very scarce in Indonesia; study how bird abundance changes across remoteness gradients, which can serve as proxies for trapping intensity; and use population models to estimate extinction risk based on an estimate of the number of birds caught and the species' life-history traits. Given the lack of high-quality demographic information for virtually all Indonesia's birds, we focused on the first 2, field-based methods to examine the effects of trapping on bird communities in lowland and highland forests. We then related changes in bird abundance to species trait predictor variables to weigh the evidence for the relative effects of trapping, hunting, and habitat change. We also interviewed trappers to determine how far they typically travel in search of valuable birds and their impressions of long-term changes in the catch rates of sought-after species. Finally, we estimated how much of Sumatra's forests may be safe from intensive trapping pressure. Given the high levels of trapping in Sumatra, we hypothesized that commercially valuable species would decline over time and as their proximity to roads increased.

Methods

Study Areas and Field Sampling

We studied changes in bird abundance from 1998 to 2011 at the Way Canguk Research and Training Area, Bukit Barisan Selatan National Park, Lampung province, southern Sumatra (Figs. 1 & 2). The Way Canguk area is one of the few remnants of lowland forest on level terrain in Sumatra (Whitten 2000; Miettinen et al. 2011). Way Canguk consists of 900 ha of lowland forest (50-m elevation and 4000-mm annual rainfall) that includes primary forest (currently 50% of the area) and forest disturbed by fire, drought, and logging (Kinnaird & O'Brien 1998). El Niño-related drought and fires damaged approximately 165 ha of forest in 1997 and 1998 (Kinnaird & O'Brien 1998; Adeney et al. 2006). Understory avian insectivore abundance is significantly lower in burned forest than in unburned forest, and open-field species have colonized burned areas in Way Canguk (Adeney et al. 2006). Way Canguk remained fire-free until 2015, and the forest has recovered, although some exotic plants have invaded (Kinnaird & O'Brien 1998). The site has been subject to trapping for the bird trade since at least the late 1990s (O'Brien & Kinnaird 1996), and trapping has continued up to the present time despite the presence of a research station and national park staff. The most commonly used trapping methods we observed in Way Canguk were attracting birds to branches covered in bird lime with a song recording or a decoy bird in a cage, mist nets combined with decoys or recordings, and snares for catching pheasants.

We quantified bird abundance at Way Canguk with 10-min, unlimited-radius, visual, and aural point counts in 1998–2002, 2007, and 2011 (Supporting Information). Sampling for this study was restricted to unburned forest and forest that was subject to only light ground fires in 1997–1998. Light fires burned dead leaf litter and damaged saplings slightly (leaving most with green leaves); large trees were unaffected (Adeney et al. 2006). We included the lightly burned areas in our survey so that we could increase our statistical power to detect changes in the avifauna over time.

We sampled bird communities along remoteness gradients in the Tanah Karo region of North Sumatra province (Karo, Deli Serdang, Langkat, and Dairi regencies) from March to November 2013 (Fig. 1). We sampled 2 areas of humid montane forest, one near Mt. Sinabung in the north and another near Lake Toba in the south (Supporting Information). These montane forests are important sources of wild birds for the Medan markets (Shepherd et al. 2004) and are therefore under heavy trapping pressure, but there are also remote forests far from roads that may have less trapping. In North Sumatra, we encountered trappers using bamboo traps with live decoys, bird lime placed on perches near live decoys and in fruiting trees, and pheasant snares. Sampling at the northern sites was done before the 2014 eruption of Mt. Sinabung.

We sampled birds aurally by walking transects from 0600 to 1030 in sunny or cloudy weather without wind or rain. Our transects were sections of forest trails approximately 400-m long separated by points spaced 300-m apart (straight line distance) (Fig. 2). Transects were surveyed in March and April ($n = 74$), June ($n = 28$), and November and December ($n = 54$) of 2013. We used the number of minutes spent walking each transect as a measure of survey effort. Transect elevation was approximated by averaging the elevation of the points at each end of each transect. Elevations sampled ranged from 1018 to 1875 m (average 1550 m) (Supporting Information). Approximately 92% of transects were in old-growth forests; the remaining transects were in secondary forests with large remnant trees. Open fields were not sampled. Remoteness was estimated by taking the straight-line distance from the center of the transect to the nearest major road (see Supporting Information for details). Transects ranged in remoteness from 0.1 to 4.9 km from the nearest road (average 1.8 km). Our field sampling was done under RISTEK permit 75/SIP/FRP/SM/III/2013. All data are archived at www.datadryad.org (doi:10.5061/dryad.jm607).

Species Trait Data

We related changes in abundance to species traits associated with 3 potential drivers of population change: the pet trade, subsistence hunting, and habitat change. We used market price as a proxy for demand for pets and, therefore, trapping pressure on a species (e.g., Crookes et al. 2005). Data on sale prices came from surveys in the 4 markets of Medan, North Sumatra, from July to September 2012 (Harris et al. 2015). Medan has the largest and most diverse wildlife markets in Sumatra; species are sold that come from across the island and the rest of Indonesia (Shepherd et al. 2004; Shepherd 2006). A group of Indonesian researchers asked sellers for bird prices during the market surveys (initial asking price, not negotiated) (Harris et al. 2015). When there were multiple prices for a species, we used the average price. We used body size as a proxy for hunting pressure, assuming that hunters would be more likely to target large-bodied species (e.g., Cardillo et al. 2005). Body sizes were the average body

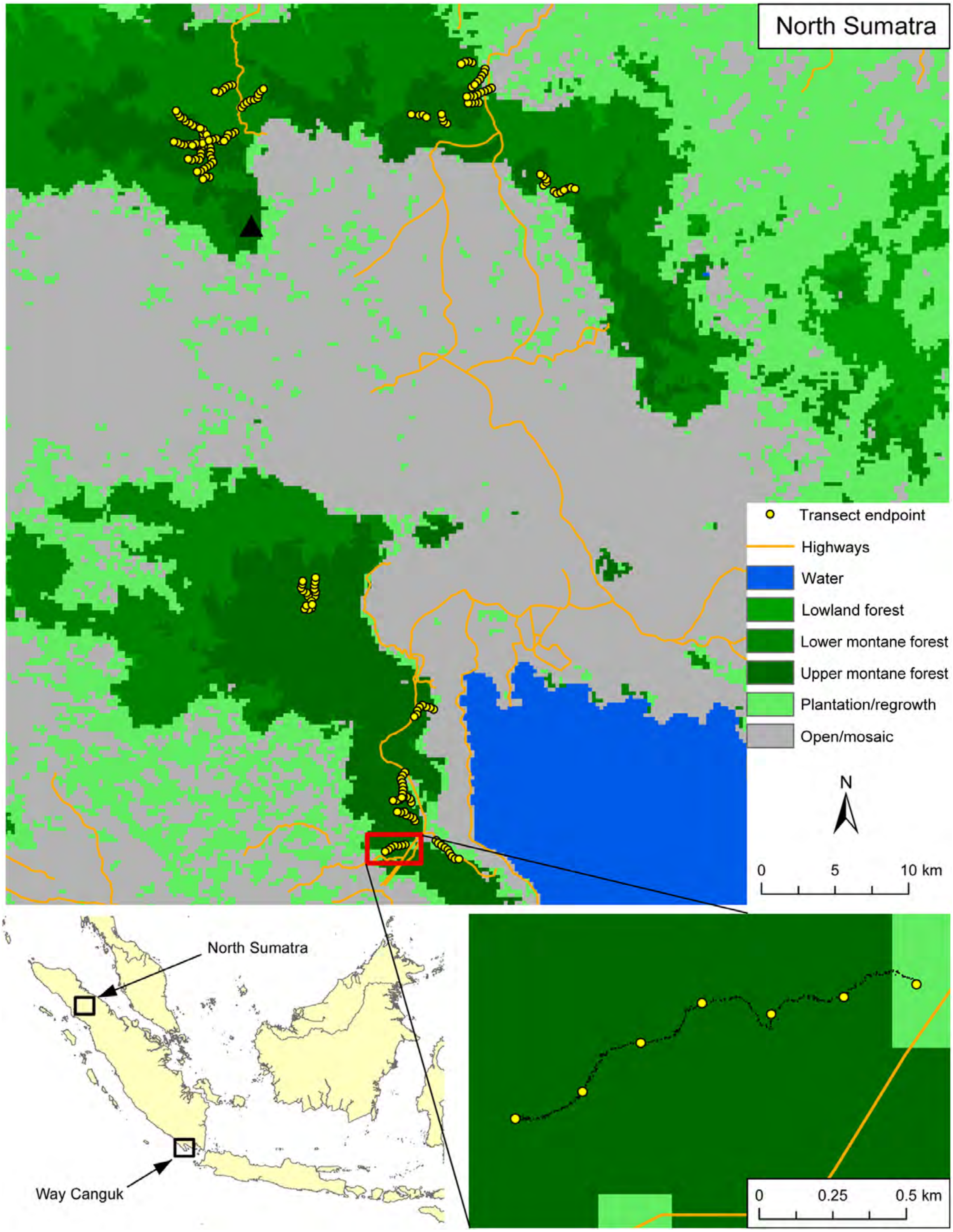

Figure 1. Locations of bird sampling sites within Sumatra (bottom left), locations of sampling sites and land cover (Miettinen et al. 2011) in northern Sumatra (main panel), and an example of a sampling transect in North Sumatra (bottom right) (black triangle, Mt. Sinabung).

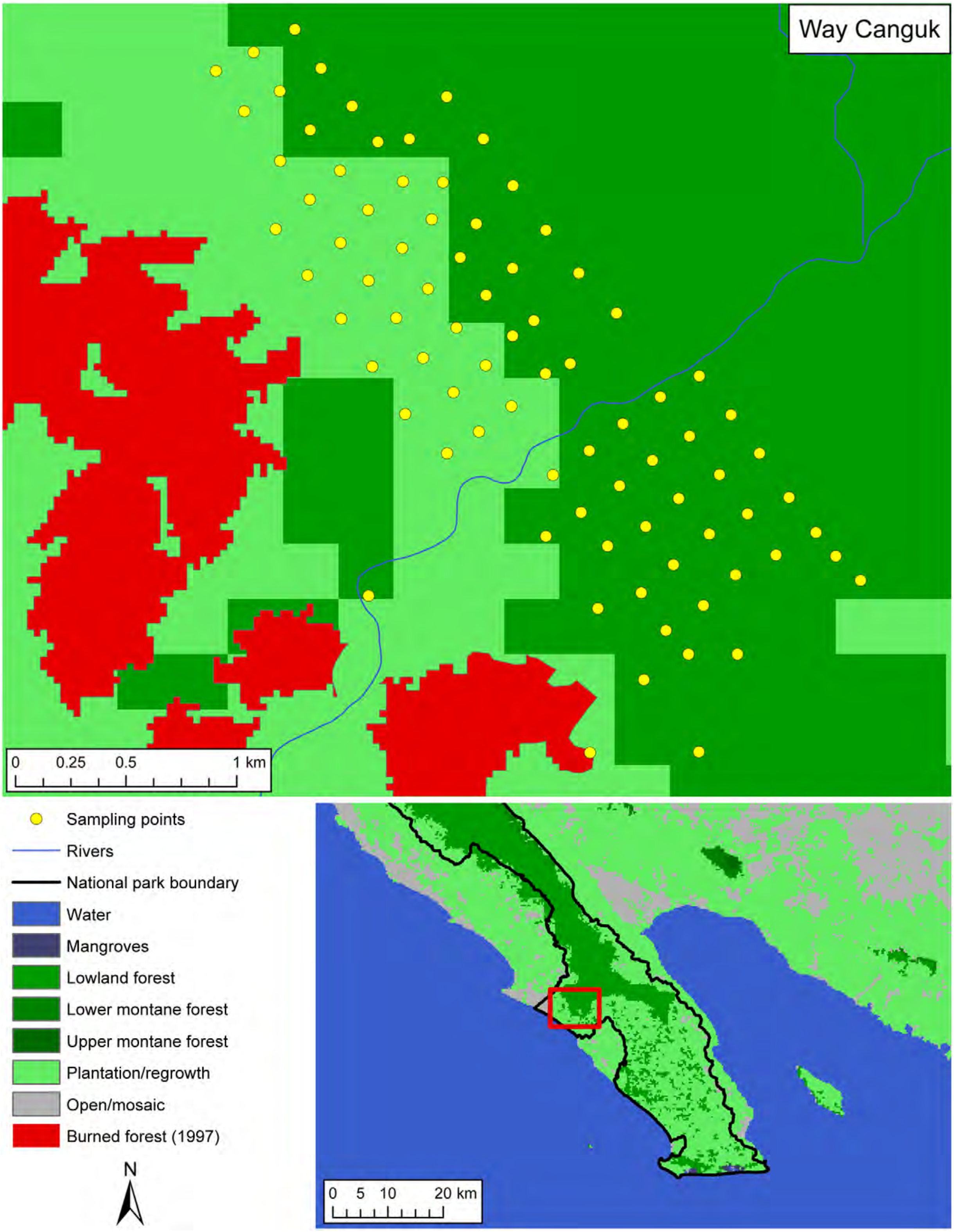

Figure 2. Location of bird sampling sites and land cover (Miettinen et al. 2011) in Way Canguk, Bukit Barisan Selatan National Park, Sumatra.

mass from a global database of avian ecological traits based on the ornithological literature (Sekercioglu et al. 2004; Sekercioglu 2012) updated with data from recent publications (del Hoyo et al. 1992–2009). We ranked species tolerance of anthropogenic disturbance on a scale from 1 to 6. For example, species with a disturbance tolerance of 1 were found only in the interior of primary forest, species with a score of 3 were found in both primary and disturbed secondary forests, and species with a score of 6 were nonforest species. We calculated these scores by combining habitat characterizations from Wells (1999, 2007) with the expert opinion of D.L.Y. (see Supporting Information for details).

In North Sumatra, drongos (*Dicrurus* spp.) and white-eyes (*Zosterops* spp.) were heard commonly, but we could not assign their calls to species. Because Sumatran Drongo (*D. sumatranus*) and Black-capped White-eye (*Z. atricapilla*) were the most commonly seen members of their respective genera in this area, we assigned the trait variables of those 2 species to the genus-level records.

Statistical Analyses

We used hierarchical Bayesian models to simultaneously model changes in abundance over time (Way Canguk) and space (North Sumatra) for each species and to relate these parameters to species traits to weigh the evidence for drivers of change in abundance (Gelman et al. 2013). We limited analyses to the set of species for which we had complete data on these traits and excluded species without price data (i.e., species which we did not find for sale in the Medan markets). We did not assume that species without price data had zero value because prices were derived from current markets, and there are many reasons why species with no price data may not be present in current markets (e.g., supply or demand).

For both Way Canguk and North Sumatra, we modeled the expected change, μ, in log-abundance over time (or change in abundance with distance from road; parameter $\beta 1$) for species i as a linear function of 3 variables representing distinct hypotheses:

$$\mu_{\beta 1,i} = \alpha_0 + \alpha_1 \text{price}_i + \alpha_2 \text{disturbance tolerance}_i + \alpha_3 \text{body size}_i, \quad (1)$$

where α is a slope parameter. For both sites, we inferred the strength of each hypothesized driver of change by evaluating the sign, effect size, and 95th percentile Bayesian credible interval (BCI) of each of the slope parameters ((1)–3). All 3 variables were standardized to an SD 1 prior to modeling so that effect sizes would be directly comparable.

Although the general model structure and basis of inference is the same across the 2 locations, due to differences in data collection and other study-specific factors, the 2 models were parameterized slightly differently. For example, we controlled for transect elevation in North Sumatra in our estimates of $\mu_{\beta 1,i}$ because sites there spanned a montane gradient and bird abundance in Indonesia is related to elevation (e.g., Harris et al. 2014). The overall Bayesian model structure and the differences between the 2 models are described in Supporting Information.

To evaluate our statistical power to detect a trapping effect, we did 2 retrospective (a posteriori) power analyses. These analyses explored the probability of rejecting the null hypothesis that there is no relationship between market price and either temporal or spatial trends in bird abundance (H_0: $\alpha_1 = 0$) for Way Canguk and North Sumatra, respectively. In both cases, we used the posterior means for all other hyperparameters (α_0, α_2, α_3, and σ_α) and a range of values for α_1 in order to probabilistically simulate trends, $\mu_{\beta 1,i}$, for each of the species in both data sets. In both cases, we simulated 5000 sets of $\mu_{\beta 1,i}$ for each of 25 potential values of α_1, ranging from −0.01 to −0.25. We then ran a linear model (identical in parameterization to the formal analysis) on each simulated set of $\mu_{\beta 1,i}$ to determine the proportion of simulations where H_0 would be rejected by finding a 95% credible interval (CI) of α_1 that did not include 0.

Trapper Interviews

Between March and July 2013, we interviewed 49 bird trappers in 21 villages in the Karo, Deli Serdang, and Langkat regencies of North Sumatra province. Trappers ranged in age from 24 to 61 years (average 39 years; see Supporting Information for details, including the interview questions). Interview methods were approved by the Princeton University Institutional Review Board for Human Subjects research, protocol #6161 (https://www.princeton.edu/ria/human-research-protection/committee-information/). We asked trappers which species they seek, how much time they spend trapping them, and how much area they cover when looking for birds each day. We used this information to approximate the proportion of Sumatra's forests that is out of reach of the average bird trapper and to examine changes in catch of sought-after species over time.

We asked each trapper to specify how many kilometers they covered each day in search of birds to approximate how far from villages or roads trappers go to catch birds. Based on their reported distances and our own observations of trapping in the field (e.g., bird snares and perches with bird lime remnants), we estimated the percentage of Sumatra's forests that was out of reach of an average trapper. We did this by comparing the area of mature forest (lowland, montane, peat swamp, and mangroves) (Miettinen et al. 2011) near primary roads (Peta Dasar Indonesia road layers [Supporting Information]) and away from roads in ArcGIS version 10 (ESRI, Redlands, California). Given that our database included only relatively major roads, our estimate of untrapped habitat is conservative.

We asked all 49 trappers to rank bird species based on their perceptions of the birds' sensitivity to trapping (i.e., vulnerability to population decline from trapping). We asked trappers to consider whether a particular species is easy to deplete based on how easy a species is to catch and the ability of the species' population to recover from exploitation. We then analyzed the cases of the 4 most vulnerable species that occur (or once occurred) in the montane forests we sampled in North Sumatra to see if the time spent searching for and catching these species had changed over time. To gather data on these temporal trends, we conducted in-depth interviews with 7 experienced trappers (all men with a mean of 15 years trapping experience). We began this section of the questionnaire by showing the trappers' photographs of 54 regularly traded species (selected by reviewing the native birds that are most commonly traded in Medan [Shepherd et al. 2004; Harris et al. 2015; Supporting Information]). If a trapper acknowledged catching the species in the photograph, then we asked him how long he spends searching for each species, how many he catches per day, and how these variables have changed over time. We used Gaussian mixed-effect models to test for statistical relationships between year and amount of time spent trapping and year and number of birds caught in the lme4 package in R (Bates et al. 2014; R Development Core Team 2015). We coded each trapper as a random intercept because trappers differed in their habits and their responses cannot be considered independent. We used Nakagawa and Schielzeth's (2013) method of calculating marginal and conditional R^2 of the mixed models.

Results

Bird Abundance

We recorded 154 species in Way Canguk, 78 of which had price data and were included in the analysis (hereafter traded birds). Based on posterior means of annual trends in abundance, 33 species of traded birds showed temporal trends in abundance (95% BCI for trends that did not include 0). Of these species, 23 species increased in abundance over time and 10 decreased in abundance (Supporting Information). Current market price and trends of species over time were significantly related; species with higher prices were more likely to decline over time (95% BCI on α_1 −0.10 to −0.03). This effect size indicated that given a market price increase of approximately \$50 (527,706 Indonesian Rupiah), the log-change in abundance per year decreased by 0.03–0.10. Thus, above a market price of 500,000 Indonesian Rupiah (approximately \$50 US), species were more likely to have declined from 1998 to 2011 than to have increased (Fig. 3). Abundance trends of trapped birds at Way Canguk also showed the effects of forest succession; forest-dwelling species intolerant of disturbance increased over time (95% BCI on α_2 −0.10 to −0.03) (Table 1 & Fig. 3). The standardized effect size of price and habitat preference was approximately equal. There was no consistent evidence for a relationship between body size and population trend (weak negative relationship, 95% BCI on α_3 −0.05 to 0.02).

In North Sumatra, we recorded 70 bird species, of which 27 were traded and thus used in the analysis. Relationships between price, disturbance tolerance, or body size and bird abundance along the remoteness gradients were not significant (all 95% BCI overlapped 0) (Table 1 & Fig. 4). There was a nonsignificant trend of larger bodied species being commoner away from roads than near roads (95% BCI −0.07 to 0.23). One species was clearly more common away from roads: the Bronze-tailed Peacock-pheasant (*Polyplectron chalcurum*), which is hunted regularly (Supporting Information). Although true relationships between abundance and remoteness were uncertain in nearly all cases, parameter means indicated that most traded species (21 of 27 species or 78%) (Supporting Information) were more common at greater distances from roads.

Both abundance models showed strong posterior predictive abilities, indicating good model fit (Supporting Information), but the data provided relatively low power to reject the null hypothesis that there is no relationship between market price and either spatial or temporal trends in bird abundance. For Way Canguk, where our empirical findings rejected the null hypothesis, a standardized effect size for α_1 would have needed to be at least −0.13 to reject the null hypothesis 80% of the time. Our empirical finding for Way Canguk was an effect size of −0.064, at which point simulations rejected the null hypothesis only 31.8% of the time (Supporting Information). In North Sumatra, where our empirical findings did not reject the null hypothesis, a standardized effect size for α_1 would have needed to be −0.20 or more extreme to reject the null hypothesis 80% of the time. Our empirical finding for North Sumatra had an effect size of −0.090, at which point the null hypothesis was rejected 24% of the time in simulations (Supporting Information). The lower power for North Sumatra can be attributed to the lower number of traded species providing inference on trends.

Trapper Interviews and Spatial Analysis

The median maximum distance covered by trappers in search of birds was 5 km (mean 7.7 km; 25 trappers provided distance estimates). We also observed evidence of trapping (human-made perches with bird lime remnants) up to 4.9 km from the nearest road. Our spatial analysis showed that 47.6% of Sumatra's remaining mature forests are within 5 km of a major road (Fig. 5).

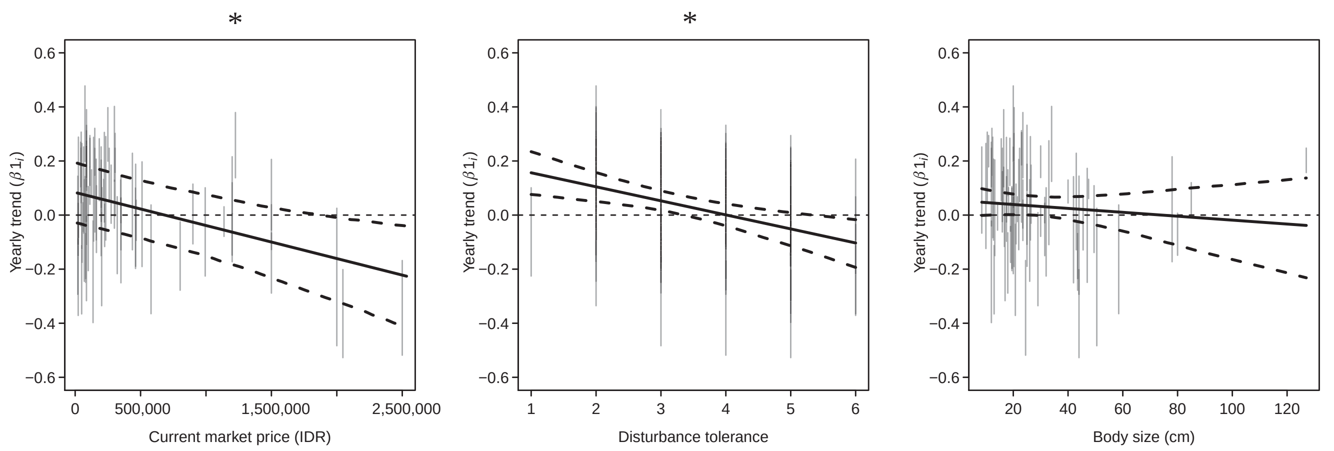

Figure 3. Relationships between bird price, disturbance tolerance, and body size and changes in abundance over time in Way Canguk, Sumatra (, significant slopes as evidenced by 95% BCI that do not overlap 0; dashed lines, 95% credible intervals for the linear trend).*

Table 1. Estimates of relative effects of price, disturbance tolerance, and body size (α parameters) on changes in bird communities over time in Way Canguk, Sumatra, and along remoteness gradients in northern Sumatra.

Parameter	*Mean (95% credible interval)*	*SD*
Way Canguk[a]		
intercept	0.256 (0.149–0.367)	0.056
price[b]	−0.064 (−0.103 to −0.026)	0.02
disturbance[b]	−0.063 (−0.101 to −0.028)	0.019
body size	−0.013 (−0.048 to 0.021)	0.017
Northern Sumatra[c]		
intercept	0.052 (−0.071 to 0.168)	0.06
price	−0.090 (−0.288 to 0.084)	0.092
disturbance	−0.070 (−0.244 to 0.103)	0.088
body size	0.083 (−0.066 to 0.231)	0.076

[a] *Lowland forest, southern Sumatra.*
[b] *Parameters with credible intervals around the coefficient estimates that do not cross 0.*
[c] *Montane forest.*

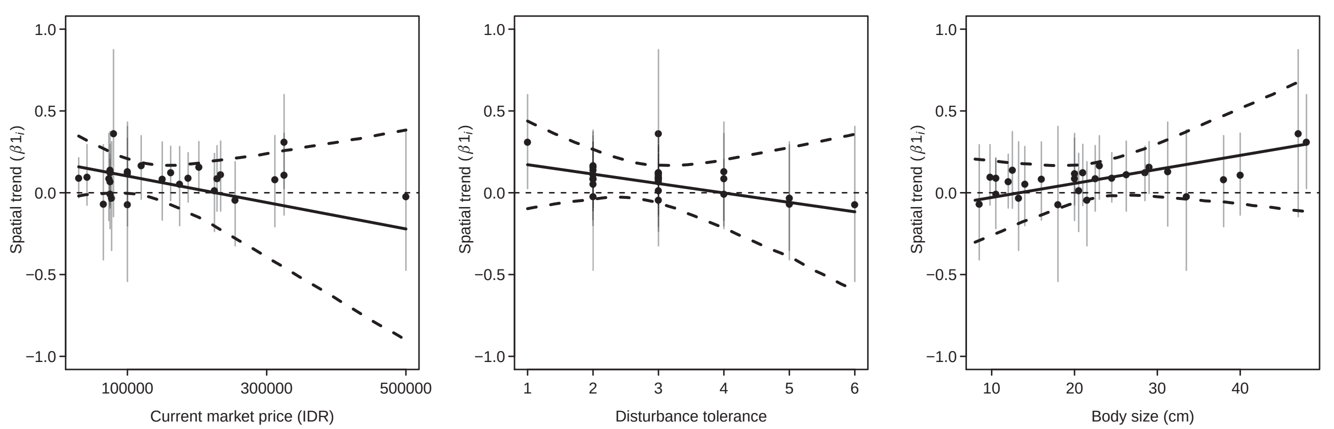

Figure 4. Relationships between bird price, disturbance tolerance, and body size and changes in bird abundance along remoteness gradients (distance from the nearest road) in northern Sumatra (dashed lines, 95% credible intervals for the linear trend). The y-axis shows the coefficient of the abundance to remoteness relationship. There were no significant relationships.

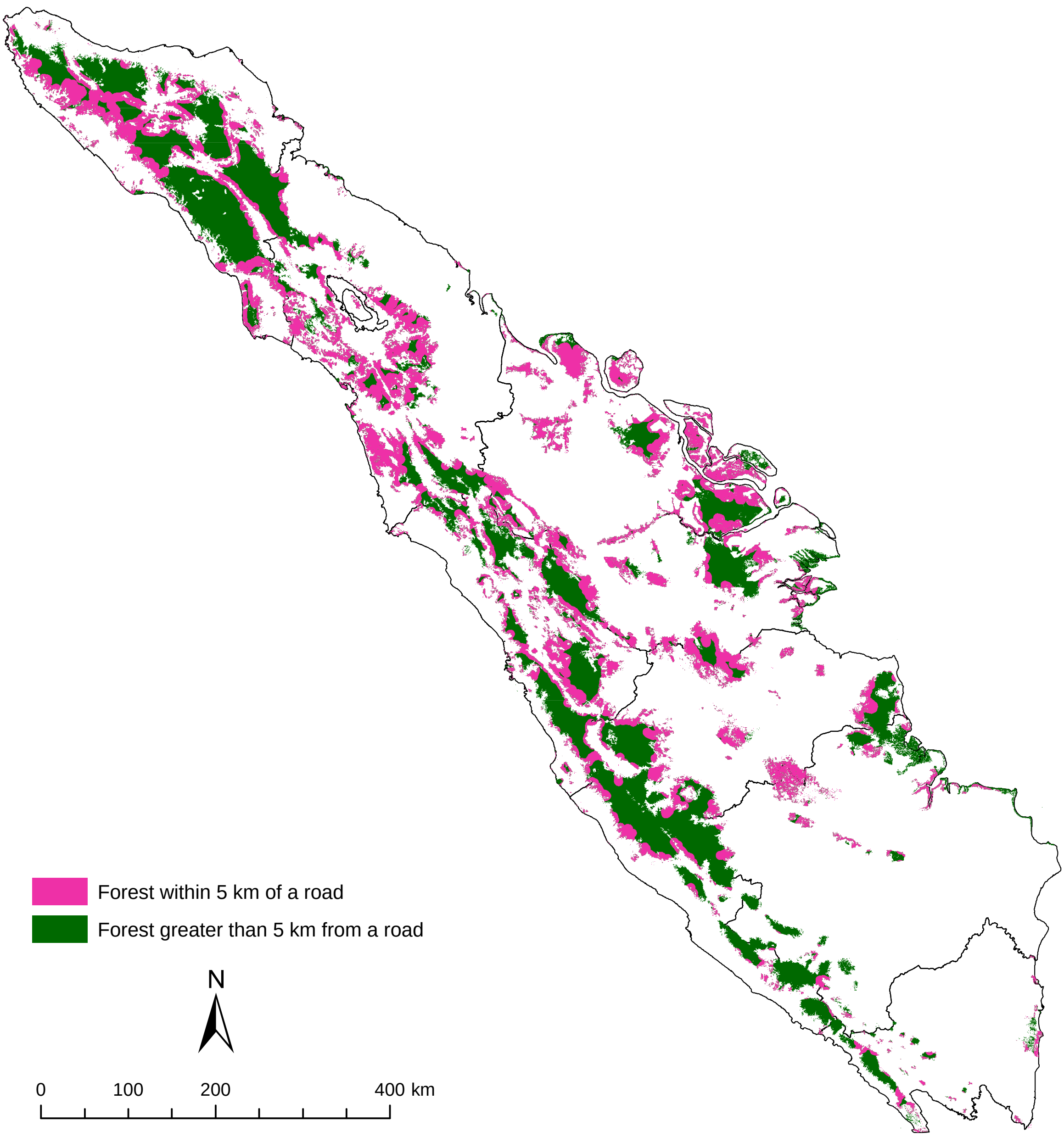

Figure 5. Sumatran forest cover in 2010 (darkest shade, forests >5 km from a road, 110,647 km^2 *in area; lightest shade, forests within 5 km of a road, 52,622 km*^{2} *in area).*

Trappers caught 51 bird species and ranked, in descending order from extremely sensitive to highly sensitive, the following species as especially sensitive to trapping (i.e., vulnerable to population decline): White-rumped Shama (*Copsychus malabaricus*), Oriental Magpie Robin (*C. saularis*), Common Green Magpie (*Cissa chinensis*), Silver-eared Mesia (*Leiothrix argentauris*), Sumatran Laughingthrush (*Garrulax bicolor*), and Chestnut-capped Laughingthrush (*G. mitratus*). Based on our field work and the trapper interviews, 4 of these species occur or once occurred (before heavy trapping) in the montane forests we sampled in North Sumatra: Silver-eared Mesia, Common Green Magpie, and Sumatran and Chestnut-capped Laughingthrushes.

In-depth interviews revealed that experienced trappers are now spending more time searching for all 4 sensitive species than they did in the 1970s and 1980s (Supporting Information). Furthermore, daily catches of Silver-eared Mesia (which was once caught in large numbers according to trappers) have fallen to nearly 0 birds taken per day (only one trapper reported catching this species in 2013), and catches of the other 3 species showed nonsignificant negative trends (Supporting Information). We did not observe Silver-eared Mesias or Sumatran Laughingthrushes in any of our surveys.

Discussion

The most frequently cited threats to Southeast Asian birds are habitat loss and hunting for food (BirdLife International 2008; Wilcove et al. 2013). Here, we present multiple lines of evidence that indicate trapping for the pet trade is causing declines in populations of multiple Sumatran birds. In Way Canguk (southern Sumatra), we found a strong negative relationship between market price and population trend, which suggests that trapping is contributing to the decadal-scale declines of multiple species.

Tolerance to anthropogenic habitat disturbance was also a significant predictor of change in bird abundance in Way Canguk, where forest-dependent species tended to increase over time and open-field species decreased. We attribute these changes to recovery of the forest after the 1997 and 1998 fires. It is also possible that trapping contributed to declines in sought-after open-country species (e.g., Bar-winged Prinia [*Prinia familiaris*]); the relative importance of trapping and habitat change was probably related to the species' market value and life history. Furthermore, some forest-dwelling species that are heavily trapped declined significantly (e.g., White-rumped Shama and Blue-crowned Hanging-parrot [*Loriculus galgulus*]), which implicates trapping. The declines of sought-after species, regardless of habitat, indicated that changes in the avifauna at Way Canguk did not result only from forest regeneration. And, the lack of a relationship between body size and change in abundance suggests that hunting for food is not likely driving bird declines in the area. Population models could be used to delve into the life-history drivers underlying the population trends we observed, perhaps with the use of demographic data from related, well-known species as a proxy for Sumatra's poorly known species (e.g., Brook et al. 2002). A demographic modeling framework could then be used to test future conservation scenarios (e.g., increased enforcement or increased demand for certain species).

In North Sumatra, there were no clear relationships between any of our predictor variables and changes in abundance along the remoteness gradient. The lack of a price relationship may indicate that trapping is not affecting bird populations in the area. However, we posit that trapping has already depleted the bird community within all the forests we surveyed and we were thus unable to detect a price effect. Our reasons for this conclusion are 4-fold. First, trapping occurs regularly out to 5 km in our study area (based on trapper interviews and direct observations during our surveys). Second, 21 of our 27 study species, all of which are traded, had positive (albeit weak) relationships between distance from road and abundance. Third, 2 of the most coveted species—Silver-eared Mesia and Sumatran Laughingthrush—were once caught in large numbers in our study area (up to 30 birds/day), according to trapper interviews, but are now caught rarely. Finally, we did not encounter either of these species in our field surveys.

Our interview results indicated that trappers are spending more time searching for prized species in North Sumatra than they used to. Despite this increase in effort, the current catch of Silver-eared Mesia is near 0, and catches of the other 3 sensitive species are either stable or decreasing over time. This apparent decrease in catch per unit effort (for some species at least) is indicative of overharvesting (Baum et al. 2003; McNamara et al. 2015), which further supports the argument that bird populations have been affected by trapping in all of our field sites in North Sumatra. Indeed, our results indicate that the bird trade may be so pervasive in parts of Indonesia that ecologists and managers need to be alert to shifting-baseline syndrome caused by trapping (Papworth et al. 2009). If we had not found that trappers seek birds at least 5 km inside the forest and that the catch of sensitive species had decreased over time, we might have concluded that bird populations were unaffected by trapping in North Sumatra. Our trapper interview data could be subject to the shifting-baseline syndrome because trapping has gone on for so long in Sumatra. For example, van Marle and Voous noted that the Common Hill Myna *Gracula religiosa* was already in decline from trapping by 1988 (van Marle & Voous 1988).

By 2010, 30% of Sumatra's original forest cover remained (Margono et al. 2012). This alone constitutes a threat to many birds. However, our finding that 47.5% of the remaining forests are within 5 km of a major road, combined with the trapping impacts we detected, suggests that some of Sumatra's birds are in far greater danger than habitat-loss statistics alone would suggest. The actual extent of trapping in Sumatra's forests is likely higher than we found because our road data sets excluded most small roads, which provide trappers with access to forest birds. In addition, tropical forest fires are much more likely to occur near roads (Adeney et al. 2009), and Indonesian fires threaten biodiversity and contribute to climate change (Adeney et al. 2006; Lohman et al. 2007). Predicted increases in road development in tropical countries (Laurance et al. 2014) raise the alarming prospect that both trappers' access to forests and fire risk will continue to increase in the future.

Our results must be interpreted cautiously. It is possible that birds are declining for reasons unrelated to trapping (or hunting or habitat loss) and that their growing scarcity is driving up their prices in the markets. We assumed that price was an adequate proxy of demand for the various uses of wild birds in Indonesia and, therefore, of trapping pressure and that bird-trapper behavior in North Sumatra is reflective of trappers across Sumatra. Our historical trapper-interview data may be subject to a retrospective bias that could have led to overestimates of bird declines (e.g., O'Donnell et al. 2010). Finally, our data provided relatively low power to detect a trapping effect in either data set.

Despite these caveats, our results highlight the urgent need for increased enforcement of trapping regulations in Indonesian protected areas. The trappers we interviewed readily stated that they often caught birds in national parks and that they rarely or never encountered park rangers.

Trapping for the pet trade occurs around the globe and involves many taxonomic groups (e.g., BirdLife International 2008; Rhyne et al. 2012; Bush et al. 2014). Our results suggest that, in Sumatra at least, trapping can have substantial effects on wild bird populations beyond the handful of species already recognized as imperiled by it. Unlike habitat loss, the impact of the pet trade cannot be seen via remote sensing and it is not visible through casual fieldwork. But, a growing body of evidence suggests the pet trade now poses a major, quiet threat to biodiversity in Indonesia and perhaps across Southeast Asia. We fervently hope that more conservation scientists will turn their attention to the pet trade to increase understanding of how widespread and serious a threat it is.

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Supporting Information

Methodological details on bird sampling, remoteness estimation, trapper interviews, and statistical analysis (Appendix S1); sampling localities in Way Canguk (Appendix S2); sampling localities in North Sumatra (Appendix S3); trapper interview questions (Appendix S4); bird species shown to trappers (Appendix S5); JAGS Bayesian modeling code for Way Canguk and North Sumatra (Appendix S6); species-specific parameter estimates for Way Canguk (Appendix S7); species-specific parameter estimates for North Sumatra (Appendix S8); variance parameters from Bayesian models (Appendix S9); statistical tests of the changes in hours walked by trappers in search of sensitive species and numbers of birds trapped per day (Appendix S10); goodness-of-fit plots for Bayesian models for Way Canguk (Appendix S11) and North Sumatra (Appendix S12); number of birds caught per day by trappers when searching for sensitive species (Appendix S13); time spent by trappers searching for sensitive species (Appendix S14); and power analyses for Way Canguk (Appendix S15) and North Sumatra (Appendix S16) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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Supporting Information

Appendix S1--Detailed Methods

Way Canguk bird sampling schedule

At Way Canguk each point sampled in a year was at least 200 m from the closest adjacent point. From 1998-2002 17 unburned and lightly burned points were visited 20-23 times each. All months were sampled and repeat counts were done at least one month after the previous count. In 2007 the same 17 points were visited at monthly intervals from January until June (Yustikasari 2008). In 2011 nearby points were sampled with the same methods in March and July (85 points total; Fig. 2; Table S1). We provide locations of sampling sites in Tables S1-2 to promote re-sampling. The full dataset will be archived at www.datadryad.org.

Estimating remoteness of North Sumatra transects

Remoteness was estimated by taking the straight line distance from the center of the transect to the nearest road in Google Earth Pro. Google Earth Pro enabled us to combine several road layers with recent satellite images. The combined road layers lined up with roads that were visible in satellite images, but the layers did not provide complete coverage of all roads in the satellite images. The road layers included three datasets of primary roads (major paved roads) from the Indonesian base map (Peta Dasar Indonesia; produced by the World Resources Institute and the Indonesian Ministry of Forestry; www.arcgis.com) and smaller regional roads in North Sumatra from Badan Informasi Geospatial (www.bakosurtanal.go.id). It was impossible to measure the exact remoteness (walking distance from the transect to the nearest road) because multiple small (and unmapped) trails were present at each sampling site.

Initiation of trapper interviews

Interviews were led by Indonesian research assistants. Trappers were selected opportunistically via introductions from acquaintances of the interviewers or by starting conversations with villagers and asking to talk to bird trappers. Given domestic trapping quotas, transport permit requirements, and regular trade of protected species, most bird trapping in Sumatra is illegal under Indonesian law (Shepherd 2006). Nonetheless, trapping laws are rarely enforced, and the vast majority of trappers were happy to be interviewed as long as their identity was not made public.

Disturbance tolerance categories

We used six categories to describe species' tolerance to anthropogenic disturbance. Category 1 species are mostly sedentary species that inhabit the interior of undisturbed forests (rarely at edges) (e.g. Bronze-tailed Peacock-pheasant *Polyplectron chalcurum*). Category 2 species are sedentary and flocking species that mostly inhabit the interior of undisturbed forests, but they are regular near edges (e.g. Black-and-crimson Oriole *Oriolus cruentus*). Category 3 species include many flocking species that inhabit the interior and edge of undisturbed and disturbed (and secondary) forests (e.g. Black-capped White-eye *Zosterops atricapilla*). Category 4 species are mostly flocking species that occasionally inhabit the forest interior, but are more frequent in forest edges (e.g. Little Pied Flycatcher *Ficedula westermanni*). Category 5 species are found primarily in forest edges and in adjacent scrub as well as in tree plantations and even in gardens and parks (e.g. Rufous Woodpecker *Micropternus brachyurus*). Category 6 species are non-forest birds (e.g. Bar-winged Prinia *Prinia familiaris*).

Statistical analysis details

We modeled abundances of birds at Way Canguk over time as deriving from a negative binomial distribution, with random year-dependent dispersion parameter, K_j. We chose a year-dependent value for K to capture the differences in observers over the years which could result in different levels of over-dispersion. We assumed that the overall surveyed region of Way Canguk contained an unknown, true average abundance of individuals of each species in a given year, which we denote as lambda, and that all surveys in a year represented random samples of lambda. Thus, species *i* in year *j* at point *k* has an abundance, y_{ijk}, defined as:

$$y_{ijk} \sim \text{NegBin}(\lambda_{ij}, K_j)$$

where λ_{ij} represents the average abundance at Way Canguk for species *i* in year *j*. We modeled abundance as a log-linear function of year, such that:

$$\log(\lambda_{ij}) = \beta_{0,i} + \beta_{1,i}\, \text{year}_j$$

where the intercept was a hierarchical random variable derived from hyper-parameters for all species, $\beta_{0,i} \sim \text{Normal}(\mu_{\beta 0}, \sigma^2_{\beta 0})$, and the slope is hierarchically derived from a normal distribution with a single hyper-parameter for variance and a species-specific mean, $\beta_{1,i} \sim \text{Normal}(\mu_{\beta 1,i}, \sigma^2_{\beta 1})$.

We used a zero-inflated Poisson mixture for the North Sumatra data because of the large quantities of zero abundances from the transect surveys. Thus, for species i on transect k:

$$y_{ik} \sim \text{Poisson}(\lambda_{ik} \times z_{ik})$$

where lambda is the average abundance of species $i$on transect k, and z_{ik} is a binary indicator variable representing the presence ($z_{ik} = 1$) or absence ($z_{ik} = 0$) of species i on transect k. We simply modeled this zero-inflation as the function of a constant species-specific probability such that:

$$z_{ik} \sim \text{Bernoulli}(p_i)$$

where p_i is drawn from a hierarchical normal distribution with mean, μ_p, and variance, σ^2_p. We modeled the mean abundance of each species in North Sumatra as a function of the distance to the nearest road and elevation:

$$\log(\lambda_{ik}) = \beta_{0,i} + \beta_{1,i}\,\text{distance}_k + \beta_{2,i}\,\text{elevation}_k$$

Both the intercept, $\beta_{0,i}$, and slope for elevation, $\beta_{2,i}$, for each species were drawn from hierarchical normal distributions, while the slope for distance was hierarchically derived from a normal distribution with a single hyper-parameter for variance and a species-specific mean, $\beta_{1,i} \sim \text{Normal}(\mu_{\beta 1,i}, \sigma^2_{\beta 1})$.

As noted in the Methods, we modeled the expected change in abundance over time (or distance from road) for species i, $\mu_{\beta 1,i}$, as a linear function of three variables representing distinct hypotheses:

$$\mu_{b1,i} = \alpha_0 + \alpha_1\text{price}_i + \alpha_2\text{disturbance tolerance}_i + \alpha_3\text{body size}_i$$

Both the Way Canguk and the North Sumatra models were run individually with JAGS (Plummer 2003) inside R version 3.2.0 (R Core Team 2015) using the package ‘rjags’ (Plummer

2015). We used vague priors in all cases due to the generally unknown nature of abundance relationships of Sumatran avifauna. JAGS code for both models is provided in the supporting code files. Models were run with three independent chains for 75,000 MCMC iterations. A posterior sample was drawn from the final 20,000 iterations and thinned by 20. Convergence was evaluated using the Gelman-Rubin diagnostic (Gelman et al. 2013), with all parameters showing convergence with values less than 1.1 and approaching or equal to 1.0.

We independently evaluated fit of both models using posterior predictive checks on species-specific indices. Specifically, we derived predicted data values (y_{ijk} or y_{ik} for Way Canguk and North Sumatra) using modeled parameters for each posterior draw, and used these to calculate the overall mean abundance ($\overline{\lambda_i}$) and standard deviation of abundance (σ_i) for each species. Modeled means and standard deviations of abundances were compared via 95% BCI to observed means and standard deviations of abundance.

For Way Canguk, 95% BCI posterior predictions of mean abundance for each species across all years overlapped with observed means for 99% of species, and posterior standard deviations of abundance overlapped with observed for 85% of species (Fig. S1). For North Sumatra, 95% BCI posterior predictions of mean abundance overlapped with observed means for 100% of species, and posterior standard deviations of abundance overlapped with observed for 96% of species (Fig. S2).

Appendix S2. Way Canguk sampling localities (note that most, but not all, points are shown in Figure 1 for clarity).

Point ID	Coordinates
2A_N_1	5.66082° S, 104.40218° E
2A_N_2	5.65921° S, 104.40047° E
2A_N_3	5.65729° S, 104.39913° E
2A_N_4	5.65534° S, 104.39786° E
2A_N_5	5.65357° S, 104.39649° E
2A_N_6	5.65168° S, 104.3952° E
2C_N_1	5.65993° S, 104.40347° E
2C_N_1_2	5.65983° S, 104.40346° E
2C_N_10	5.64523° S, 104.39276° E
2C_N_2	5.65833° S, 104.40244° E
2C_N_2_2	5.6578° S, 104.40223° E
2C_N_3	5.65693° S, 104.4012° E
2C_N_3_2	5.65579° S, 104.40074° E
2C_N_4	5.6553° S, 104.4001° E
2C_N_4_2	5.65378° S, 104.3996° E
2C_N_5	5.65378° S, 104.39898° E
2C_N_5_2	5.65211° S, 104.39817° E
2C_N_6	5.65224° S, 104.39783° E
2C_N_6_2	5.65017° S, 104.39691° E
2C_N_7	5.65047° S, 104.39659° E
2C_N_8	5.6489° S, 104.39538° E
2C_N_9	5.64688° S, 104.39392° E
2E_N_1	5.65889° S, 104.4048° E
2E_N_10	5.64448° S, 104.3943° E
2E_N_2	5.65723° S, 104.40374° E
2E_N_3	5.6557° S, 104.40256° E
2E_N_4	5.65412° S, 104.4014° E

2E_N_5	5.65246° S, 104.40034° E
2E_N_6	5.6509° S, 104.39896° E
2E_N_7	5.6493° S, 104.39782° E
2E_N_8	5.64764° S, 104.3966° E
2E_N_9	5.64605° S, 104.39537° E
2G_N_1	5.65757° S, 104.40618° E
2G_N_10	5.64355° S, 104.39597° E
2G_N_2	5.65603° S, 104.40484° E
2G_N_3	5.65437° S, 104.40376° E
2G_N_4	5.65284° S, 104.40271° E
2G_N_5	5.65128° S, 104.40155° E
2G_N_6	5.64974° S, 104.40038° E
2G_N_7	5.64813° S, 104.39936° E
2G_N_8	5.64667° S, 104.39831° E
2G_N_9	5.64513° S, 104.39704° E
2I_N_1	5.65716° S, 104.40718° E
2I_N_2	5.65541° S, 104.40571° E
2I_N_3	5.65328° S, 104.40484° E
2I_N_4	5.65146° S, 104.40336° E
2I_N_5	5.64978° S, 104.40201° E
2I_N_6	5.64801° S, 104.40064° E
2K_N_1	5.6551° S, 104.40907° E
2K_N_2	5.65347° S, 104.40754° E
2K_N_3	5.65173° S, 104.4062° E
2K_N_4	5.64991° S, 104.40486° E
2K_N_5	5.64801° S, 104.40365° E
2K_N_6	5.64628° S, 104.40216° E
2Z_1	5.65841° S, 104.40565° E
2Z_2	5.65698° S, 104.40413° E
2Z_3	5.65507° S, 104.40309° E
2Z_4	5.65323° S, 104.40179° E

2Z_5	5.65143° S, 104.40034° E
2Z_6	5.64961° S, 104.39912° E
E_S_1	5.65766° S, 104.41244° E
E_S_1000	5.665° S, 104.418° E
E_S_1200	5.666° S, 104.419° E
E_S_2	5.65924° S, 104.41374° E
E_S_3	5.66082° S, 104.4149° E
E_S_4	5.66261° S, 104.4161° E
E_S_5	5.66405° S, 104.41719° E
G_S_1	5.65851° S, 104.41085° E
G_S_2	5.66011° S, 104.41204° E
G_S_3	5.66169° S, 104.41327° E
G_S_4	5.66329° S, 104.4144° E
G_S_5	5.66496° S, 104.41556° E
I_S_1	5.65962° S, 104.40933° E
I_S_1000	5.673° S, 104.408° E
I_S_2	5.6611° S, 104.41053° E
I_S_3	5.66266° S, 104.4116° E
I_S_4	5.66411° S, 104.41285° E
I_S_5	5.66576° S, 104.41392° E
K_S_1	5.66071° S, 104.40796° E
K_S_1000	5.668° S, 104.413° E
K_S_1200	5.669° S, 104.414° E
K_S_2	5.66214° S, 104.4092° E
K_S_200	5.662° S, 104.409° E
K_S_3	5.6638° S, 104.41026° E
K_S_4	5.66535° S, 104.41139° E
K_S_5	5.66701° S, 104.41261° E
K_S_600	5.665° S, 104.411° E
M_S_1	5.6617° S, 104.40648° E
M_S_1000	5.669° S, 104.412° E

M_S_2	5.66323° S, 104.40763° E
M_S_3	5.66488° S, 104.4088° E
M_S_4	5.6665° S, 104.41008° E
M_S_400	5.66458924° S, 104.4087156° E
M_S_5	5.66803° S, 104.41108° E
O_S_1000	5.67002499° S, 104.41019149° E
O_S_1400	5.67297215° S, 104.41242459° E
O_S_200	5.66419839° S, 104.40618997° E
O_S_600	5.66714413° S, 104.4083193° E
Q_S_1200	5.66662252° S, 104.39897566° E
Q_S_400	5.66662252° S, 104.39897566° E
S_S_1200	5.673° S, 104.408° E
W_S_200	5.66662252° S, 104.39897566° E

Appendix S3. North Sumatra sampling localities.

transect ID	starting point coordinates	ending point coordinates	elevation (m above sea level)
2.AT.4to5	3.26972° N, 98.52809° E	3.26819° N, 98.52627° E	1018
2.AT.5to6	3.26819° N, 98.52627° E	3.26876° N, 98.52403° E	1044
3.AT.6to7	3.26876° N, 98.52403° E	3.26858° N, 98.52176° E	1069
3.AT.7to8	3.26858° N, 98.52176° E	3.26742° N, 98.51961° E	1088
1.KR.1to2	3.2258° N, 98.38131° E	3.2246° N, 98.37925° E	1484
1.KR.2to3	3.2246° N, 98.37925° E	3.2243° N, 98.37695° E	1495
2.KR.3to4	3.2243° N, 98.37695° E	3.22209° N, 98.37601° E	1518
2.KR.4to5	3.22209° N, 98.37601° E	3.22033° N, 98.37444° E	1571
3.KR.5to6	3.22033° N, 98.37444° E	3.22054° N, 98.37208° E	1595
4.KR.6to7	3.22054° N, 98.37208° E	3.22155° N, 98.36994° E	1606
5.KR.9to10	3.22074° N, 98.36536° E	3.22066° N, 98.36305° E	1619
4.KR.7to8	3.22155° N, 98.36994° E	3.22098° N, 98.36768° E	1624
5.KR.8to9	3.22098° N, 98.36768° E	3.22074° N, 98.36536° E	1626
9.KR.20to21	3.23674° N, 98.34646° E	3.23865° N, 98.34521° E	1482
9.KR.19to20	3.23491° N,	3.23674° N,	1522

	98.34783° E	98.34646° E	
6.KR.campto14	3.22854° N, 98.3583° E	3.2291° N, 98.35733° E	1550
8.KR.18to19	3.2341° N, 98.34988° E	3.23491° N, 98.34783° E	1554
6.KR.14to15	3.2291° N, 98.35733° E	3.2299° N, 98.35521° E	1568
8.KR.17to18	3.23208° N, 98.35101° E	3.2341° N, 98.34988° E	1583
7.KR.15to16	3.2299° N, 98.35521° E	3.23127° N, 98.3532° E	1587
7.KR.16to17	3.23127° N, 98.3532° E	3.23208° N, 98.35101° E	1594
10.KR.campto22	3.22854° N, 98.3583° E	3.22791° N, 98.35972° E	1530
10.KR.22to13	3.22791° N, 98.35972° E	3.22716° N, 98.36193° E	1568
11.KR.13to12	3.22716° N, 98.36193° E	3.22489° N, 98.36171° E	1596
11.KR.12to11	3.22489° N, 98.36171° E	3.22253° N, 98.36181° E	1603
12.KR.11to23	3.22253° N, 98.36181° E	3.21895° N, 98.36142° E	1619
12.KR.10to24	3.22066° N, 98.36305° E	3.21807° N, 98.35935° E	1627
13.KR.24to25	3.21807° N, 98.35935° E	3.21853° N, 98.35714° E	1630
13.KR.25to26	3.21853° N, 98.35714° E	3.21741° N, 98.35512° E	1644
14.KR.28to29	3.24048° N, 98.38534° E	3.24254° N, 98.38669° E	1373
14.KR.29to30	3.24254° N, 98.38669° E	3.2439° N, 98.38864° E	1379

15.KR.30to31	3.2439° N, 98.38864° E	3.24515° N, 98.39068° E	1384
15.KR.31to32	3.24515° N, 98.39068° E	3.24529° N, 98.39298° E	1401
16.KR.32to33	3.24529° N, 98.39298° E	3.24649° N, 98.39495° E	1433
16.KR.33to34	3.24649° N, 98.39495° E	3.24871° N, 98.39554° E	1475
17.KR.34to35	3.24871° N, 98.39554° E	3.25065° N, 98.39693° E	1511
17.KR.35to36	3.25065° N, 98.39693° E	3.25226° N, 98.39866° E	1559
21.KR.41to42	3.24997° N, 98.37147° E	3.25067° N, 98.36927° E	1362
20.KR.40to41	3.25129° N, 98.37354° E	3.24997° N, 98.37147° E	1379
19.KR.39to40	3.2529° N, 98.37515° E	3.25129° N, 98.37354° E	1395
18.KR.37to38	3.2545° N, 98.37955° E	3.25392° N, 98.37719° E	1400
18.KR.38to39	3.25392° N, 98.37719° E	3.2529° N, 98.37515° E	1401
1.S.1tosettlement	3.23645° N, 98.48923° E	3.23773° N, 98.48933° E	1575
2.S.2to3	3.23601° N, 98.49393° E	3.23619° N, 98.49625° E	1729
2.S.3to4	3.23619° N, 98.49625° E	3.23485° N, 98.49827° E	1777
1.B.1to2	3.19313° N, 98.57009° E	3.19477° N, 98.57182° E	1358
1.B.2to3	3.19477° N, 98.57182° E	3.19703° N, 98.57168° E	1373
2.B.3to4	3.19703° N, 98.57168° E	3.19848° N, 98.56989° E	1471

2.B.4to5	3.19848° N, 98.56989° E	3.2° N, 98.56817° E	1644
5.B.11to12	3.25265° N, 98.5381° E	3.25162° N, 98.53602° E	1144
5.B.10to11	3.25329° N, 98.52614° E	3.25265° N, 98.5381° E	1235
3.B.7to8	3.18809° N, 98.57826° E	3.1888° N, 98.58044° E	1364
4.B.8to9	3.1888° N, 98.58044° E	3.19003° N, 98.58253° E	1371
4.B.9to10	3.19003° N, 98.58253° E	3.25329° N, 98.52614° E	1374
3.B.6to7	3.18931° N, 98.57629° E	3.18809° N, 98.57826° E	1388
3.S.5to6	3.23072° N, 98.51073° E	3.23207° N, 98.50875° E	1541
4.S.6to7	3.23207° N, 98.50875° E	3.2344° N, 98.50818° E	1667
5.S.7to8	3.2344° N, 98.50818° E	3.23658° N, 98.50758° E	1803
2.BB.4to5	3.26439° N, 98.53416° E	3.26216° N, 98.5336° E	1032
2.BB.5to6	3.26216° N, 98.5336° E	3.26013° N, 98.53236° E	1075
3.BB.6to7	3.26013° N, 98.53236° E	3.25806° N, 98.5312° E	1131
3.BB.7to8	3.25806° N, 98.5312° E	3.25645° N, 98.52956° E	1197
4.BB.8to9	3.25645° N, 98.52956° E	3.25473° N, 98.52794° E	1262
4.BB.9to10	3.25473° N, 98.52794° E	3.25329° N, 98.52614° E	1326
5.BB.11to12	3.25265° N, 98.5381° E	3.25162° N, 98.53602° E	1144

5.BB.12to13	3.25162° N, 98.53602° E	3.25067° N, 98.53388° E	1208
6.BB.13to14	3.25067° N, 98.53388° E	3.2498° N, 98.53173° E	1269
7.BB.14to15	3.2498° N, 98.53173° E	3.24879° N, 98.52957° E	1336
7.BB.15to16	3.24879° N, 98.52957° E	3.24774° N, 98.52748° E	1411
8.BB.16to17	3.24774° N, 98.52748° E	3.24761° N, 98.52516° E	1490
8.BB.17to18	3.24761° N, 98.52516° E	3.24735° N, 98.52286° E	1623
1.SI.14to15	2.87314° N, 98.49424° E	2.87123° N, 98.49285° E	1673
2.SI.16to17	2.86898° N, 98.49266° E	2.86754° N, 98.49088° E	1691
1.SI.15to16	2.87123° N, 98.49285° E	2.86898° N, 98.49266° E	1693
21.KR.211to212	3.21692° N, 98.36205° E	3.21746° N, 98.35985° E	1626
22.KR.213to214	3.21691° N, 98.35767° E	3.21728° N, 98.35546° E	1626
21.KR.212to213	3.21746° N, 98.35985° E	3.21691° N, 98.35767° E	1632
22.KR.214to215	3.21728° N, 98.35546° E	3.21825° N, 98.35343° E	1646
23.KR.215to216	3.21825° N, 98.35343° E	3.21776° N, 98.35034° E	1666
23.KR.216to217	3.21776° N, 98.35034° E	3.21815° N, 98.34808° E	1690
24.KR.217to218	3.21815° N, 98.34808° E	3.21929° N, 98.34614° E	1707
24.KR.218to219	3.21929° N, 98.34614° E	3.21974° N, 98.34394° E	1715

25.KR.225to226	3.19803° N, 98.36567° E	3.19832° N, 98.36343° E	1502
25.KR.226to227	3.19832° N, 98.36343° E	3.19691° N, 98.36165° E	1540
26.KR.229to230	3.213° N, 98.36038° E	3.21072° N, 98.36001° E	1552
27.KR.230to231	3.21072° N, 98.36001° E	3.20858° N, 98.35911° E	1552
27.KR.231to232	3.20858° N, 98.35911° E	3.20896° N, 98.3569° E	1563
26.KR.228to229	3.21526° N, 98.36048° E	3.213° N, 98.36038° E	1583
28.KR.232to233	3.20896° N, 98.3569° E	3.20845° N, 98.35462° E	1586
29.KR.233to234	3.20845° N, 98.35462° E	3.20914° N, 98.35243° E	1612
34.KR.2.8to2.9	3.20434° N, 98.36424° E	3.20299° N, 98.36232° E	1487
33.KR.2.7to2.8	3.20568° N, 98.36608° E	3.20434° N, 98.36424° E	1488
34.KR.2.9to2.10	3.20299° N, 98.36232° E	3.20179° N, 98.36015° E	1525
33.KR.2.6to2.7	3.20728° N, 98.36779° E	3.20568° N, 98.36608° E	1526
32.KR.2.5to2.6	3.20945° N, 98.36687° E	3.20728° N, 98.36779° E	1550
31.KR.2.4to2.5	3.21155° N, 98.36596° E	3.20945° N, 98.36687° E	1557
31.KR.2.3to2.4	3.21378° N, 98.36635° E	3.21155° N, 98.36596° E	1569
30.KR.2.2to2.3	3.21607° N, 98.36629° E	3.21378° N, 98.36635° E	1586
30.KR.2.1to2.2	3.21793° N, 98.36486° E	3.21607° N, 98.36629° E	1593

1.SB.1to2	3.24374° N, 98.53056° E	3.24373° N, 98.52829° E	1411
1.SB.2to3	3.24373° N, 98.52829° E	3.24351° N, 98.52608° E	1488
2.SB.3to4	3.24351° N, 98.52608° E	3.24356° N, 98.52384° E	1597
7.SI.37to38	2.78735° N, 98.47681° E	2.78586° N, 98.47514° E	1564
6.SI.36to37	2.78857° N, 98.47875° E	2.78735° N, 98.47681° E	1572
6.SI.35to36	2.78815° N, 98.48097° E	2.78857° N, 98.47875° E	1578
5.SI.34to35	2.78876° N, 98.48312° E	2.78815° N, 98.48097° E	1583
5.SI.33to34	2.78915° N, 98.48531° E	2.78876° N, 98.48312° E	1585
7.SI.38to39	2.78586° N, 98.47514° E	2.78494° N, 98.47307° E	1556
11.SI.8to9	2.78052° N, 98.51589° E	2.78034° N, 98.51815° E	1651
11.SI.7to8	2.7819° N, 98.51396° E	2.78052° N, 98.51589° E	1655
8.SI.1to2	2.79165° N, 98.50409° E	2.78998° N, 98.50568° E	1658
8.SI.2to3	2.78998° N, 98.50568° E	2.78869° N, 98.5077° E	1660
10.SI.6to7	2.78389° N, 98.51265° E	2.7819° N, 98.51396° E	1661
9.SI.3to4	2.78869° N, 98.5077° E	2.78741° N, 98.50969° E	1663
10.SI.5to6	2.78598° N, 98.51146° E	2.78389° N, 98.51265° E	1663
9.SI.4to5	2.78741° N, 98.50969° E	2.78598° N, 98.51146° E	1664

12.SI.26to27	2.80362° N, 98.49134° E	2.80561° N, 98.4902° E	1662
13.SI.28to29	2.80642° N, 98.48806° E	2.80716° N, 98.48593° E	1662
13.SI.29to30	2.80716° N, 98.48593° E	2.8092° N, 98.48487° E	1663
14.SI.30to31	2.8092° N, 98.48487° E	2.80887° N, 98.48255° E	1665
12.SI.27to28	2.80561° N, 98.4902° E	2.80642° N, 98.48806° E	1667
14.SI.31to32	2.80887° N, 98.48255° E	2.80917° N, 98.48039° E	1667
17.SI.47to48	2.81606° N, 98.48025° E	2.81606° N, 98.47785° E	1696
17.SI.46to47	2.81686° N, 98.48233° E	2.81606° N, 98.48025° E	1702
16.SI.45to46	2.81841° N, 98.48406° E	2.81686° N, 98.48233° E	1705
15.SI.42to43	2.81502° N, 98.48902° E	2.81721° N, 98.4882° E	1708
15.SI.43to44	2.81721° N, 98.4882° E	2.81832° N, 98.48626° E	1708
16.SI.44to45	2.81832° N, 98.48626° E	2.81841° N, 98.48406° E	1709
3.SI.11to12	2.87311° N, 98.50046° E	2.87351° N, 98.49814° E	1647
3.SI.10to11	2.87203° N, 98.50253° E	2.87311° N, 98.50046° E	1649
4.SI.12to13	2.87351° N, 98.49814° E	2.87454° N, 98.49606° E	1655
4.SI.13to14	2.87454° N, 98.49606° E	2.87314° N, 98.49424° E	1663
18.SI.18to19	2.8334° N, 98.4849° E	2.83152° N, 98.48359° E	1651

18.SI.19to20	2.83152° N, 98.48359° E	2.82932° N, 98.48275° E	1693
21.SI.past25	2.81799° N, 98.48326° E	2.81733° N, 98.48309° E	1695
21.SI.24to25	2.8202° N, 98.48365° E	2.81799° N, 98.48326° E	1700
20.SI.23to24	2.82248° N, 98.48393° E	2.8202° N, 98.48365° E	1711
19.SI.21to22	2.82699° N, 98.48333° E	2.8248° N, 98.48389° E	1720
20.SI.22to23	2.8248° N, 98.48389° E	2.82248° N, 98.48393° E	1722
19.SI.20to21	2.82932° N, 98.48275° E	2.82699° N, 98.48333° E	1723
3.SBU.6to7	2.94866° N, 98.42241° E	2.95058° N, 98.42274° E	1567
3.SBU.5to6	2.94647° N, 98.42181° E	2.94866° N, 98.42241° E	1583
2.SBU.4to5	2.94453° N, 98.42277° E	2.94647° N, 98.42181° E	1594
2.SBU.3to4	2.94346° N, 98.42483° E	2.94453° N, 98.42277° E	1607
1.SBU.2to3	2.94162° N, 98.42596° E	2.94346° N, 98.42483° E	1640
1.SBU.1to2	2.94063° N, 98.42796° E	2.94162° N, 98.42596° E	1654
4.SBU.8to9	2.9384° N, 98.42781° E	2.93625° N, 98.42825° E	1699
4.SBU.9to10	2.93625° N, 98.42825° E	2.93402° N, 98.42798° E	1766
5.SBU.10to11	2.93402° N, 98.42798° E	2.93322° N, 98.426° E	1844
6.SBU.12to13	2.93355° N, 98.42371° E	2.93553° N, 98.42487° E	1872

6.SBU.11to12	2.93322° N, 98.426° E	2.93355° N, 98.42371° E	1875
9.SBU.18to19	2.95049° N, 98.43022° E	2.95263° N, 98.43042° E	1583
9.SBU.17to18	2.94816° N, 98.42969° E	2.95049° N, 98.43022° E	1634
8.SBU.16to17	2.9459° N, 98.42963° E	2.94816° N, 98.42969° E	1665
7.SBU.15to16	2.94384° N, 98.43042° E	2.9459° N, 98.42963° E	1683
7.SBU.14to15	2.94161° N, 98.43002° E	2.94384° N, 98.43042° E	1722

Appendix S4. Research questions for semi-structured interviews with bird trappers in Sumatra.

Alias penangkap________________________

Tanggal________________________________

Lokasi_________________________________

Nama interviewer________________________

Nomor penangkap interviewed sama sama (kalau tidak sendiri)_____

BEING A TRAPPER ***MENJADI PENANGKAP BURUNG***

How long have you been a trapper? ***Sudah berapa lama Anda menjadi penangkap/ pemikat burung?***

How/Why did you become a trapper? Please rank all applicable reasons from most important to least important. ***Mengapa Anda menjadi perangkap/ pemikat burung? Silahkan urutkan alasan dari yang paling penting .***

A. Sudah menjadi Tradisi bisnis keluarga (Orang-tua dan Kakek/Nenek adalah pedagang juga) (traditional family business) ***B. Untuk memperoleh Pendapatan/ Uang***(to make money) ***C. Keamanan pekerjaan***(job security) ***D. Tidak ada pilihan lain*** (no other options) ***E. Kesenangan pribadi padaburung*** Personal interest in birds and wildlife ***F. Yang lain (Silahkandijelaskan)*** Other, please specify

What do you like about working as a trapper? ***Apakah yang Anda sukai dari pekerjaan ini? Mengapa?***

And what do you not like about it? ***Dan apa yang tidak anda sukai dari pekerjaan menangkap/ memikat burung?***

TRAPPING***PENANGKAPAN***

How often do you search for birds? Please give the minimum and maximum number of days you may go trapping in one week. ***Seberapa sering pergi cari/ memikat burung?Berapa kali? Mohon informasi berapa kali anda pergi memikat burung dalam seminggu, paling banyak dan paling sedikit?***

Where do you trap birds (habitat type)? ***Dimana Anda menangkap burung? Apakah di hutan, kebun atau sawah?***

On which trails to you usually search for birds? Can you please describe the location of these trails? ***Pada Jalur yang mana Anda biasa mencari burung? Dapatkah Anda menjelaskan lokasi jalur tersebut?***

Can you please estimate the number of trappers that use those trails per week? **Dapatkah Anda memperkirakan jumlah pemikat burung yang masuk di jalur tersebut dalam seminggu?**

How much area do you cover each day? How many km? ***Berapa luas kawasan yang Anda jelajahi untuk mencari burung setiap hari? Berapa kilometer jelajahi setiap hari, paling banyak dan paling sedikit?***

Do you stay in the forest overnight? If so how often? ***Bila Anda mencari burung, apakah menginap di hutan? Kalau ya, berapa sering?***

Who owns the land where you trap? Do you ever have to ask for permission from the land owner to trap? ***Siapa pemilik kawasan di mana Anda mencari burung? apakah Anda pernah meminta izin kepada pemilik kawasan tersebut?***

Do you know of any species that are used for traditional medicine, religious release, or song competitions? **Apakah Anda tahu jenis burung yang digunakan untuk obat tradisional, upacara keagamaan atau kontes kicau?**

TRENDS OF TARGET SPECIES

Generally, do you think that the bird trade in Sumatra has increased or decreased and why? **Menurut Anda, apakah *Umumnya, perdagangan burungmeningkat atau menurun? Dan mengapa***

In general, is it getting harder to find birds? **Secara *Umum, apakah semakin lebih sulit untuk menemukan burung tersebut? Kalau Ya, mengapa?***(If yes, why?)

Approximately how many birds do you catch per week? **Kira-kira berapa banyak burung yang tertangkap dalam seminggu, *paling banyak dan paling sedikit*?**

So you can catch X birds per month (multiplied by 4)? **Jadi, Anda dapat mengangkap sekitar …. Burung dalam sebulan? (Dikalikan 4 minggu)**

So that is Y birds per year (multiplied by 12)? **Jadi, Anda dapat menangkap sekitar….burung dalam setahun? (Dikalikan 12 bulan)**

SELLING ***PENJUALAN***

What do you do with your birds? ***Apa yang Anda lakukan dengan burung-burung milikAnda?***

Please choose all that apply and/or rank the choices. **(<u>Silahkan pilih jika semua benar dan urutkan pilihan Anda</u>)**

A. Sell to middle men **(Di Jual ke pengumpul burung.)** B. Sell directly to markets. if so , please specify which market**. (Di Jual langsung ke pasar, jika ya, pasar yang mana?** C. Sell to directly to customer **(Langsung dijual kepada konsumen)** D. Give to friends **(Diberikan kepada teman)** E. Keep for personal use **(Dipelihara sendiri)**

Approximately how many birds do you sell per week? **Kira-kira berapa banyak burung yang Anda jual dalam seminggu?**

So you can sell X birds per month (multiplied by 4)? **Jadi, Anda dapat menjual sekitar…. Burung dalam sebulan? (Dikalikan 4 minggu)**

So that is Y birds per year (multiplied by 12)? **Jadi, Anda dapat menjual sekitar….burung dalam setahun? (Dikalikan 12 bulan)**

Which markets do the birds go to? ***Ke pasar mana burung-burung Anda dijual?***

Generally, what are the price trends for the bird trade within the last 5-10 years? ***Umumnya, bagaimanakah kecenderungan harga perdagangan burung dalam kurun waktu 5-10 tahun terakhir?***
Mengapa?

What trapping methods do you use for the following species [show photos] ? Do you particularly target this species or do you opportunistically catch it? Do you target another species after the population of this one decreases? How many do you catch per month (over time)? How far do you have to go to catch the species? Does the pair or whole family group enter the cage/get stuck in the lime, or is only one individual bird usually fooled? What are the price trends of this species over time? Percent mortality? Use?

Teknik penangkapan seperti apa yang Anda gunakan? Apakah Anda hanya membuat perangkap untuk satu jenis burung target, ataukah tidak ada target? Apakah anda mencari jenis pengganti jika burung yang ditargetkan berkurang? Berapa banyak yang dapat kamu tangkap per-bulan(dalam rentang waktu; misalnya 5 tahun)? Seberapa Jauh Anda berusaha mendapatkan suatu jenis? Apakah satu atau semuanya dari kelompok burung yang datang tersebut terperangkap/ terjerat? Bagaimana tren harga jenis burung ini (dalam rentang waktu; misalnya 5 tahun)? bagaimana persentase kematian burung? Untuk apa alasan pembeli burung tersebut?

teknik penangkapan	
khusus atau tidak	
jenis pengganti	
jumlah / bulan	
berapa jauh berusaha (km atau jam)	
ekor / kelompok	
harga (Rp)	
persent yang mati (tulis perangkap, jl., atau rumah)	
untuk apa (pelihara, obat, makan, kontes, lepas agama)	

OTHER ISSUES ***HAL LAIN***

Do you also hunt animals in the forest? **Apakah anda juga menjerat/ menangkap hewan lain di hutan?**

If so what kind? Mammals, birds, frogs, snakes, etc. **Jenis apa? Mamalia, burung (ayam hutan, merpati, burung hantu, lain), katak, ular, dsb**

Why do you hunt them? For food, medicine, to sell? **Untuk apa menangkap hewan tersebut? Untuk dimakan, atau obat, atau dijual? Kalau dijual, unutk apa?**

Do you collect any other forest products from the area (timber, plants, mushrooms, honey, etc.)? If so what are they used for? **Apakah Anda mengumpulkan hasil hutan yang lain seperti tanaman, jamur, madu, getah dsb? Jika ya, untuk diapakan?**

How often to people from outside the village come to catch birds? **Seberapa sering orang luar kampung(bukan penduduk sekitar) datang memikat/ menangkap burung disana?**

What species do they target? **Jenis apa yang dicari mereka (beda dari yang Anda dicari)?**

How long do they spend in the forest? **Berapa lama mereka di hutan untuk itu?**

Do you think trapping has any effect on the number of birds in the forest? **Apakah menurut Anda penangkapan burung berdampak pada jumlah burung yang ada di hutan?**

If so, which species seem most resilient? **Kalau ya, jenis apa yang Nampak bertahan (masih banyak sesudah penangkapan)?**

Which species seem most sensitive? **Jenis apa yang terlihat sensitive? Terpengaruh keberadaannya karena adanya penangkapan?**

Are any other factors (for example, deforestation, pesticides) affecting bird populations in your area? **Apakah ada faktor lain atau permasalahan (contohnya penebangan hutan, pestisida) yang berdampak pada burung di kawasan Anda?**

How do the effects of trapping on bird populations compare to other factors? **Bagaimana dampak penangkapan burung bila dibandingkan dengan faktor lain (tersebut di atas) apakah lebih kuat?**

Has the number of bird trappers in your area increased, decreased, or stayed the same over the last five years? **Apakah jumlah penangkap burung ditempat anda meningkat, berkurang, atau masih sama seperti 5-10 tahun terakhir?**

Where do new trappers come from? **Darimana para pemikat/penangkap bahru datang? Mereka orang tua atau anak mudah? Lokal atau dari luar?**

Are your children interested in being trappers/traders? **Apakah Anak-anak Anda tertarik untuk menjadi penangkap atau pedagang burung?**

Would you like your children to continue trapping and why? **Apakah Anda mengharapkan anak-anak dan cucu-cucu melanjutkan pekerjaan sebagai penangkap burung?**

If there was an alternative source of income, I would prefer: **Kalau ada sumber pendapatan atau penghasilan yang lain, Saya lebih suka:**
Farmer **(Petani)** Forestry **(petugas Kehutanan)** Mining **(pegawai Pertambangan)** Restaurant/ Hotels **(pekerja Rumah Makan / hotel)** Factory **(buruh Pabrik)** Cleaner **(petugas Kebersihan)** Study at University **(Belajar (di Universitas)** Other **(Lainnya.....) ______________________**

Do you know of any efforts by the government to restrict trade? **Apakah anda tahu upaya Pemerintah Indonesia untuk mengurangi perdagangan?**

Would you need a permit to trap birds? **Apakah Anda perlu izin untuk menangkap burung?**

Did the outbreak of Avian Flu in 2003 have an impact on the demand for the number (and species) of birds you trap? **Apakah kejadian wabah flu- burung pada tahun 2003, berdampak pada permintaan baik pada jumlah (dan jenis) yang anda tangkap?**

Have you ever been ill or injured from working in the trade? **Apakah anda pernah sakit atau terluka dari bekerja dalam penangkapan dan perdagangan burung?**

And if YES, what caused it? (eg, injury in the forest, bird flu, bites, scratches) ***Kalau YA, karena apa? (eg, sakit di hutan, terserang flu- burung, dipatuk, digaruk) dan bagaiman sering?***

RESPONDENT INFORMATION ***INFORMASI RESPONDEN***
Dapatkah saya menanyakan umur dan asal anda? (Could I please ask your age and ethnic origin?)

Jeniskelamin: Umur:__________________________tahun______
Male (Laki-Laki) Female (Perempuan)

Suku: Anda berasaldarimana?

1. Java 2. Sumatra
   - Aceh
   - Sumatra Utara
   - Sumatra Barat
   - Sumatra Selatan

3. Indo-Cina 4. Kalimantan 5. NusaTengara 7. Yang lain

Education Level (Tingkat Pendidikan) OPTIONAL:
1. SD 2. SMP 3. SMA 4. Universitas

What proportion of the household income comes from trapping? **Seberapa besar (persentase) pendapatan rumahtangga dari memikat/ menangkap burung?**

Please give your approximate monthly income (OPTIONAL). **Bagaimana perkiraan jumlah pendapatan rumahtangga selain dari memikat?**

Terima Kasih untuk waktu dan bantuannya

Appendix S5. Species of which photographs were shown to trappers during interviews.

English name	Scientific name
Hoogerwerf's Pheasant	*Lophura hoogerwerfi*
Bronze-tailed Peacock-Pheasant	*Polyplectron chalcurum*
Spotted Dove	*Spilopelia chinensis*
Zebra Dove	*Geopelia striata*
Scops Owl sp.	*Otus sp.*
Wreathed Hornbill	*Rhyticeros undulatus*
Fire-tufted Barbet	*Psilopogon pyrolophus*
Black-browed Barbet	*Psilopogon oorti*
wood pecker sp.	*Dinopium sp.*
Blue-crowned Hanging Parrot	*Loriculus galgulus*
Red-breasted Parakeet	*Psittacula alexandri*
Long-tailed Parakeet	*Psittacula longicauda*
Long-tailed Shrike	*Lanius schach*
Blyth's Shrike-babbler	*Pteruthius aeralatus*
Black-naped Oriole	*Oriolus chinensis*
Common Green Magpie	*Cissa chinensis*
Sumatran Treepie	*Dendrocitta occipitalis*
Slender-billed Crow	*Corvus enca*
Cinereous Tit	*Parus cinereus*
Straw-headed Bulbul	*Pycnonotus zeylanicus*
Black-headed Bulbul	*Pycnonotus atriceps*
Ruby-throated Bulbul	*Pycnonotus dispar*
Scaly-breasted Bulbul	*Pycnonotus squamatus*
Sooty-headed Bulbul	*Pycnonotus aurigaster*
Orange-spotted Bulbul	*Pycnonotus bimaculatus*
Yellow-vented Bulbul	*Pycnonotus goiavier*
Ochraceous Bulbul	*Alophoixus ochraceus*
Sunda Bulbul	*Ixos virescens*
Bar-winged Prinia	*Prinia familiaris*

Ashy Tailorbird	*Orthotomus ruficeps*
Sumatran Laughingthrush	*Garrulax bicolor*
Sunda Laughingthrush	*Garrulax paliatus*
Chestnut-capped Laughingthrush	*Garrulax mitratus*
Black Laughingthrush	*Garrulax lugubris*
Silver-eared Mesia	*Leiothrix argentauris*
Long-tailed Sibia	*Heterophasia picaoides*
Asian Fairy-bluebird	*Irena puella*
Asian Glossy Starling	*Aplonis panayensis*
Common Hill Myna	*Gracula religiosa*
Javan Myna	*Acridotheres javanicus*
Common Myna	*Acridotheres tristis*
Daurian Starling	*Agropsar sturninus*
Oriental Magpie-Robin	*Copsychus saularis*
White-rumped Shama	*Copsychus malabaricus*
Greater Green Leafbird	*Chloropsis sonnerati*
Sumatran Leafbird	*Chloropsis media*
Blue-masked Leafbird	*Chloropsis venusta*
Orange-bellied Flowerpecker	*Dicaeum trigonostigma*
Baya Weaver	*Ploceus philippinus*
Pin-tailed Parrotfinch	*Erythrura prasina*
Scaly-breasted Munia	*Lonchura punctulata*
Chestnut Munia	*Lonchura atricapilla*
White-headed Munia	*Lonchura maja*
Java Sparrow	*Lonchura oryzivora*

Appendix S6. JAGS Bayesian modeling code for Way Canguk and North Sumatra

1. Model code in the BUGS language for Way Canguk analysis of change in abundance over time

```
# Negative Binomial Model

model {

  # Priors

  for(j in 1:n.year) {

    K[j] ~ dunif(0,100)

  }

  alpha0 ~ dnorm(0, 0.001)

  alpha1 ~ dnorm(0, 0.001)

  alpha2 ~ dnorm(0, 0.001)

  alpha3 ~ dnorm(0, 0.001)

  sigma.alpha ~ dgamma(0.001, 0.001)

  tau.alpha <- pow(sigma.alpha, -2)

  mu.beta0 ~ dnorm(0, 0.001)

  sigma.beta0 ~ dgamma(0.001, 0.001)

  tau.beta0 <- pow(sigma.beta0, -2)


# species-level trend

  for(k in 1:n.species) {

    beta0[k] ~ dnorm(mu.beta0, tau.beta0)

    beta1[k] ~ dnorm(mu.beta1[k], tau.alpha)
```

```
    mu.beta1[k] <- alpha0 + alpha1*price[k] + alpha2*disturb[k] +
alpha3*size[k]


# year-level trend

    for(j in 1:n.year) {

      log(mu.year[j,k]) <- beta0[k] + beta1[k]*year[j]

      p[j,k] <- K[j] / (K[j] + mu.year[j,k])


      # point-level data

      for(i in 1:n.point[j]) {

        y[i,j,k] ~ dnegbin(p[j,k], K[j])

      }

    }

  }

} # end model
```

2. Model code in the BUGS language for North Sumatra analysis of change in abundance with distance

```
# Zero-inflated Poisson

model {

  # Priors

  alpha0 ~ dnorm(0, 0.01)

  alpha1 ~ dnorm(0, 0.01)

  alpha2 ~ dnorm(0, 0.01)

  alpha3 ~ dnorm(0, 0.01)

  sigma.alpha ~ dunif(0.001, 1000)

  tau.alpha <- pow(sigma.alpha, -2)


  mu.beta0 ~ dunif(-10, 10)

  sigma.beta0 ~ dunif(0.001, 100)

  tau.beta0 <- pow(sigma.beta0, -2)


  mu.beta2 ~ dunif(-10, 10)

  sigma.beta2 ~ dunif(0.001, 100)

  tau.beta2 <- pow(sigma.beta2, -2)


  mu.p ~ dunif(-10, 10)

  sigma.p ~ dunif(0.001, 100)

  tau.p <- pow(sigma.p, -2)
```

```
  # Model for North Sumatra (change in abundance over space)

  # species-level trend

  for(k in 1:n.species) {

    beta0[k] ~ dnorm(mu.beta0, tau.beta0)

    beta1[k] ~ dnorm(mu.beta1[k], tau.alpha)

    mu.beta1[k] <- alpha0 + alpha1*price[k] + alpha2*disturb[k] +
alpha3*size[k]

    beta2[k] ~ dnorm(mu.beta2, tau.beta2)



    logit.p[k] ~ dnorm(mu.p, tau.p)

    logit(p[k]) <- logit.p[k]



    # transect trend

    for(i in 1:n.int) {

      log(mu.int[i,k]) <- beta0[k] + beta1[k]*distance[i] + beta2[k]*elev[i]

      z[i,k] ~ dbern(p[k])

      y[i,k] ~ dpois(z[i,k] * mu.int[i,k])

    }

  }

} # end model
```

Appendix S7. Species specific parameter estimates, Way Canguk.

English name	Scientific name	Trend*	Mean coefficient (95% credible interval)	SD
A. Trend (beta)				
Crested Partridge	*Rollulus rouloul*		-0.043 (-0.244 to 0.131)	0.095
Great Argus	*Argusianus argus*	+	0.203 (0.157 to 0.248)	0.023
Crested Serpent Eagle	*Spilornis cheela*		-0.147 (-0.364 to 0.035)	0.101
Wallace's Hawk-Eagle	*Nisaetus nanus*		-0.218 (-0.488 to 0.029)	0.129
Common Emerald Dove	*Chalcophaps indica*	+	0.205 (0.092 to 0.329)	0.06
Green Imperial Pigeon	*Ducula aenea*	-	-0.146 (-0.235 to -0.067)	0.043
Mountain Imperial Pigeon	*Ducula badia*		-0.025 (-0.251 to 0.172)	0.109
Greater Coucal	*Centropus sinensis*		-0.01 (-0.135 to 0.109)	0.062
Raffles's Malkoha	*Rhinortha chlorophaea*		0.02 (-0.028 to 0.066)	0.024
Red-billed Malkoha	*Zanclostomus javanicus*		-0.043 (-0.248 to 0.141)	0.098
Chestnut-breasted Malkoha	*Phaenicophaeus curvirostris*		-0.03 (-0.128 to 0.062)	0.048
Plaintive Cuckoo	*Cacomantis merulinus*	-	-0.185 (-0.367 to -0.033)	0.086
Square-tailed Drongo-Cuckoo	*Surniculus lugubris*		-0.009 (-0.107 to 0.079)	0.047
Indian Cuckoo	*Cuculus micropterus*		-0.047 (-0.153 to 0.045)	0.049
Barred Eagle-Owl	*Bubo sumatranus*		0.055 (-0.128 to 0.228)	0.09
Diard's Trogon	*Harpactes diardii*	+	0.259 (0.128 to 0.403)	0.07
Scarlet-rumped Trogon	*Harpactes duvaucelii*		0.041 (-0.053 to 0.129)	0.047
Rufous-collared Kingfisher	*Actenoides concretus*	+	0.249 (0.133 to 0.381)	0.064
White-crowned Hornbill	*Berenicornis comatus*		0.027 (-0.168 to 0.214)	0.095
Rhinoceros Hornbill	*Buceros rhinoceros*	+	0.064 (0.003 to 0.121)	0.03
Wreathed Hornbill	*Rhyticeros undulatus*		-0.072 (-0.149 to 0.004)	0.04
Golden-whiskered Barbet	*Psilopogon chrysopogon*	+	0.196 (0.14 to 0.255)	0.029
Red-crowned Barbet	*Psilopogon rafflesii*		0.085 (-0.108 to 0.273)	0.097

Red-throated Barbet	*Psilopogon mystacophanos*	+	0.247 (0.186 to 0.312)	0.032
Blue-eared Barbet	*Psilopogon duvaucelii*	+	0.245 (0.104 to 0.396)	0.074
Brown Barbet	*Caloramphus fuliginosus*		0.06 (-0.026 to 0.142)	0.043
White-bellied Woodpecker	*Dryocopus javensis*		-0.066 (-0.305 to 0.143)	0.112
Rufous Woodpecker	*Micropternus brachyurus*		0.007 (-0.189 to 0.188)	0.095
Buff-necked Woodpecker	*Meiglyptes tukki*		0.004 (-0.108 to 0.113)	0.056
Blue-crowned Hanging Parrot	*Loriculus galgulus*	-	-0.185 (-0.39 to -0.019)	0.095
Blue-rumped Parrot	*Psittinus cyanurus*	-	-0.169 (-0.289 to -0.067)	0.056
Long-tailed Parakeet	*Psittacula longicauda*	-	-0.347 (-0.525 to -0.199)	0.083
Black-and-red Broadbill	*Cymbirhynchus macrorhynchos*		0.043 (-0.127 to 0.207)	0.084
Black-and-yellow Broadbill	*Eurylaimus ochromalus*		-0.007 (-0.056 to 0.039)	0.024
Malayan Banded Pitta	*Hydrornis irena*		0.023 (-0.024 to 0.067)	0.023
Hooded Pitta	*Pitta sordida*		0.09 (-0.101 to 0.278)	0.095
Green Iora	*Aegithina viridissima*	+	0.231 (0.147 to 0.323)	0.044
Scarlet Minivet	*Pericrocotus speciosus*		-0.042 (-0.202 to 0.103)	0.078
Dark-throated Oriole	*Oriolus xanthonotus*	+	0.055 (0.007 to 0.102)	0.025
Sumatran Drongo	*Dicrurus sumatranus*		-0.15 (-0.336 to 0.005)	0.088
Greater Racket-tailed Drongo	*Dicrurus paradiseus*	+	0.097 (0.061 to 0.132)	0.018
Black-naped Monarch	*Hypothymis azurea*		0.069 (-0.025 to 0.158)	0.047
Asian Paradise Flycatcher	*Terpsiphone paradisi*	+	0.14 (0.029 to 0.252)	0.057
Crested Jay	*Platylophus galericulatus*		-0.048 (-0.222 to 0.106)	0.083
Black Magpie	*Platysmurus leucopterus*	+	0.087 (0.043 to 0.129)	0.021
Slender-billed Crow	*Corvus enca*	-	-0.145 (-0.278 to -0.03)	0.064
Black-headed Bulbul	*Pycnonotus atriceps*	-	-0.146 (-0.316 to -0.004)	0.081
Ruby-throated Bulbul	*Pycnonotus dispar*		-0.005 (-0.06 to 0.049)	0.027

Olive-winged Bulbul	*Pycnonotus plumosus*		0.009 (-0.188 to 0.2)	0.101
Cream-vented Bulbul	*Pycnonotus simplex*	+	0.12 (0.071 to 0.167)	0.025
Asian Red-eyed Bulbul	*Pycnonotus brunneus*	-	-0.106 (-0.174 to -0.042)	0.033
Grey-cheeked Bulbul	*Alophoixus bres*	+	0.148 (0.048 to 0.247)	0.051
Yellow-bellied Bulbul	*Alophoixus phaeocephalus*	+	0.293 (0.199 to 0.4)	0.05
Buff-vented Bulbul	*Iole olivacea*		0.15 (-0.006 to 0.303)	0.08
Streaked Bulbul	*Ixos malaccensis*		0.138 (-0.029 to 0.31)	0.086
Bar-winged Prinia	*Prinia familiaris*	-	-0.229 (-0.363 to -0.112)	0.065
Rufous-tailed Tailorbird	*Orthotomus sericeus*	+	0.184 (0.104 to 0.271)	0.043
Ashy Tailorbird	*Orthotomus ruficeps*		0.101 (-0.041 to 0.246)	0.071
Chestnut-backed Scimitar Babbler	*Pomatorhinus montanus*	+	0.324 (0.198 to 0.473)	0.07
Pin-striped Tit-Babbler	*Macronus gularis*	+	0.237 (0.18 to 0.294)	0.029
Rufous-crowned Babbler	*Malacopteron magnum*	+	0.194 (0.109 to 0.283)	0.044
Black-capped Babbler	*Pellorneum capistratum*	+	0.109 (0.04 to 0.175)	0.035
Black Laughingthrush**	*Garrulax lugubris*		0.107 (-0.092 to 0.288)	0.095
Asian Fairy-bluebird	*Irena puella*		-0.016 (-0.095 to 0.057)	0.039
Velvet-fronted Nuthatch	*Sitta frontalis*		0.101 (-0.09 to 0.287)	0.097
Common Hill Myna	*Gracula religiosa*		-0.022 (-0.077 to 0.03)	0.027
Oriental Magpie-Robin	*Copsychus saularis*		-0.073 (-0.223 to 0.067)	0.075
White-rumped Shama	*Copsychus malabaricus*	-	-0.324 (-0.519 to -0.169)	0.09
Verditer Flycatcher	*Eumyias thalassinus*		0.094 (-0.063 to 0.243)	0.079
White-crowned Forktail	*Enicurus leschenaulti*		0.077 (-0.033 to 0.182)	0.055
Yellow-rumped Flycatcher	*Ficedula zanthopygia*		0.032 (-0.152 to 0.204)	0.091
Greater Green Leafbird	*Chloropsis sonnerati*		-0.04 (-0.193 to 0.095)	0.073
Lesser Green Leafbird	*Chloropsis cyanopogon*	+	0.162 (0.052 to 0.281)	0.057
Blue-winged Leafbird	*Chloropsis cochinchinensis*		-0.033 (-0.112 to 0.039)	0.038

Crimson-breasted Flowerpecker	*Prionochilus percussus*		0.071 (-0.128 to 0.27)	0.099
Orange-bellied Flowerpecker	*Dicaeum trigonostigma*		0.093 (-0.069 to 0.249)	0.081
Ruby-cheeked Sunbird	*Chalcoparia singalensis*	+	0.174 (0.046 to 0.307)	0.066
Brown-throated Sunbird	*Anthreptes malacensis*		0.058 (-0.096 to 0.206)	0.079
B. Intercept (beta)				
Crested Partridge	*Rollulus rouloul*		-5.138 (-6.655 to -3.855)	0.725
Great Argus	*Argusianus argus*		-3.052 (-3.607 to -2.516)	0.284
Crested Serpent Eagle	*Spilornis cheela*		-4.443 (-5.719 to -3.306)	0.617
Wallace's Hawk-Eagle	*Nisaetus nanus*		-5.517 (-7.506 to -3.947)	0.918
Common Emerald Dove	*Chalcophaps indica*		-5.591 (-7.068 to -4.376)	0.688
Green Imperial Pigeon	*Ducula aenea*		-1.386 (-1.841 to -0.898)	0.238
Mountain Imperial Pigeon	*Ducula badia*		-6.128 (-8.193 to -4.462)	0.945
Greater Coucal	*Centropus sinensis*		-4.081 (-5.14 to -3.164)	0.508
Raffles's Malkoha	*Rhinortha chlorophaea*		-1.656 (-2.116 to -1.196)	0.235
Red-billed Malkoha	*Zanclostomus javanicus*		-5.498 (-7.196 to -4.067)	0.807
Chestnut-breasted Malkoha	*Phaenicophaeus curvirostris*		-3.092 (-3.816 to -2.385)	0.362
Plaintive Cuckoo	*Cacomantis merulinus*		-3.177 (-4.013 to -2.373)	0.414
Square-tailed Drongo-Cuckoo	*Surniculus lugubris*		-3.261 (-3.997 to -2.575)	0.368
Indian Cuckoo	*Cuculus micropterus*		-3.026 (-3.731 to -2.345)	0.35
Barred Eagle-Owl	*Bubo sumatranus*		-6.041 (-7.959 to -4.439)	0.886
Diard's Trogon	*Harpactes diardii*		-6.488 (-8.355 to -4.97)	0.867
Scarlet-rumped Trogon	*Harpactes duvaucelii*		-3.624 (-4.477 to -2.865)	0.405
Rufous-collared Kingfisher	*Actenoides concretus*		-6.006 (-7.693 to -4.663)	0.771
White-crowned Hornbill	*Berenicornis comatus*		-5.894 (-7.711 to -4.356)	0.861
Rhinoceros Hornbill	*Buceros rhinoceros*		-2.769 (-3.327 to -2.193)	0.294
Wreathed Hornbill	*Rhyticeros undulatus*		-2.209 (-2.776 to -1.662)	0.285

Golden-whiskered Barbet	*Psilopogon chrysopogon*	-3.813 (-4.544 to -3.157)	0.353
Red-crowned Barbet	*Psilopogon rafflesii*	-6.705 (-8.855 to -4.922)	1.03
Red-throated Barbet	*Psilopogon mystacophanos*	-4.213 (-5.034 to -3.456)	0.4
Blue-eared Barbet	*Psilopogon duvaucelii*	-6.595 (-8.439 to -5.011)	0.886
Brown Barbet	*Caloramphus fuliginosus*	-3.728 (-4.548 to -2.965)	0.408
White-bellied Woodpecker	*Dryocopus javensis*	-5.963 (-7.975 to -4.284)	0.944
Rufous Woodpecker	*Micropternus brachyurus*	-5.72 (-7.547 to -4.229)	0.833
Buff-necked Woodpecker	*Meiglyptes tukki*	-3.869 (-4.822 to -3.058)	0.45
Blue-crowned Hanging Parrot	*Loriculus galgulus*	-3.613 (-4.594 to -2.726)	0.473
Blue-rumped Parrot	*Psittinus cyanurus*	-1.813 (-2.363 to -1.23)	0.285
Long-tailed Parakeet	*Psittacula longicauda*	-1.345 (-1.939 to -0.761)	0.295
Black-and-red Broadbill	*Cymbirhynchus macrorhynchos*	-5.591 (-7.283 to -4.228)	0.778
Black-and-yellow Broadbill	*Eurylaimus ochromalus*	-1.366 (-1.782 to -0.928)	0.221
Malayan Banded Pitta	*Hydrornis irena*	-1.684 (-2.119 to -1.237)	0.23
Hooded Pitta	*Pitta sordida*	-6.731 (-8.841 to -4.988)	0.995
Green Iora	*Aegithina viridissima*	-4.979 (-6.118 to -3.969)	0.548
Scarlet Minivet	*Pericrocotus speciosus*	-4.403 (-5.604 to -3.366)	0.563
Dark-throated Oriole	*Oriolus xanthonotus*	-2.188 (-2.664 to -1.708)	0.241
Sumatran Drongo	*Dicrurus sumatranus*	-3.508 (-4.449 to -2.684)	0.448
Greater Racket-tailed Drongo	*Dicrurus paradiseus*	-1.404 (-1.809 to -0.984)	0.211
Black-naped Monarch	*Hypothymis azurea*	-3.987 (-4.865 to -3.149)	0.434
Asian Paradise Flycatcher	*Terpsiphone paradisi*	-5.089 (-6.397 to -3.997)	0.611
Crested Jay	*Platylophus galericulatus*	-4.585 (-5.852 to -3.529)	0.597
Black Magpie	*Platysmurus leucopterus*	-2.016 (-2.463 to -1.553)	0.233
Slender-billed Crow	*Corvus enca*	-2.657 (-3.35 to -1.974)	0.353

Black-headed Bulbul	*Pycnonotus atriceps*	-3.293 (-4.134 to -2.468)	0.429
Ruby-throated Bulbul	*Pycnonotus dispar*	-1.655 (-2.136 to -1.155)	0.254
Olive-winged Bulbul	*Pycnonotus plumosus*	-6.251 (-8.282 to -4.579)	0.965
Cream-vented Bulbul	*Pycnonotus simplex*	-2.707 (-3.241 to -2.193)	0.267
Asian Red-eyed Bulbul	*Pycnonotus brunneus*	-1.255 (-1.688 to -0.797)	0.228
Grey-cheeked Bulbul	*Alophoixus bres*	-4.837 (-5.954 to -3.811)	0.552
Yellow-bellied Bulbul	*Alophoixus phaeocephalus*	-5.546 (-6.892 to -4.402)	0.634
Buff-vented Bulbul	*Iole olivacea*	-6.316 (-8.135 to -4.767)	0.875
Streaked Bulbul	*Ixos malaccensis*	-6.576 (-8.581 to -4.927)	0.936
Bar-winged Prinia	*Prinia familiaris*	-1.593 (-2.157 to -1.013)	0.292
Rufous-tailed Tailorbird	*Orthotomus sericeus*	-4.56 (-5.57 to -3.656)	0.488
Ashy Tailorbird	*Orthotomus ruficeps*	-5.404 (-7.001 to -4.102)	0.727
Chestnut-backed Scimitar Babbler	*Pomatorhinus montanus*	-6.814 (-8.797 to -5.253)	0.912
Pin-striped Tit-Babbler	*Macronus gularis*	-3.832 (-4.53 to -3.165)	0.351
Rufous-crowned Babbler	*Malacopteron magnum*	-4.775 (-5.874 to -3.8)	0.517
Black-capped Babbler	*Pellorneum capistratum*	-3.489 (-4.204 to -2.796)	0.36
Black Laughingthrush	*Garrulax lugubris*	-6.855 (-8.932 to -5.033)	0.992
Asian Fairy-bluebird	*Irena puella*	-2.611 (-3.207 to -2.025)	0.304
Velvet-fronted Nuthatch	*Sitta frontalis*	-6.798 (-9.069 to -4.991)	1.046
Common Hill Myna	*Gracula religiosa*	-1.587 (-2.038 to -1.131)	0.231
Oriental Magpie-Robin	*Copsychus saularis*	-3.986 (-5.071 to -3.069)	0.504
White-rumped Shama	*Copsychus malabaricus*	-1.744 (-2.343 to -1.1)	0.32
Verditer Flycatcher	*Eumyias thalassinus*	-5.713 (-7.365 to -4.297)	0.793
White-crowned Forktail	*Enicurus leschenaulti*	-4.479 (-5.574 to -3.513)	0.523
Yellow-rumped Flycatcher	*Ficedula zanthopygia*	-5.895 (-7.729 to -4.375)	0.861
Greater Green Leafbird	*Chloropsis sonnerati*	-4.158 (-5.26 to -3.178)	0.531
Lesser Green Leafbird	*Chloropsis cyanopogon*	-5.178 (-6.498 to -4.033)	0.626

Blue-winged Leafbird	*Chloropsis cochinchinensis*	-2.451 (-3 to -1.893)	0.283
Crimson-breasted Flowerpecker	*Prionochilus percussus*	-6.609 (-8.881 to -4.873)	1.019
Orange-bellied Flowerpecker	*Dicaeum trigonostigma*	-5.907 (-7.609 to -4.478)	0.815
Ruby-cheeked Sunbird	*Chalcoparia singalensis*	-5.761 (-7.307 to -4.415)	0.728
Brown-throated Sunbird	*Anthreptes malacensis*	-5.446 (-6.987 to -4.108)	0.737

*In section A, + and – signs in the trend column show species that increased or decreased significantly over time, respectively; the other species showed no significant changes.

**Black Laughingthrush is normally a montane species. We heard the species at Way Canguk and made a recording of its song.

Appendix S8. Species specific parameter estimates, North Sumatra. Bronze-tailed Peacock-Pheasant was significantly more common away from roads; the other species showed no significant changes.

English name	Scientific name	Mean coefficient (95% credible interval)	SD
A. Trend (beta)			
Bronze-tailed Peacock-Pheasant	*Polyplectron chalcurum*	0.31 (0.026 to 0.6)	0.144
Mountain Imperial Pigeon	*Ducula badia*	0.362 (-0.146 to 0.874)	0.26
Fire-tufted Barbet	*Psilopogon pyrolophus*	0.124 (-0.048 to 0.284)	0.083
Black-browed Barbet	*Psilopogon oorti*	-0.044 (-0.324 to 0.189)	0.13
Greater Yellownape	*Chrysophlegma flavinucha*	-0.023 (-0.473 to 0.384)	0.219
Black-and-crimson Oriole	*Oriolus cruentus*	0.086 (-0.112 to 0.288)	0.103
Sumatran Drongo	*Dicrurus sumatranus*	0.157 (-0.005 to 0.312)	0.078
Common Green Magpie	*Cissa chinensis*	0.08 (-0.208 to 0.349)	0.141
Sumatran Treepie	*Dendrocitta occipitalis*	0.109 (-0.136 to 0.364)	0.126
Cinereous Tit	*Parus cinereus*	-0.033 (-0.352 to 0.312)	0.167
Orange-spotted Bulbul	*Pycnonotus bimaculatus*	0.086 (-0.169 to 0.362)	0.132
Ochraceous Bulbul	*Alophoixus ochraceus*	0.014 (-0.237 to 0.24)	0.119
Sunda Bulbul	*Ixos virescens*	0.115 (-0.076 to 0.335)	0.101
Mountain Leaf Warbler	*Phylloscopus trivirgatus*	0.09 (-0.031 to 0.214)	0.062
Hill Prinia	*Prinia superciliaris*	-0.072 (-0.542 to 0.405)	0.243
Spot-necked Babbler	*Stachyris striolata*	0.082 (-0.167 to 0.311)	0.117
Sunda Laughingthrush	*Garrulax paliatus*	0.09 (-0.057 to 0.245)	0.075
Chestnut-capped Laughingthrush	*Garrulax mitratus*	0.167 (-0.04 to 0.348)	0.097

Black Laughingthrush	*Garrulax lugubris*	0.109 (-0.112 to 0.316)	0.109
Long-tailed Sibia	*Heterophasia picaoides*	0.13 (-0.203 to 0.432)	0.162
Black-capped White-eye	*Zosterops atricapilla*	0.094 (-0.075 to 0.294)	0.091
Rufous-browed Flycatcher	*Anthipes solitaris*	0.138 (-0.094 to 0.373)	0.115
Large Niltava	*Niltava grandis*	0.123 (-0.078 to 0.296)	0.092
Indigo Flycatcher	*Eumyias indigo*	0.052 (-0.201 to 0.282)	0.123
Snowy-browed Flycatcher	*Ficedula hyperythra*	0.069 (-0.093 to 0.235)	0.081
Little Pied Flycatcher	*Ficedula westermanni*	-0.008 (-0.219 to 0.207)	0.107
Orange-bellied Flowerpecker	*Dicaeum trigonostigma*	-0.069 (-0.41 to 0.294)	0.176
B. Trend (Intercept)			
Bronze-tailed Peacock-Pheasant	*Polyplectron chalcurum*	-1.401 (-1.949 to -0.796)	0.298
Mountain Imperial Pigeon	*Ducula badia*	-2.077 (-4.188 to -0.228)	1.046
Fire-tufted Barbet	*Psilopogon pyrolophus*	-0.337 (-0.797 to 0.063)	0.218
Black-browed Barbet	*Psilopogon oorti*	-0.943 (-1.762 to -0.209)	0.388
Greater Yellownape	*Chrysophlegma flavinucha*	-1.225 (-2.441 to -0.167)	0.596
Black-and-crimson Oriole	*Oriolus cruentus*	-1.582 (-2.248 to -0.811)	0.369
Sumatran Drongo	*Dicrurus sumatranus*	-0.178 (-0.526 to 0.164)	0.176
Common Green Magpie	*Cissa chinensis*	-1.912 (-3.989 to -0.01)	1.033
Sumatran Treepie	*Dendrocitta occipitalis*	-0.875 (-1.649 to -0.187)	0.377
Cinereous Tit	*Parus cinereus*	-1.528 (-2.865 to -0.245)	0.692
Orange-spotted Bulbul	*Pycnonotus bimaculatus*	-1.082 (-3.042 to 0.495)	0.906
Ochraceous Bulbul	*Alophoixus ochraceus*	-1.988 (-4.489 to 0.147)	1.203
Sunda Bulbul	*Ixos virescens*	-2.061 (-4.584 to -0.047)	1.196
Mountain Leaf Warbler	*Phylloscopus*	0.443 (0.27 to 0.612)	0.088

	trivirgatus		
Hill Prinia	*Prinia superciliaris*	-0.921 (-3.317 to 0.941)	1.078
Spot-necked Babbler	*Stachyris striolata*	-2.057 (-4.204 to -0.176)	1.016
Sunda Laughingthrush	*Garrulax paliatus*	1.752 (1.372 to 2.091)	0.183
Chestnut-capped Laughingthrush	*Garrulax mitratus*	-0.292 (-0.817 to 0.177)	0.254
Black Laughingthrush	*Garrulax lugubris*	-1.994 (-4.176 to -0.095)	1.063
Long-tailed Sibia	*Heterophasia picaoides*	0.149 (-0.673 to 0.81)	0.377
Black-capped White-eye	*Zosterops atricapilla*	0.011 (-0.38 to 0.361)	0.19
Rufous-browed Flycatcher	*Anthipes solitaris*	-1.704 (-2.835 to -0.493)	0.628
Large Niltava	*Niltava grandis*	-1.034 (-1.563 to -0.438)	0.297
Indigo Flycatcher	*Eumyias indigo*	-1.172 (-2.187 to -0.252)	0.5
Snowy-browed Flycatcher	*Ficedula hyperythra*	-0.338 (-0.819 to 0.068)	0.227
Little Pied Flycatcher	*Ficedula westermanni*	-1.149 (-1.663 to -0.529)	0.287
Orange-bellied Flowerpecker	*Dicaeum trigonostigma*	-1.931 (-4.389 to 0.185)	1.172
C. Occurrence (p)			
Bronze-tailed Peacock-Pheasant	*Polyplectron chalcurum*	0.73 (0.41 to 0.984)	0.161
Mountain Imperial Pigeon	*Ducula badia*	0.184 (0.013 to 0.822)	0.203
Fire-tufted Barbet	*Psilopogon pyrolophus*	0.574 (0.39 to 0.835)	0.112
Black-browed Barbet	*Psilopogon oorti*	0.473 (0.222 to 0.908)	0.173
Greater Yellownape	*Chrysophlegma flavinucha*	0.295 (0.088 to 0.802)	0.179
Black-and-crimson Oriole	*Oriolus cruentus*	0.681 (0.311 to 0.987)	0.191
Sumatran Drongo	*Dicrurus sumatranus*	0.65 (0.485 to 0.861)	0.096
Common Green Magpie	*Cissa chinensis*	0.166 (0.013 to 0.748)	0.187
Sumatran Treepie	*Dendrocitta occipitalis*	0.468 (0.231 to 0.88)	0.167

Cinereous Tit	*Parus cinereus*	0.326 (0.078 to 0.883)	0.216
Orange-spotted Bulbul	*Pycnonotus bimaculatus*	0.08 (0.009 to 0.349)	0.091
Ochraceous Bulbul	*Alophoixus ochraceus*	0.128 (0.006 to 0.718)	0.176
Sunda Bulbul	*Ixos virescens*	0.14 (0.005 to 0.74)	0.187
Mountain Leaf Warbler	*Phylloscopus trivirgatus*	0.87 (0.764 to 0.973)	0.054
Hill Prinia	*Prinia superciliaris*	0.058 (0.003 to 0.345)	0.097
Spot-necked Babbler	*Stachyris striolata*	0.179 (0.014 to 0.742)	0.186
Sunda Laughingthrush	*Garrulax paliatus*	0.045 (0.018 to 0.083)	0.017
Chestnut-capped Laughingthrush	*Garrulax mitratus*	0.356 (0.218 to 0.563)	0.087
Black Laughingthrush	*Garrulax lugubris*	0.182 (0.015 to 0.798)	0.2
Long-tailed Sibia	*Heterophasia picaoides*	0.075 (0.031 to 0.149)	0.031
Black-capped White-eye	*Zosterops atricapilla*	0.41 (0.287 to 0.565)	0.071
Rufous-browed Flycatcher	*Anthipes solitaris*	0.441 (0.11 to 0.962)	0.244
Large Niltava	*Niltava grandis*	0.677 (0.384 to 0.976)	0.165
Indigo Flycatcher	*Eumyias indigo*	0.374 (0.135 to 0.858)	0.186
Snowy-browed Flycatcher	*Ficedula hyperythra*	0.55 (0.37 to 0.808)	0.112
Little Pied Flycatcher	*Ficedula westermanni*	0.708 (0.405 to 0.978)	0.159
Orange-bellied Flowerpecker	*Dicaeum trigonostigma*	0.123 (0.005 to 0.694)	0.169

Appendix S9. Variance parameters from hierarchical Bayesian models of changes in bird abundance.

Parameter	Mean (95% credible interval)	SD
A. Way Canguk		
hyper-parameter sigma.alpha, variance	0.132 (0.105 to 0.166)	0.016
hyper-parameter sigma.beta0, variance	1.84 (1.52 to 2.23)	0.183
over-dispersion parameter K[1], variance - year1	0.117 (0.089 to 0.152)	0.016
over-dispersion parameter K[2], variance - year2	0.142 (0.106 to 0.19)	0.021
over-dispersion parameter K[3], variance - year3	0.097 (0.077 to 0.121)	0.011
over-dispersion parameter K[4], variance - year4	0.169 (0.107 to 0.262)	0.041
over-dispersion parameter K[5], variance - year5	0.221 (0.105 to 0.449)	0.089
over-dispersion parameter K[6], variance - year6	0.06 (0.05 to 0.072)	0.006
over-dispersion parameter K[7], variance - year7	12.4 (2.13 to 79.3)	18.2
B. North Sumatra		
hyper-parameter mu.beta0, mean (intercept)	0.322 (-1.704 to -0.437)	0.322
hyper-parameter mu.beta2, mean (elevation)	0.084 (-0.191 to 0.133)	0.084
hyper-parameter mu.p, mean (zero-inflation)	0.518 (-1.886 to 0.17)	0.518
hyper-parameter sigma.alpha, variance	0.051 (0.004 to 0.193)	0.051
hyper-parameter sigma.beta0, variance	0.289 (0.729 to 1.874)	0.289
hyper-parameter sigma.beta2, variance	0.085 (0.146 to 0.486)	0.085
hyper-parameter sigma.p, variance	0.429 (1.257 to 2.957)	0.429

Appendix S10. Statistical tests of the changes in (A) hours walked by trappers in search of the four most sensitive species in our study area in North Sumatra and (B) numbers of birds trapped per day.

model	AIC*c* weight	ΔAIC*c*	marginal R^2	conditional R^2	df
A. Hours walked by trappers over time					
Silver-eared mesia *Leiothrix argentauris*					
year	0.645	0	0.87	0.87	4
null	0.355	1.2	0	0	3
Common green magpie *Cissa chinensis*					
year	0.836	0	0.36	0.9	4
null	0.164	3.3	0	0	3
Sumatran laughingthrush *Garrulax bicolor*					
year	0.985	0	0.8	0.8	4
null	0.015	8.3	0	0	3
Chestnut-capped laughingthrush *Garrulax mitratus*					
year	0.85	0	0.46	0.64	4
null	0.15	3.5	0	0	3
B. Birds caught by trappers over time					
Silver-eared mesia *Leiothrix argentauris*					
year	0.956	0	0.55	0.73	4
null	0.044	6.1	0	0	3
Common green magpie *Cissa chinensis*					
null	0.806	0	0	0	3
year	0.194	2.8	0.21	0.77	4
Sumatran laughingthrush *Garrulax bicolor*					
null	0.7	0	0	0	3
year	0.3	1.7	0.18	0.7	4
Chestnut-capped laughingthrush *Garrulaxmitratus*					
null	0.557	0	0	0	3

year	0.443	0.5	0.13	0.7	4

Supporting References

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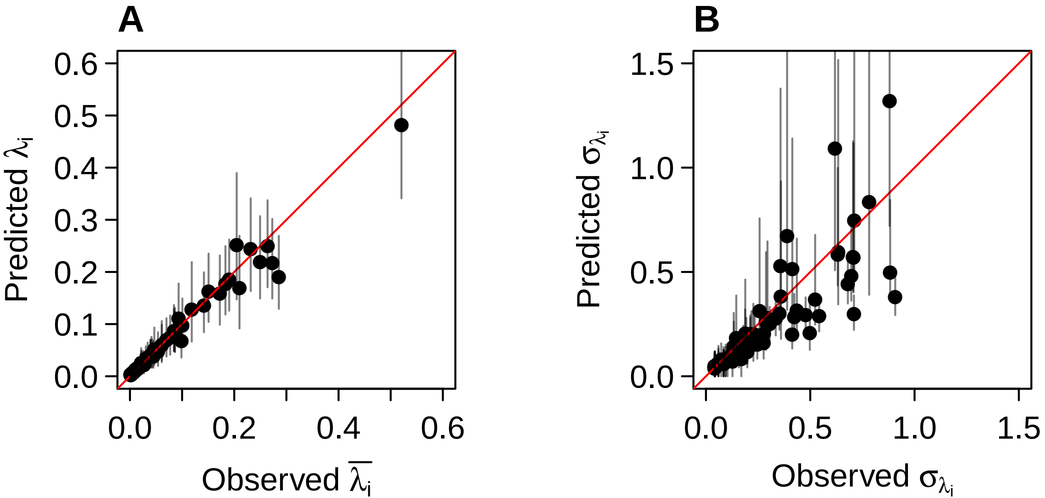
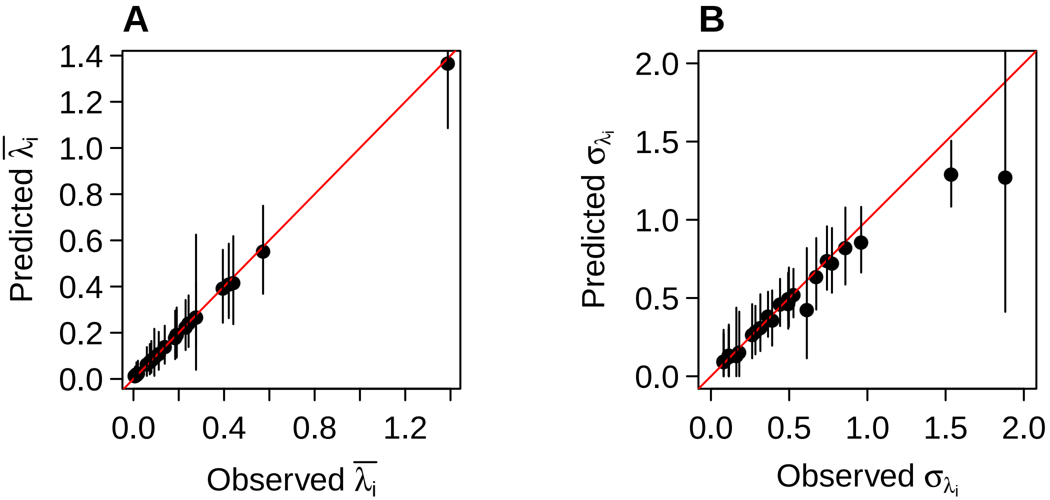
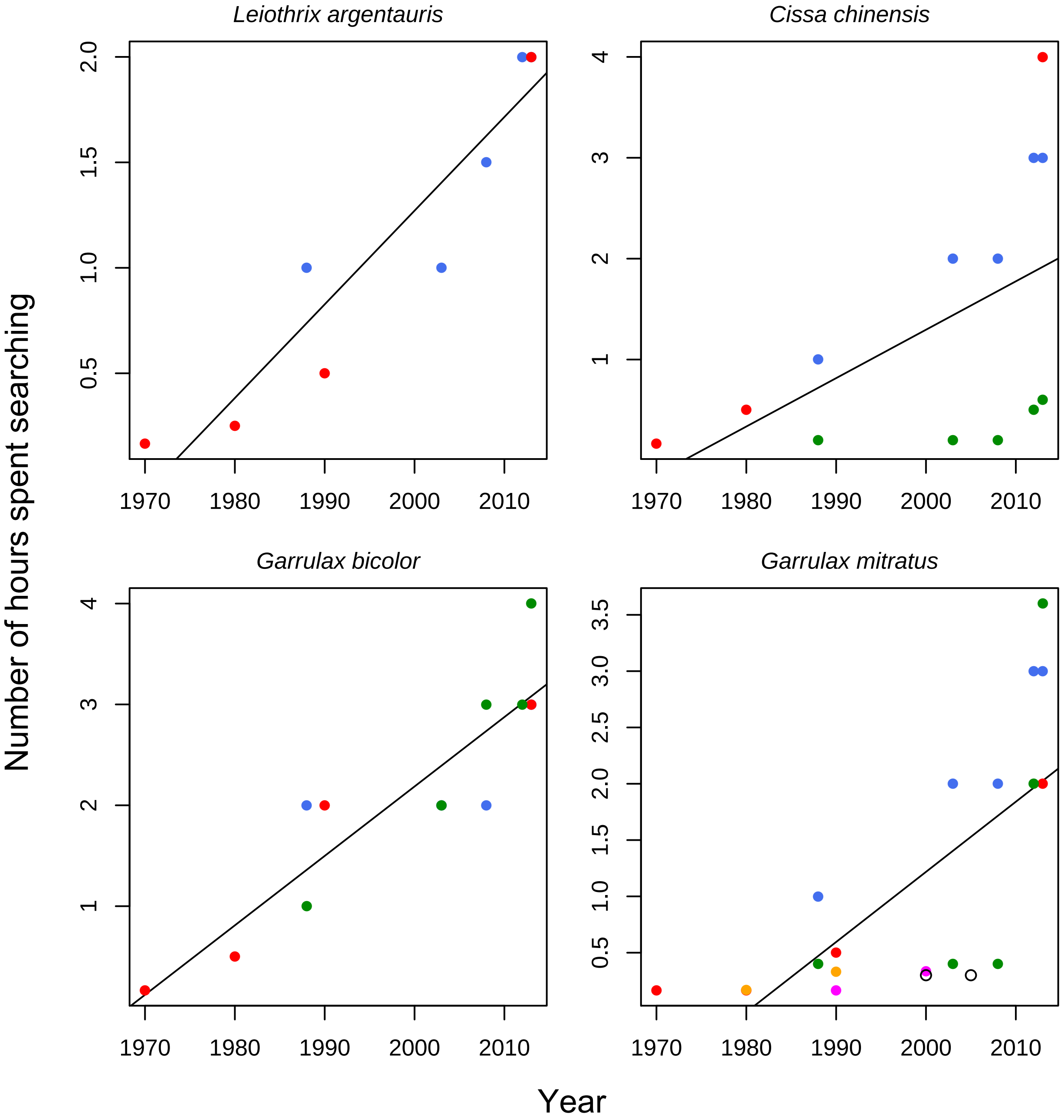


Appendix S11. Goodness-of-fit plots for Bayesian hierarchical models, Way Canguk.

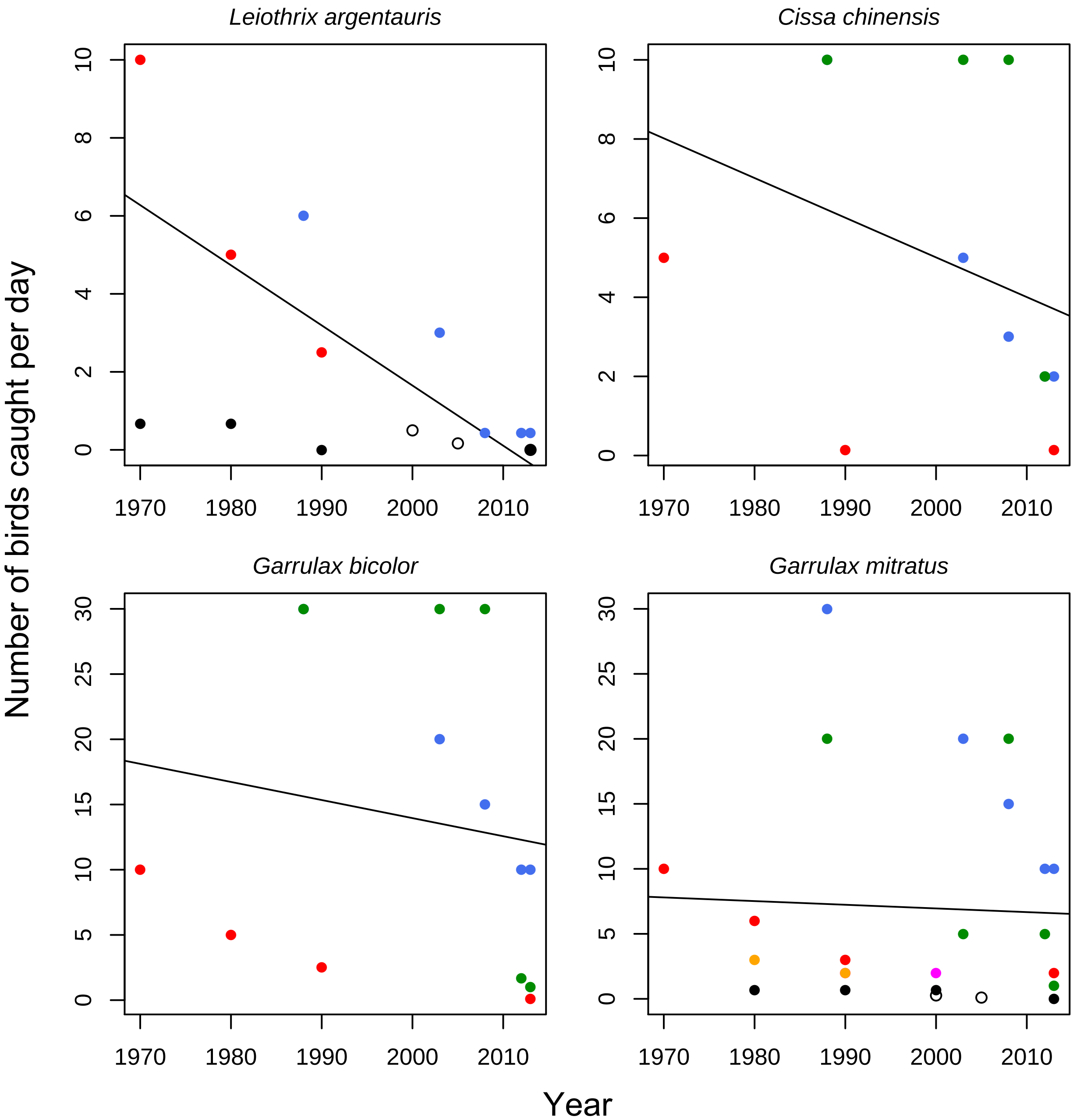


Appendix S12. Goodness-of-fit plots for Bayesian hierarchical models, North Sumatra.



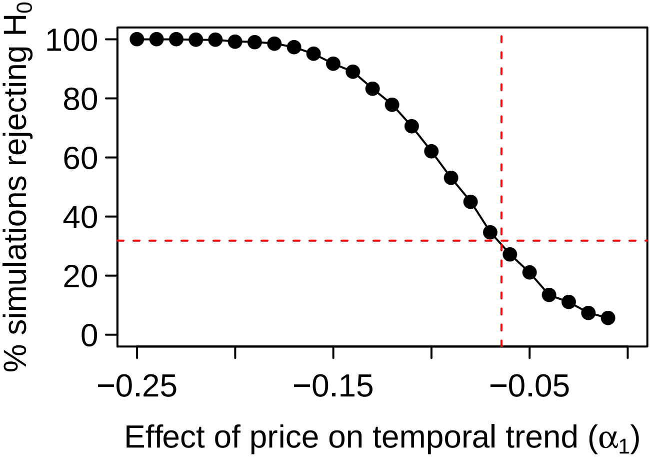
Leiothrix argentauris
Cissa chinensis
Garrulax bicolor
Garrulax mitratus
Number of hours spent searching
Year
1970
1980
1990
2000
2010
0.5
1.0
1.5
2.0
1
2
3
4
2.5
3.0
3.5

Appendix S13. Number of birds caught per day by trappers when searching for the species they ranked to be the most sensitive to trapping. Data point colors show different trappers.


Leiothrix argentauris
Cissa chinensis
Garrulax bicolor
Garrulax mitratus
Number of birds caught per day
Year
1970
1980
1990
2000
2010
0
2
4
6
8
10
0
5
10
15
20
25
30

Appendix S14. Time spent by trappers searching for the species they ranked to be the most sensitive to trapping. Data point colors show different trappers.

Appendix S15. A posteriori power analysis for Way Canguk evaluating the percent of simulations that rejected the null hypothesis (that there is no relationship between price and temporal trend) given varying true relationships of price to trend.



Appendix S16. A posteriori power analysis for North Sumatra evaluating the percent of simulations that rejected the null hypothesis (that there is no relationship between price and spatial trend) given varying true relationships of price to trend.