Effects of Anthropogenic Disturbances on Habitat Use of Bornean Birds

Katherine Lauck1,2, Sarah L. Carroll3, Elly Mufliati4,5, Sadtata Noor Adirahmanta6, Novia Sagita4, Siti Kartikawati4,5, Adam Miller2,4

1US Fulbright Program

2Planet Indonesia – USA

3Graduate Degree Program in Ecology, 1476 Campus Delivery, Colorado State University, Fort Collins, CO, U.S.A., 80523 Colorado State University

4Yayasan Planet Indonesia

5Universitas Tanjungpura

6Balai Konservasi Sumber Daya Alam

# Abstract

# Introduction

Indonesia’s tropical forests are global biodiversity hotspots (Myers et al. 2000, Brooks et al. 2002). Across the archipelago, anthropogenic pressures have led to extensive deforestation from agricultural expansion, logging, mining, and fires (Achard 2002, Sodhi et al. 2004, Hansen et al. 2013, Margono et al. 2014, Abood et al. 2015), making land use change the leading driver of species endangerment and extinction (Nijman 2010, Nijman et al. 2012, Newbold et al. 2015, Symes et al. 2018). Roads facilitate land use change by increasing access to nearby forest (Laporte et al. 2007). In addition, they provide access points to previously inaccessible interior forest for hunting and trapping and transportation networks for distribution (Suárez et al. 2009, Harris et al. 2017, Symes et al. 2018). Commercial hunting and trapping feed the international wildlife trade in which Indonesia supplies Europe and East Asia with wildlife for pets, consumption, and medical applications (e.g. Slow Loris exported to Europe and Pangolin and Helmeted Hornbill exported to East Asia, primarily China; Collar and Juniper 1992, Bennett et al. 2002, Alves et al. 2010, Alves and Alves 2011, Drury 2011, Fernandes-Ferreira et al. 2012, Nóbrega Alves et al. 2013, Bush et al. 2014, McNamara et al. 2016). Commercially valuable species are thus doubly threatened by habitat loss and hunting or trapping, both of which increase with proximity to roads (Laporte et al. 2007, Suárez et al. 2009, Harris et al. 2017, Symes et al. 2018).

The same access points and transportation networks that supply the international wildlife trade also supply a lesser known but thriving domestic bird trade (Nijman 2010, Harris et al. 2017) encompassing thousands of species and millions of individuals (Jepson and Ladle 2005, Chng et al. 2015, 2016, 2018, Chng and Eaton 2016, Rentschlar et al. 2018). The caged bird trade and Indonesia’s rapid rate of deforestation have driven avian species declines, extirpations, and extinctions (e.g. Javan Pied Starling, Bali Starling, Straw-headed Bulbul; Collar and Juniper 1992, Collar et al. 1994, Wright et al. 2001, Jepson and Ladle 2005, Harris et al. 2017, Bergin et al. 2017). Most of these declines have been documented on Java, which is the most densely populated island in the world, retains only 5% of its historical forest [CITE], and is the cultural and demand center of the bird trade (Burivalova et al. 2017).

Conservationists suspect that commercially valuable bird species in Kalimantan (Indonesian Borneo) are also declining (Lee et al. 2016) because recent and accelerating land use change (Miettinen et al. 2011, 2012) may have increased access to forest for trapping. However, Borneo’s remoteness and image as a bastion of pristine forest have shielded its bird trade from investigation prior to a 2018 finding that it is widespread and lucrative (Rentschlar et al. 2018). Contrary to its pristine reputation, Kalimantan lost an estimated 15.4% of its forested land area between 2000-2010 alone (Miettinen et al. 2011, 2012) to massive commercial expansion of oil palm plantations and logging combined with associated forest fires (Curran 2004). Sumatra has experienced similar changes to Kalimantan over a similar period, and Sumatran forest bird species that are sold for more money have declined more steeply, implicating the trade in their decline. Furthermore, commercially valuable birds are absent from Sumatran forest less than 5 km from a road (Harris et al. 2017). This information along with suspected declines of Bornean forest species (Harris et al. 2015) suggests that commercially valuable birds in Kalimantan are likely disappearing even from intact and protected forests.

If these declines are occurring, and especially if they are occurring in protected areas, birds under extreme demand in the Indonesian bird trade such as Grey-cheeked Bulbul and White-rumped Shama may quickly and quietly vanish in the manner of Straw-headed Bulbul (Lee et al. 2016, Bergin et al. 2017, Chiok et al. 2019). While forest birds are trapped and sold in Kalimantan (Rentschlar et al. 2018), no study has yet documented population-level effects of trapping on wild bird communities in Kalimantan. Because proximity to roads increases access to intact forest and thereby increases trapping pressure in nearby forest (Harris et al. 2017), we quantified population-level effects of trapping by comparing the distributions of commercially valuable species to those of non-valuable species over a gradient of distance to roads. We hypothesized that commercially valuable birds would be less likely to be found near roads than non-valuable birds in Gunung Niyut Nature Reserve in West Kalimantan, Indonesia. We used a hierarchical community occupancy model to account for variation in detection and habitat effects.

# Methods

## Study area

Cagar Alam Gunung Niyut is an isolated preserve in the northwest corner of West Kalimantan, Indonesia. Its 124,500 hectares protect an island of intact forest surrounded by agricultural land. Of particular interest are its ~2000 hectares of intact lowland forest in Kabupaten Landak to the southeast. Little remains of West Kalimantan’s lowland primary forest, and this section has the potential to support threatened primary forest species, and in particular, songbird species valuable in the wild bird trade. We accessed this section through the border village Tauk (Fig. 1).

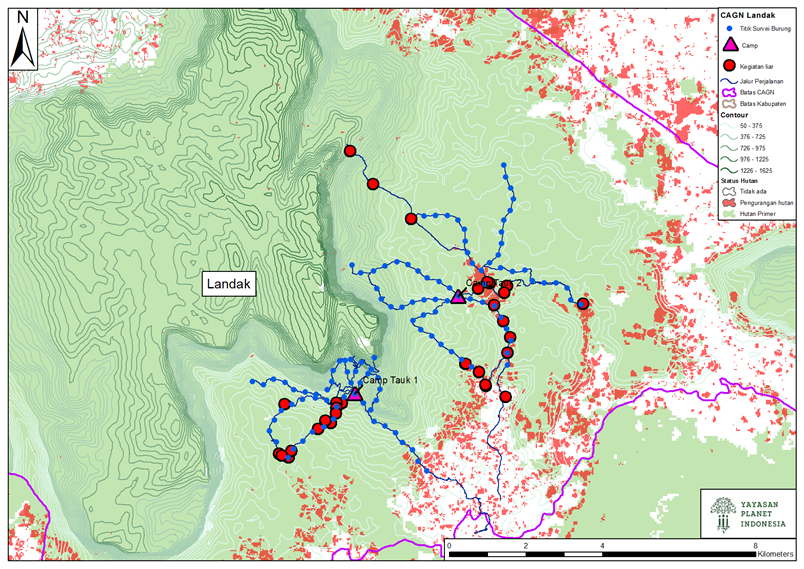


Figure 1. Study sites in Cagar Alam Gunung Niyut, Kabupaten Landak. Blue circles correspond to point count locations, pink triangles correspond to our base camps, and red circles correspond to illegal activity detected (hunting, logging, or clear-cutting for agriculture). The pink line delineates the border of Gunung Niyut Nature Preserve, red fill indicates forest loss 2011-2015 (Hansen et al. 2013), green indicates primary forest, and white indicates nonforest.

## Point counts

Two teams of three to four people, consisting of two trained observers, one local guide, and sometimes one accompanying government employee, conducted 10-minute 100 m radius point counts at points every 300 m along each of 14 transects, between 5:30 and 10am. These transects were spread in an approximately radial pattern around two base camps approximately 5 km apart. On average, each transect contained 8 points, for a total of 115 points. Almost all points were surveyed once a month from October 2017 to February 2018, for a total of five occasions per point, except for 12 points where one occasion was missed for logistical reasons. Our survey team was split into two teams that each surveyed half of the transects each month. At each point, the teams recorded the time, date, weather, and observer, then sat silently for 5 minutes before beginning to collect data. All point counts were digitally recorded. All detected individuals were recorded along with the detection method (visual or auditory) including individuals that could not be identified. For each unknown individual, time relative to the start of the point count was recorded. After data collection in the field, the primary recordist for each point count listened to the recording a second time to verify species identification and to identify calls that could not be identified in the field.

## Development of habitat covariates

In May 2018, a team of three observers visually estimated percent water cover, rounded to the nearest 10%, at each of the 115 point count locations. In addition, we utilized remotely sensed data and GIS to characterize forest structure and condition, topography, and measures of anthropogenic disturbance hypothesized to influence avian occupancy dynamics (Table 1). Landsat 8 Surface Reflectance NDVI images were composited and cloud masked in Google Earth Engine for the study period (October 2017- February 2018) to produce mean NDVI values across the study area (Vermote et al. 2016, Gorelick et al. 2017). We calculated forest canopy disturbance metrics utilizing LandTrendr implemented in Google Earth Engine (Kennedy et al. 2018). LandTrendr is an algorithm that uses time series analysis of Landsat imagery to fit pixel-wise change trajectories of vegetation indices to identify and map forest canopy disturbance events (Lorenz et al. 2015, Cohen et al. 2018, Kennedy et al. 2018). We considered disturbance that occurred within the last ten years to be recent for primary tropical forest in Asia and so we calculated LandTrendr disturbance metrics for 2007-2017 (Canterbury et al. 2000, Cole et al. 2014). We hypothesized that species’ response to forest structure and condition may change with territory size, so these covariates were assessed at multiple spatial scales (Pearman 2002, Glisson et al. 2017). We calculated the average value of NDVI, forest height, proportion of disturbed canopy, and proportion of intact forest across buffers with radii of 100m, 500m, 1000m, and 1500m from each point count location (Glisson et al. 2017).

We calculated Euclidean distance to the nearest roads and other human disturbances including agricultural clearings, illegal logging areas, and dwellings/structures located during surveys. All spatial covariate data were processed and extracted for point count locations using ArcMap v10.6 (*ArcGIS* 2004). To determine which variables to include in our starting model set, we assessed collinearity of habitat variables using the lattice R package (Sarkar 2008). One variable out of each set of collinear variables were included in the starting model set for occupancy (Elbroch and Wittmer 2012). All covariates were scaled to 0-1 as recommended by (MacKenzie and Hines 2018).

Table 1. Habitat covariates developed for occupancy models.

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| --- | --- | --- | --- | --- |
| Habitat  Covariate | Hypothesized  Effect | Data Product  Satellite and Sensor | Spatial Resolution | Data Sources |
| Normalized Difference Vegetation Index (NDVI) |  | Landsat 8 Surface Reflectance OLI/TIRS | 30m | Vermote et al. 2016, Gorelick et al. 2017 |
| Elevation, slope,  and aspect |  | ASTER Global Digital Elevation Model V002 | 30m | NASA LP DAAC 2011 |
| Forest canopy height  ( canopy cover > 5m) |  | Forest Canopy Height Map; derived from Geoscience Laser Altimeter System (GLAS) LiDAR | 1000m | Simard et al. 2011 |
| Proportion of canopy recently disturbed (2007-2017) | Species specific response to disturbance levels | LandTrendr disturbance metrics: Landsat 7 TM & Landsat 8 OLI/TIRS TOA b | 30m | Kennedy et al. 2010; Kennedy et al. 2018 |
| Proportion of intact forest in 2016 |  | REG Borneo Forest Cover 2016; derived from Landsat 5,7, & 8 | 30m | Gaveau 2017 |
| Distance to roads |  | Open Street Map Kalimantan roads layer | 30m | OpenStreetMap contributors (2015) |

## Occupancy model

We used a multispecies single-season occupancy model to estimate the effects of habitat covariates, disturbed canopy, distance from roads, and a binary indicator of whether a species was commercially valuable on the occupancy probability of 115 sites for a community of 206 bird species, while also accounting for imperfect detection (Kery and Schaub 2011). We considered a species commercially valuable if it was sold for an average of xxx or more in Kalimantan bird markets (Rentschlar et al. 2018). We assumed that the true state of occupancy (*zi,j*) for species *i* and site *j* was a Bernoulli random variable with probability of occupancy (*ψi,j*) such that

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We assumed that the detection or non-detection (*yi,j,k*) for each species *i* at each point count location *j* and occasion *k* was a Bernoulli random variable with detection probability (*pi,j,k*) conditional on the true state of occupancy (*zi,j*)such that

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We modeled detection (*pi,j,k*) as

We modeled occupancy probability (*ψi,j*) as

Parameters in the *α* family were simple fixed effects. Parameters in the *β* family were estimated for each species, with species terms drawn from a normal distribution of mean and variance estimated from the data. Parameters in the *δ* family correspond to variance around a mean of 0 to incorporate additional variation for each species or site that could not be explained by other fixed or random effects.

While we detected 206 species in total, we excluded those species with fewer than 10 detections (111 species). In addition, we excluded *Rhinoplax vigil* because its mobile lifestyle and far-reaching call ensure that our point counts were not far enough apart for spatial independence, which violates the assumption of independence of detection. Furthermore, mobile species such as birds are capable of traveling among points, which would violate the assumption of independence of occurrence. To prevent this assumption from being violated, we set our points 300 m apart, which is accepted in the literature for territorial and sedentary birds [CITE]. To account for spatial autocorrelation, we estimated the random effect of transect (8-15 points that were spatially grouped; *δ*1). We fitted the model to our point count data in a Bayesian framework using Markov Chain Monte Carlo simulation to obtain the posterior distribution for each parameter. Our models were implemented in JAGS (Plummer 2017) and run using the R package R2jags (Su and Yajima 2020). Non-informative priors were used throughout. Specifically, means and fixed effects were drawn from a normal(0, 100) distribution and sigma terms were drawn from a uniform(0, 10) distribution. We four chains for 50,000 iterations with a thinning interval of 20 to reduce autocorrelation and 20,000 iterations of burn-in, resulting in 1,500 samples of the posterior. We checked convergence by visually inspecting trace plots and with the Gelman-Rubin convergence diagnostic (Gelman and Rubin 1992), ensuring that all values were less than 1.1. For full code, see supplemental information.

We report posterior means for all parameter estimates detailing how each species responded to each microhabitat variable and interactions with commercial value (i.e., *β*1-7). Microhabitat variables and interactions were considered to significantly affect species when the 95% Bayesian credible interval (BCI) for the mean (l) of the random effect distribution governing species’ responses did not overlap 0. We considered there to be significant variability among species in their responses when the corresponding *σ* of the distribution was greater than 0.

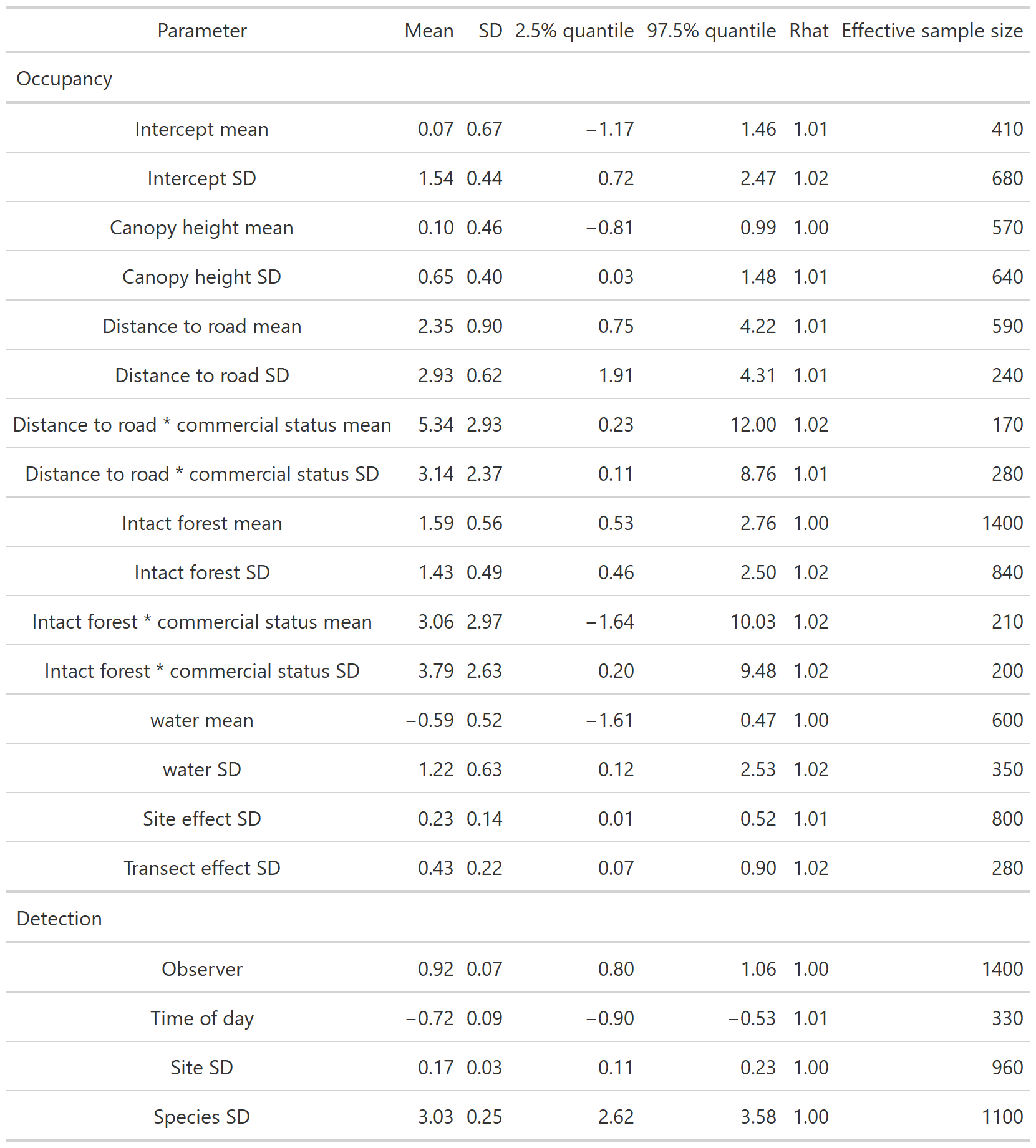
# Results

We detected a total of 206 species, 95 of which were detected at least ten times. The five most frequently detected species were *Psilopogon australis, Psilopogon chrysopogon, Psilopogon mystacophanos, Arachnothera longirostra, Pycnonotus erythropthalmos,* and *Alcippe brunneicauda*. We detected seven species that are either sold at high prices as pets (Lee et al. 2016, Rentschlar et al. 2018) or sale of its casque (Helmeted Hornbill: *Rhinoplax vigil*): *Alophoixus tephrogenys* (10 detections), *Chloropsis sonnerati* (11 detections), *Copsychus malabaricus* (39 detections), *Hydrornis schwaneri* (1 detection), *Irena puella* (64 detections), *Loriculus galgulus* (83 detections), *Platylophus galericulatus* (2 detections),  *R. vigil* (74 detections), and *Spilornis cheela* (20 detections). We had insufficient detection data for *P*. *galericulatus* and *H. schwaneri* to produce informative results using occupancy modeling, and so excluded these species from occupancy models.

## Detection probability

Detection varied between observers. Birds were more likely to be detected earlier in the day, and detection varied significantly among both sites and species, though much more among species (*σ* = 0.16 and 4.55, respectively; see Table 2).

Table 2. Posterior distributions, Rhat, and effective sample size of model parameters. For occupancy parameters, only hyperparameters (mean and standard deviation of per-species random effects) are included here. A table of all parameters may be found in the Appendix.



*Are commercially valuable species more likely to occupy sites further from roads than commercially non-valuable species?*

Species were significantly more likely to occupy sites that were further from roads, and this effect was stronger for commercially valuable species compared to commercially non-valuable species (Table 1, Fig. 2). Occupancy of commercially valuable species increased faster over the distance to roads gradient than occupancy of commercially non-valuable species (Fig. 2).

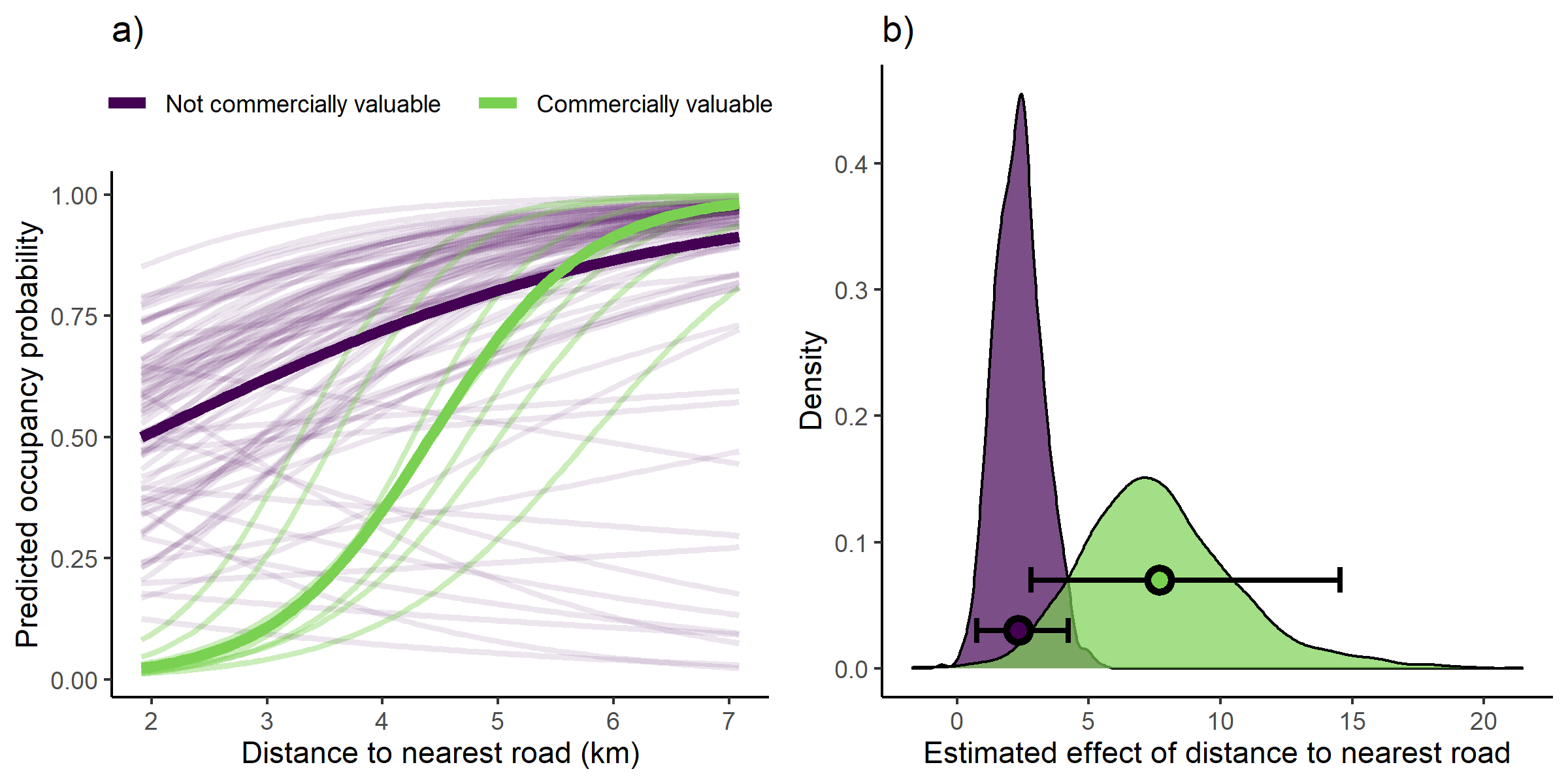


Figure 2. Most species are more likely to occupy areas further from roads, but this effect is significantly stronger for commercially valuable species. a) Each thin line traces the relationship between distance to nearest road and a species’ occupancy. The green lines indicate commercially valuable species, and purple lines indicate non-valuable species. Thick lines trace the means for each group. b) Posterior distribution of the effect of distance to road, split between commercially valuable (green) and non-valuable (purple) species. The dot indicates the mean for each group, and the horizontal error bars represent the 95% confidence interval for the mean of each group.

## Are commercially valuable species more likely to occupy sites with higher percentages of intact forest than commercially non-valuable species?

While all species were significantly more likely to occupy sites with higher percent intact forest, commercially valuable species were not more likely to occupy sites with higher percentages of intact forest than commercially non-valuable species (Fig. 3).

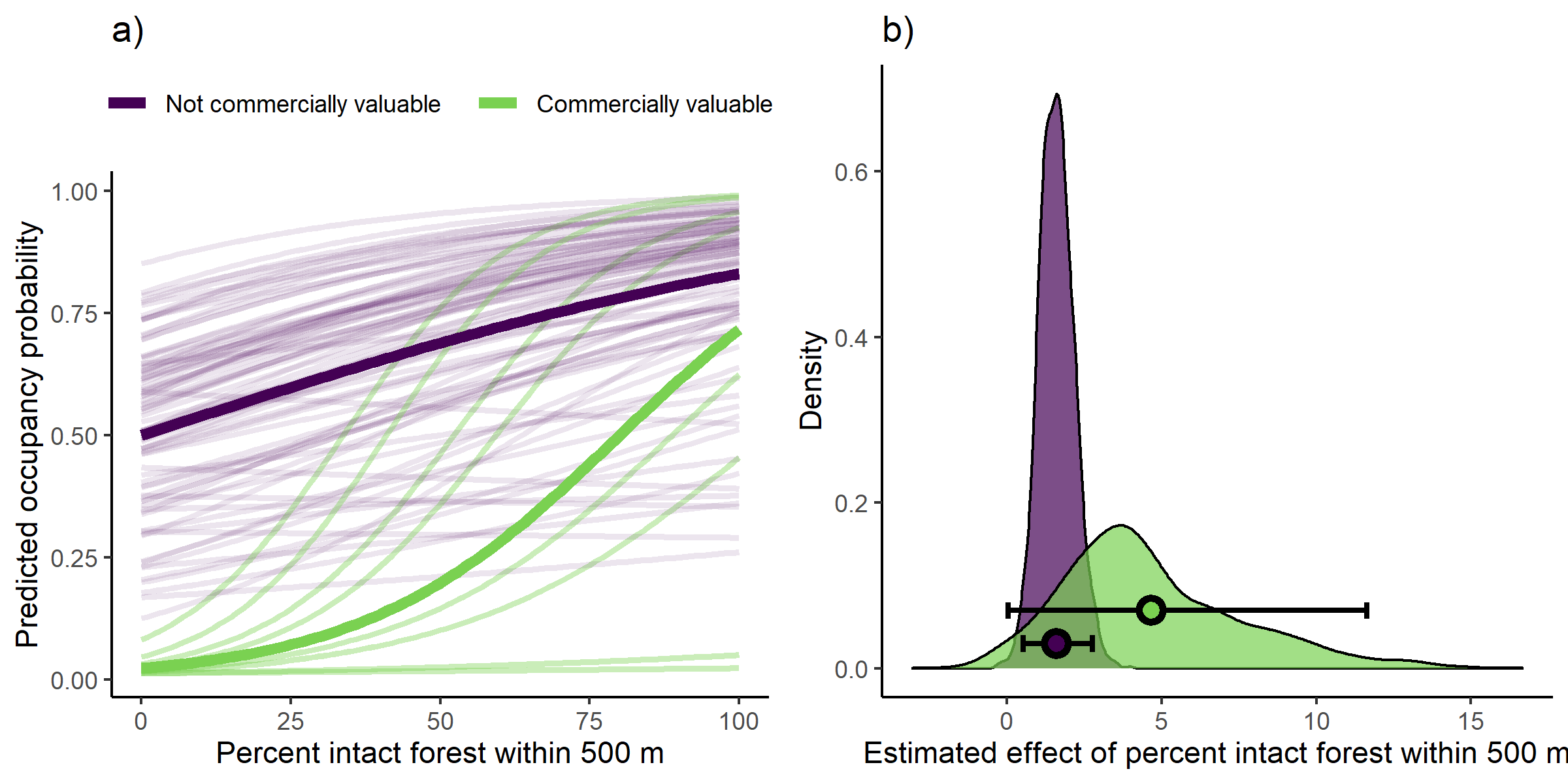


Figure 3. Most species are more likely to occupy areas with more intact forest, and we found similar rates of occupancy for commercially valuable and non-valuable species. a) Each thin line traces the relationship between percent intact forest within 500m and a species’ occupancy. The green lines indicate commercially valuable species, and purple lines indicate non-valuable species. Thick lines trace the means for each group. b) Posterior distribution of the effect of percent intact forest within 500m, split between commercially valuable (green) and non-valuable (purple) species. The dashed line indicates the mean for each group, and the horizontal error bars represent the 95% confidence interval for the mean of each group.

# Discussion

To our knowledge, this is the first study demonstrating the community-level impact of distance to road as a proxy for forest access, which we argue indicates trapping intensity, on commercially valuable songbird species in Indonesian Borneo. Our results highlight the sensitivity of primary rainforest species to habitat disturbance, with the average species likely to occupy sites further from roads and with more intact forest. Encouragingly, our results do not suggest that commercially valuable birds in this protected area are especially sensitive to forest degradation. In addition, the average commercially valuable species occupies sites further from roads than commercially non-valuable species. This trend suggests that extreme trapping pressure near roads could be preventing commercially valuable species from inhabiting otherwise suitable forest. However, because we did not directly quantify trapping pressure, we cannot establish causation.

The IUCN Asian Songbird Trade Specialist Group identified five of the commercially valuable species detected in this study (*C. sonnerati*, *C. malabaricus*, *A. tephrogenys*, *I. puella*, *P. galericulatus*) as threatened by trade based on their ubiquitous presence at markets and severe population declines on Java and Sumatera (Lee et al. 2016). These results may indicate a similar decline on Indonesian Borneo. While it is conceivable that only trapped species would learn to avoid humans, the presence of humans increases perceived predation risk for most birds (Bötsch et al. 2018). Therefore, if the primary cause of declines in occupancy near to roads was avoidance instead of the removal of individuals, the observed difference in occupancy near roads between commercially valuable and not valuable birds would be unlikely. If commercially valuable species are disappearing from primary forest in Borneo as suggested by our results, domestic demand for these species has funded efforts to reach even very remote and rural areas. However, our study was conducted in one remnant forest, and therefore we are unable to demonstrate that our results are representative of wild bird populations across Indonesian Borneo. To gain a more complete understanding of the scale of exploitation, this study could be replicated in protected areas across Indonesia, especially in Indonesian Borneo and eastern Indonesia.

Data regarding wild populations of these birds, especially on the island of Borneo, is scarce. While *C. sonnerati* is classified as endangered and *A. tephrogenys* is classified as vulnerable, *C. malabaricus*, *I. puella*, *P. galericulatus*, and *L. galgulus* are classified as least concern (IUCN 2021). However, for these species, the IUCN also reports that the total number of mature individuals is unknown. This lack of data impedes our ability to eliminate the possibility that natural rareness caused these species’ low occupancy in our survey, but our personal experiences in the region have led us to suspect that it did not. During 2013-2014 Ivy Expeditions to Malaysian Borneo in which KSL participated, both Grey-cheeked Bulbul and White-rumped Shama (White-crowned) were detected regularly (unpublished). Furthermore, two of Indonesia’s most persecuted species, Straw-headed Bulbul and Sunda Laughingthrush, were common up until the 1990s (Chiok et al. 2019, Leupen et al. 2020).

Currently rare and valuable species may be subject to an anthropogenic Allee effect in which their increasing rareness increases their desirability which balances the increasing costs of finding and trapping ever more rare species (Courchamp et al. 2006). Indeed, supply of frequently traded species in Sumatran markets does not increase with price increases, suggesting that those species’ wild source populations are being depleted (Krishna et al. 2019). In addition, Harris et al. (2015) identified several Sumatran species whose supply was decreasing or holding steady as their market price increased, suggesting that trappers are currently engaged in trapping the few remaining individuals of these highly prized species. Long-term studies of Kalimantan markets may reveal this same signature of decline for the commercially valuable species we detected.

Data clarifying the current status of songbirds in Kalimantan could help urge governments into action. Neither the regional West Kalimantan government nor the national Indonesian government has a plan to reduce trapping or promote in-situ conservation of its threatened songbirds. Globally, efforts to reduce poaching have primarily focused on increased enforcement, but this approach may instead disincentivize biodiversity conservation (Cooney et al. 2017). Community-based conservation (CBC) offers an alternative that engages rural residents living near wildlife in designing and implementing conservation actions. If CBC efforts invest in local governance (Berkes 2007), embrace a multi-dimensional view of human well-bring (Woodhouse et al. 2015), and are based on local context and values (Waylen et al. 2010), they are more likely to successfully reduce the negative impacts of overexploitation on wildlife and society.

Our study was not designed to measure the reach of trappers into the forest, but estimated occupancy of commercially valuable species did increase over the studied gradient of distance to roads (~2-10 km). In Sumatra, bird trappers stated that their usual maximum distance traveled from a road was about 5 km (Harris et al. 2017). If the reach of trappers in our study area was similar, we successfully studied a large portion of the trapping pressure gradient. A survey of trappers’ habits, whether conducted via interviews or field cameras, would clarify the details of their reach into the forest. In addition, understanding the role of social and economic factors in the cost-benefit analysis that governs how far trappers choose to search for birds would provide guidance for conservationists working to decrease take. Only xx% of Kalimantan primary forest is located more than 5 km from a road. However, if this hypothetical reach of trappers is reduced by only half a kilometer by changing the cost-benefit balance of searching farther into the forest, xx% of additional forest would potentially be habitable for commercially valuable species. On the other hand, road construction (e.g. planned roads; Alamgir et al. 2019) would allow trappers to penetrate deeper into the last refuges available for commercially valuable birds.

If Indonesia fails to protect the species of concern recommended by the Asian Songbird Crisis Summit (Lee et al. 2016) based upon the negative impacts of the trade on wild populations, these species are likely to quickly vanish from remaining forest across the archipelago. The Conservation Act No. 5 of 1990 prohibited the use, keeping, or destruction of protected animals and plants (UU Pemerintah Republik Indonesia No. 5 1990). In 1999 the list of protected animals and plants included a few songbirds such as Bali Myna and the Rufous-fronted Laughingthrush (Peraturan Pemerintah Republik Indonesia No. 7 1999). Both songbirds have been traded to the very threshold of extinction: ICUN reports that fewer than 50 Bali Myna remain, and fewer than 250 Rufous-fronted Laughingthrush remain (IUCN 2021). In 2018, the national government of Indonesia updated its protected species list to include [list the songbirds](Peraturan Menteri Lingkungan Hidup dan Kehutanan 2018a). Indonesians whose cultural identities are strongly linked to keeping songbirds (a group that includes Indonesian President Joko Widodo) pressured the national government into removing of some of the most valuable and overexploited species from the list of protected species (e.g. Straw-headed Bulbul, which is classified by the IUCN as Critically Endangered)(Peraturan Menteri Lingkungan Hidup dan Kehutanan 2018b). This unfortunate about-face highlights the massive domestic demand for them.

This demand in turn highlights that songbird species provide valuable cultural services. In Indonesia, the domestic bird trade developed from Javanese cultural practices of keeping birds in homes. Jepson (2010) and Marshall et al. (2020) describe how bird keepers practice intensive husbandry of kept birds, enter them in song contests, teach them new song variants, and pay enormous prices for the most prized individuals. Furthermore, many forest bird species, especially colorful, large, and charismatic ones, play roles in mythology, forest stewardship, and forest understanding for the Dayak and Ibon ethnic groups of Borneo (author KSL personal experience living with Dayak people). This anecdote echoes findings from Costa Rica, where forest birds have been found to provide more cultural services than their agriculture-associated counterparts (Echeverri et al. 2020). Lastly, ecotourism could potentially provide an alternative to extractive uses of forest and increase the well-being of local people under the right conditions (Chung et al. 2018), but the loss of charismatic and rare bird species reduces the value of forests for bird-watchers, an increasingly important group of ecotourists (Puhakka et al. 2011). If charismatic singers disappear from forests, the domestic caged bird industry will suffer, the cultural identity of Indonesians may be diminished, and the tourism value of forests will decline, which may encourage deforestation [CITE tourism literature].

This study documents the effects of illegal trapping activity on wild populations of threatened songbirds. Despite residing within a Nature Preserve (*Cagar Alam*) whose regulations prohibit harvesting of any kind, valuable songbird populations are showing signs of trapping pressure in this isolated park. Our results also highlight that most species that we detected depend on primary forest for their survival, and therefore, ongoing deforestation of Gunung Niyut Nature Preserve will further decrease suitable habitat for all but a few birds in our study community. CAGN is an island of forest in an area that was mainly deforested in the 1980s and 1990s (Global Forest Watch 2018) and is one of West Kalimantan’s last large plots of intact forest. This remnant habitat is vital to the continued persistence of these primary forest species. Furthermore, we detected no individuals of Straw-headed Bulbul during this study, which indicates that past trapping pressure reached deep into the park. If indeed Straw-headed Bulbul was trapped out of the Preserve in the past, currently valuable species could be trapped out in the future. However, the presence of threatened songbirds documented here underscores how vital it is to protect Cagar Alam Gunung Niyut. Road construction near or in primary forest will likely further reduce the viable habitat available for commercially valuable birds.

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# Supplementary Material

*Biases and possible weaknesses of this study*

Team 1 frequently observed some species that were not expected to be common and were very rarely observed by Team 2 (e.g. *Arachnothera flavigaster* observed 26 times by Team 1 and 1 time by Team 2, and expected to be “uncommon” based on Birds of the Indonesian Archipelago). In addition, Team 2 observed many common species many more times than Team 1 (e.g. *Loriculus galgulus* observed 0 times by Team 1 and 83 times by Team 2, and expected to be “fairly common” based on Birds of the Indonesian Archipelago). Team 2 was led by a team member with 2+ years of experience identifying Bornean bird calls, and Team 1 had only been provided a month-long training before the start of the project, so this bias is expected to relate to misidentification and detection that is biased towards loud and complex song types. Indeed, species underreported by Team 1 tended to have quieter, simpler, and/or higher-pitched calls, or were extremely common (e.g. all of the *Prionochilus*, *Loriculus galgulus*, *Dicaeum trigonostigma*, *Cyanoderma rufifrons*, *Arachnothera longirostra*, *Aegithina viridissima*).