Effects of Anthropogenic Disturbances on Habitat Use of Bornean Birds

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# Abstract

# Introduction

Land use change is driving habitat loss and biodiversity declines globally, and the highest rates of these changes are in the tropics (Newbold et al. 2015). In addition, the tropics provide most of the supply for the global trade in wildlife for pets, consumption, and medical applications (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). The effect of this demand for tropical wildlife is intensified by the increased access to intact forest provided by land use change, and in particular, the development of roads for extractive activities (i.e. logging and mining; Suárez et al. 2009, Harris et al. 2017, Symes et al. 2018).

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, and fires (Achard 2002, Sodhi et al. 2004, Hansen et al. 2013, Margono et al. 2014, Abood et al. 2015), and combined with hunting, trapping, and the international wildlife trade (e.g. Pangolin and Helmeted Hornbill exported to East Asia), are major drivers of species endangerment and extinction (Nijman 2010, Nijman et al. 2012, Symes et al. 2018). These global problems are intensified by a 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 (Collar and Juniper 1992, Collar et al. 1994, Wright et al. 2001, Jepson and Ladle 2005, Harris et al. 2017, Bergin et al. 2017).

The majority of these declines have been documented on Java, which is the most densely populated island in the world, retains a tiny proportion of its historical forest, and is the cultural and demand center of the bird trade (Burivalova et al. 2017). Kalimantan (Indonesian Borneo) has experienced recent and accelerating deforestation, losing an estimated 15.4% of forest between 2000-2010 alone (Miettinen et al. 2011, 2012) to massive expansion of oil palm plantations and logging enterprises combined with recent, and often associated, forest fires (Curran 2004). Concurrently, Rentschlar et al. (2018) documented the unprecedented scale of the caged bird trade in Kalimantan, but to date we are unaware of any study quantifying the effects of trade on wild birds in Kalimantan. Sumatra has experienced similar changes to Kalimantan over a similar time period, and Harris et al. (2017) found that bird market price predicted the slope of decline for Sumatran forest birds, implicating the trade in their decline. Furthermore, they found that commercially valuable birds were absent from forest less than 5 km from a road. Given this information, and expert-derived suspected declines including species found in Bornean forests (Harris et al. 2015), it is likely that commercially valuable birds in Kalimantan are 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). These and other songbird species provide crucial 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 dominant roles in mythology, forest stewardship, and forest understanding for the Dayak and Ibon ethnic groups of Borneo (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).

While it is clear that forest birds are trapped and sold in Kalimantan (Rentschlar et al. 2018), no study has yet documented community-level effects of trapping on wild bird communities in Kalimantan. To understand how strongly trapping is affecting the distribution of commercially valuable species, we tested the hypothesis that that commercially valuable birds will be found further from roads than commercially 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 compared the effect of distance from roads and forest disturbance to account for edge effects. If increased distance to roads increases the probability that trapped species will occupy forest faster than the probability that non-trapped species will occupy forest, then it is clear that

# 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 ~20 square kilometers 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).

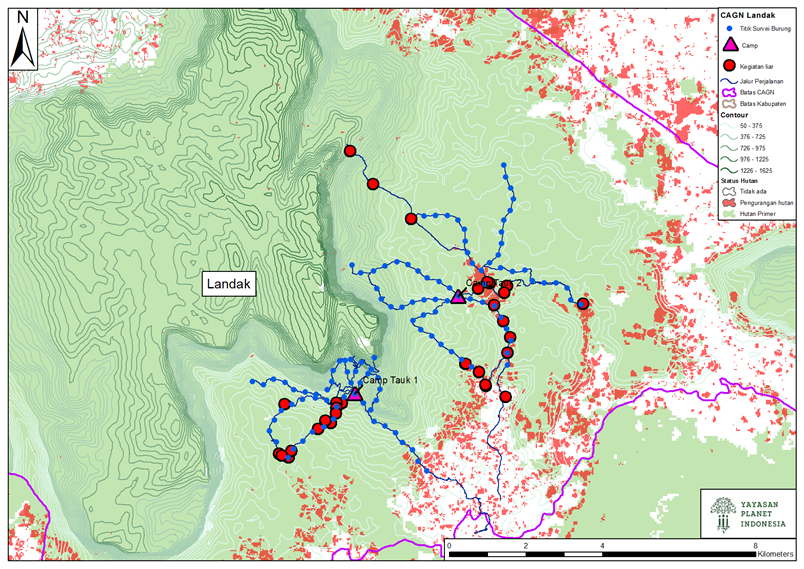


Figure 1. Study sites in Cagar Alam Gunung Niyut, Kabupaten Landak. Blue circles correspond to point count locations, pink triangles correspond to our base camps, and red circles correspond to illegal activity detected (hunting, logging, or clear-cutting for agriculture). The pink line delineates the border of Gunung Niyut Nature Preserve, red fill indicates forest loss 2011-2015, 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, but isolated by topography. 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 recorded percent water cover 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 commercial demand 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 assumed that the true state of occupancy (*zi,j*) for species *i* and site *j* resulted from the probability of occupancy (*ψi,j*) for species *i* and site *j* such that

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We assumed that the state of detection or non-detection (*yi,j,k*) for each species *i* at each point count location *j* and occasion *k* given the true state of occupancy (*zi,j*) for each species *i* at each point *j* resulted from true occupancy (*zi,j*) of species *i* and point *j* and detection probability (*pi,j,k*) of species *i* at point *j* and occasion *k* 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 effect terms. 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* and *γ* families were random intercepts (variance estimated from the data around a mean of 0) designed to incorporate additional variation for each species or site that could not be explained by other fixed or random effects.

All habitat and point count covariates were standardized and scaled to a 0-1 range as recommended by Kery and Schaub (2011). While we detected 206 species in total, we excluded those species with fewer than 10 detections to reduce the number of uninformative posterior distributions. 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 one of the key assumptions of occupancy modeling. To account for spatial autocorrelation, we grouped points by transect. We fitted the model to our point count data using Markov Chain Monte Carlo simulation to calculate 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 iterated over the model 50,000 times with a thinning interval of 20 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 extracted the posterior distribution for all parameter estimates detailing how each species responded to each microhabitat variable and interactions with commercial value (i.e., *β*1-6). Microhabitat variables and interactions were considered to significantly affect species on average 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

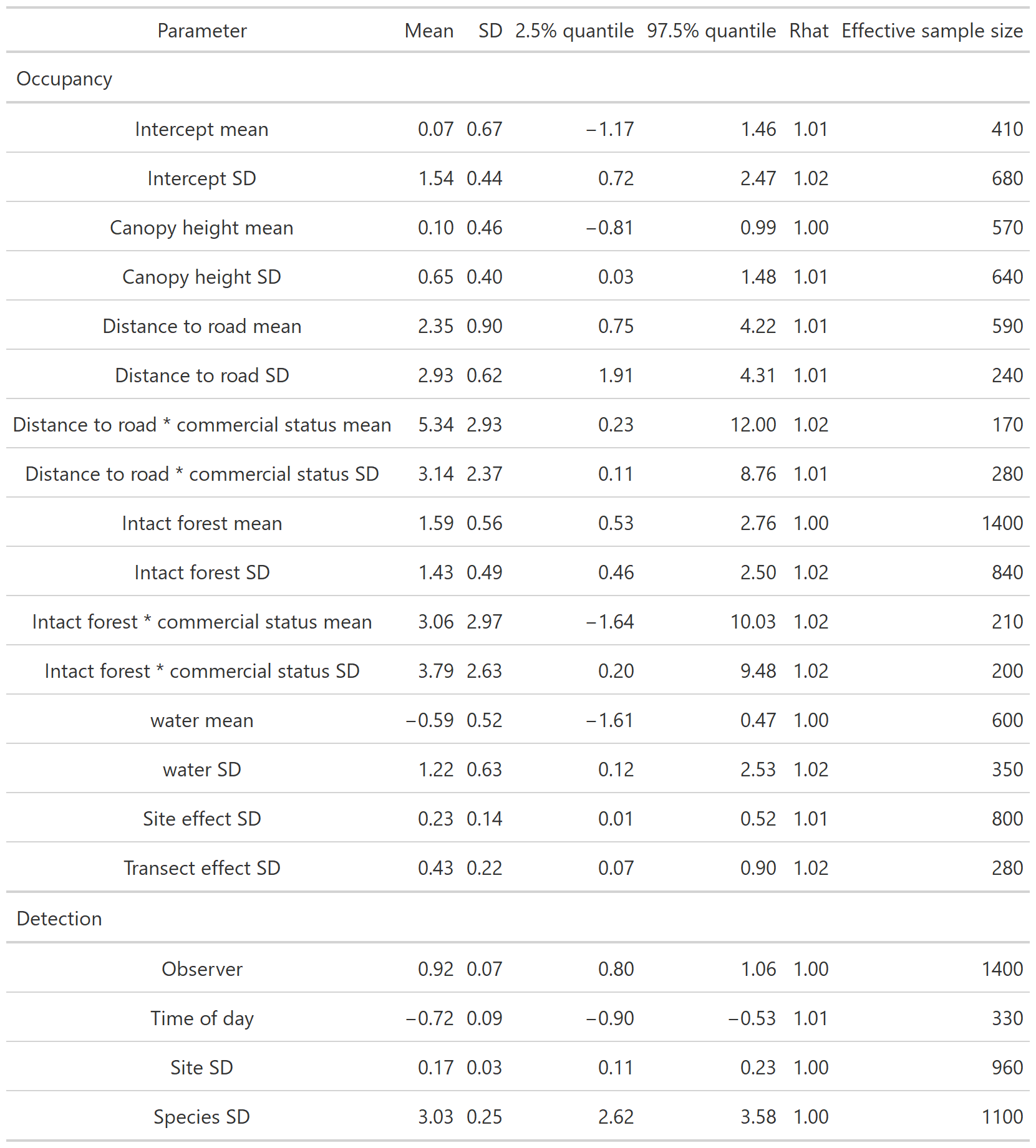
We detected a total of 206 species. 95 species were detected at least ten times and 111 were detected less than ten times. The five most frequently detected species were *Psilopogon australis, Psilopogon chrysopogon, Psilopogon mystacophanos, Arachnothera longirostra, Pycnonotus erythropthalmos,* and *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). However, because *P*. *galericulatus* and *H. schwaneri* were only detected 2 and 1 times respectively, we did not have enough data on these species to produce informative posterior distributions using occupancy modeling.

## Model validation

## 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. Commercially valuable species were significantly more likely to occupy sites further from roads than 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). [something about the inflection point?]

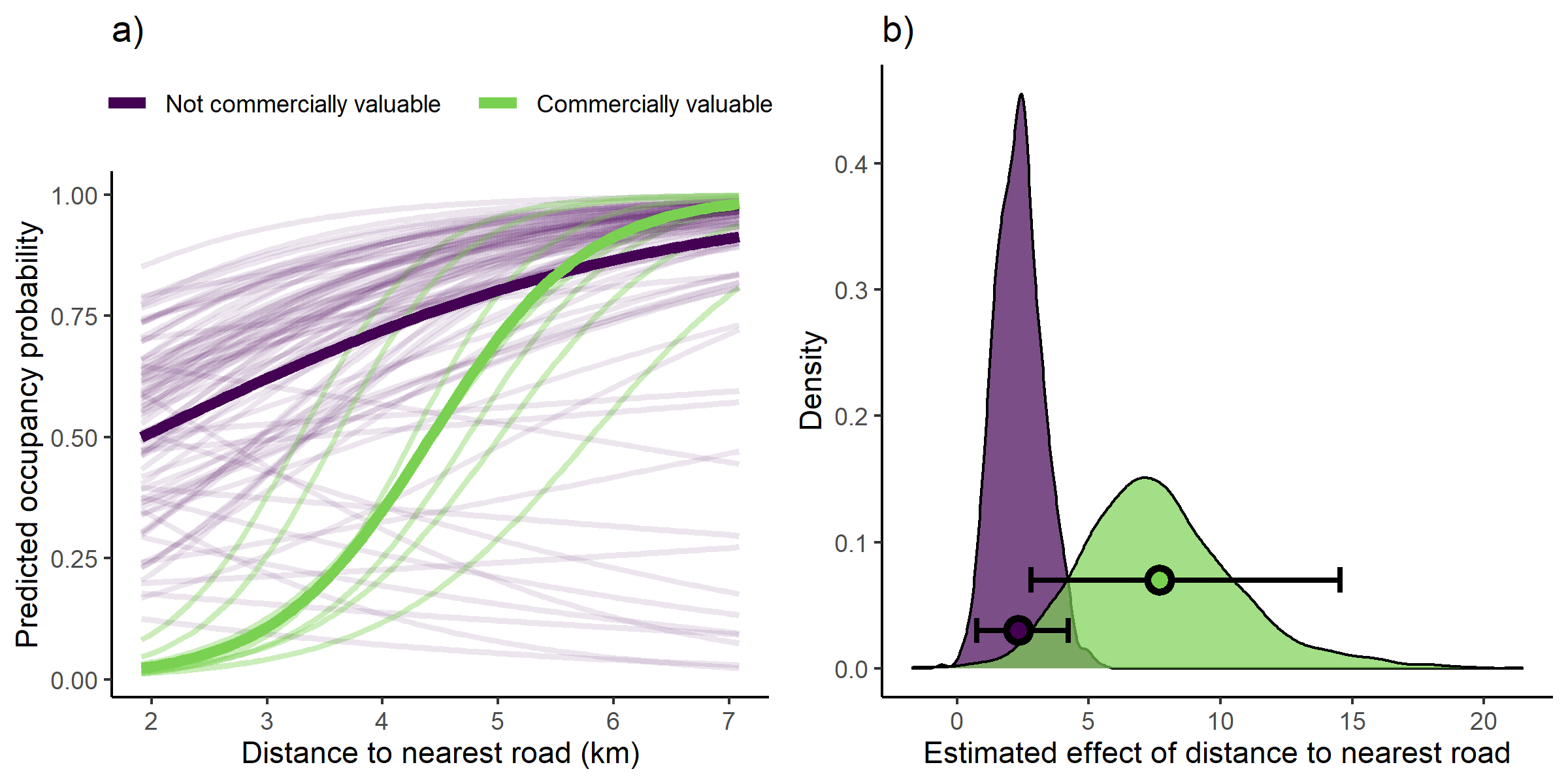


Figure 2. Most species are more likely to occupy areas further from roads, but this effect is significantly stronger for commercially valuable species. a) Each thin line traces the relationship between distance to nearest road and a species’ occupancy. The green lines indicate commercially valuable species, 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).

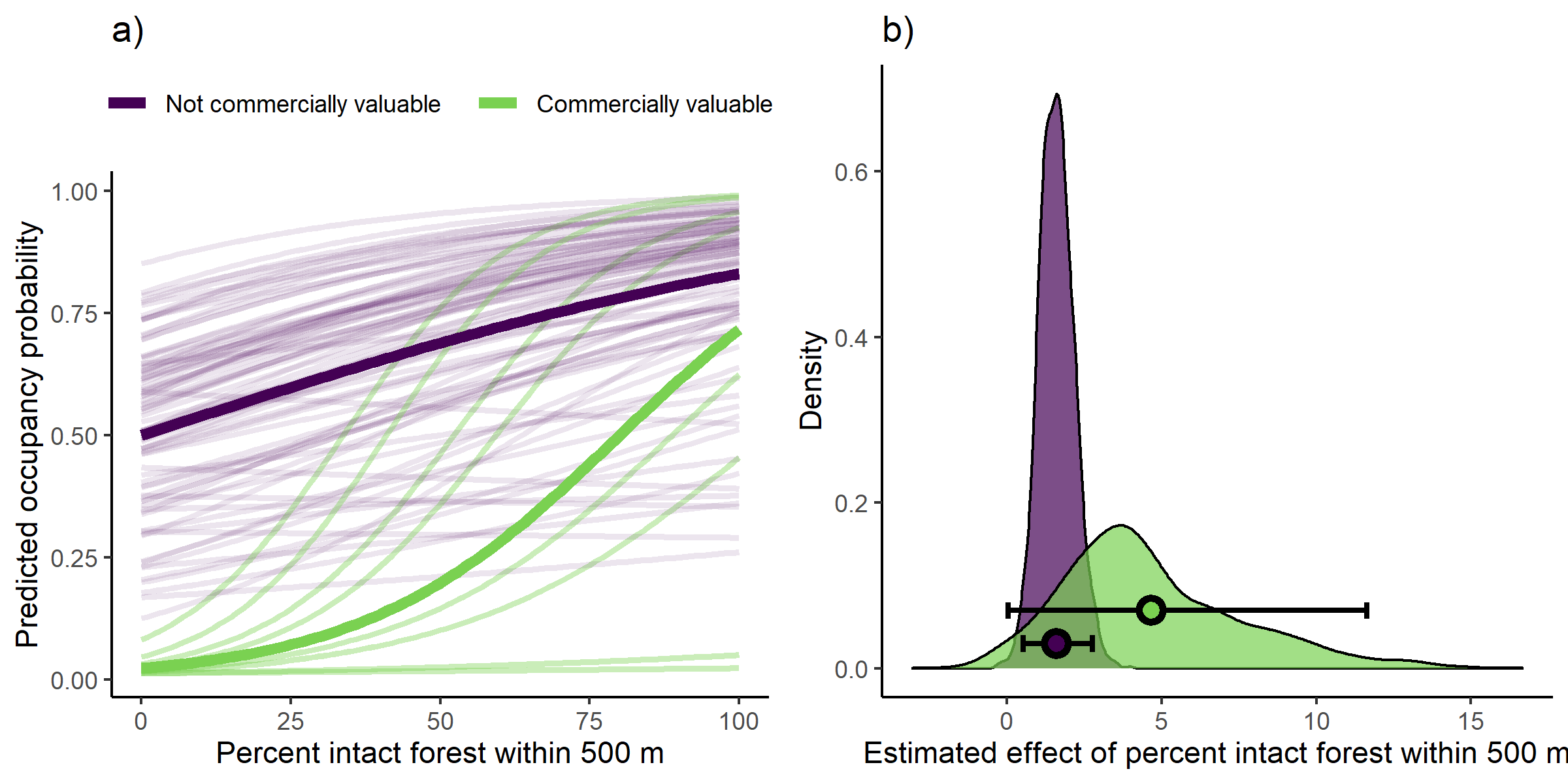


Figure 3. Most species are more likely to occupy areas with more intact forest, and this effect is not significantly stronger for commercially valuable species. a) Each thin line traces the relationship between percent intact forest within 500m and a species’ occupancy. The green lines indicate commercially 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

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 both habitat disturbance and wildlife trade. The average commercially valuable species occupies sites further from roads than commercially non-valuable species. This trend suggests either extreme trapping pressure or an avoidance effect. Because we did not measure density, we cannot directly distinguish between these two effects.

While it is possible that only trapped species would learn to avoid humans, Bötsch et al. (2018) suggest that the presence of humans increases perceived predation risk for most birds. Furthermore, several of the commercially valuable species (*C. sonnerati*, *C. malabaricus*, *A. tephrogenys*, *I. puella*, *P. galericulatus*) were classified as threatened by trade based on severe declines that have already occurred on Java and Sumatera (Lee et al. 2016), so we caution against dismissing these range contractions out of hand. If commercially valuable species are indeed vanishing from habitable forest as suggested by our results, the demand for songbirds reaches very far indeed from urban Java into very remote, rural areas of the archipelago. As access to rural forests continues to increase, and globalization weakens indigenous control over forests and resources, the last refuges for these species will quickly vanish.

Furthermore, Figure 2a illustrates that the relationship between distance to roads and occupancy for commercially valuable species has an inflection point around 5 km. This inflection point could indicate a maximum distance that hunters are willing to travel. In Sumatra, hunters stated that their usual maximum was indeed about 5 km [CITE Harris 2017]. A survey of hunters’ habits, whether conducted via interviews or field cameras, would clarify the details of their reach into the forest. Only xx% of Kalimantan primary forest is located more than 5 km from a road. Further road construction (e.g. planned roads [CITE Alamgir et al 2019 Scientific Reports]) would allow hunters to penetrate ever further into the last refuges available for commercially valuable birds.

This study was conducted in a protected area whose regulations prohibit the collection of any biological material, including birds. It is rural and difficult to access, and yet commercially valuable birds are still absent from near-road locations. Therefore, designating forest as protected must be accompanied by a suite of

*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*).

## Recommendations

As recommended by (Rentschlar et al. 2018), strategies to mitigate illegal poaching of songbirds must be multi-pronged and engage all stakeholders. Most critically, these songbirds must be nationally protected. Regrettably, after the Conservation Act No. 5 of 1990 was updated in 2018, the songbird keeper community pressured the removal of some of the most valuable and overexploited species (Straw-headed Bulbul, which is classified by the IUCN as Critically Endangered). This unfortunate about-face puts these birds at risk once again and highlights the massive domestic demand for them. We echo calls by others (e.g. Jepson and Ladle 2005, Chng et al. 2015, Chng and Eaton 2016) for Indonesia to finally 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.

Until education and behavior change campaigns are able to address the root causes, prices for rare birds will continue to rise and tempt poachers into protected areas. We also echo Rentschlar et al. (2018) in their assertion that captive breeding cannot mitigate demand for wild birds in Kalimantan in the absence of comprehensive regulation and enforcement.

Our results highlight the obvious: most species depend on primary forest for their survival, and therefore, any ongoing deforestation of Cagar Alam Gunung Niyut (CAGN) must halt immediately. Though Gaveau (2017) estimates that 50% of the island remains forested, CAGN is an island of forest in an area that was deforested mainly in the 1980s and 1990s (Global Forest Watch 2018), and remains one of West Kalimantan’s last large plots of intact forest. This remnant habitat must be protected. To reach this objective, conservationists and policymakers must work with communities living in and near CAGN to understand the proximate causes of deforestation and help alleviate the poverty that may drive local people to log and trap.

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. 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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