Dramatic loss of forest-dependent bird species from Semenggoh Nature Reserve, Sarawak, over 60 years

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The species composition and abundance of birds at Semenggoh Nature Reserve, Sarawak, was examined using mist-nets over 14 months during 2015–2016, and compared to results obtained by Fogden (1976), who mist-netted birds there over 14 months in 1964–1965. We mist-netted 55 species, including nine that were not recorded by Fogden, seven of which are common colonisers of anthropogenic habitats. In striking contrast, Fogden captured or observed 139 species, 93 (62.8%) of which were not recorded in our mist-netting study. Up to May 2021, eBird contained records of 186 species among 133 lists submitted by 54 observers. Combining all data sources yields a grand total of 223 species for Semenggoh, 75 of which were recorded only in eBird, although 43 of these species involved only one or two sightings over 42 years of records, and 47 species are non-dependent on forests. On the other hand, 37 species recorded by Fogden in 1964–1965 were missing from eBird lists. Although we captured or observed eight of these species, it seems likely that that the remaining 29, of which 25 (86%) are forest-dependent, have been extirpated from Semenggoh since 1965. Moreover, up to 10 additional forest-dependent species recorded by Fogden may have disappeared in the decade since 2004, suggesting that up to 39 species have been lost from this protected area. Nevertheless, Semenggoh still has considerable conservation value, with 182 species being recorded since 2013, including three Endangered and five Vulnerable species, and thus deserves full protection.

INTRODUCTION

Borneo is the largest of the five main landmasses on the Sunda shelf of South-East Asia. Malaysian Borneo (Sabah and Sarawak) represents 198,160 km^2 (26.9%) of the total landmass (737,188 km^2). Of the 673 bird species that have been recorded in Borneo, at least 59 are endemic to the island (Phillipps & Phillipps 2014). Within Malaysian Borneo, approximately 592 and 557 species of birds have been reported in Sabah and Sarawak, respectively (Davison & Yeap 2012). The dominant climax vegetation of Borneo is equatorial mixed dipterocarp forest, which supports a high diversity of birds (Phillipps & Phillipps 2014). Gaveau *et al.* (2014) estimated that 75.7% (about 558,050 km^2) of Borneo's area was forested in 1973 but, based on the forest cover map for 2010 derived from ALOS-PALSAR and LANDSAT images, this had declined by a further 168,493 km^2 (30.2%) by 2010.

In 2010, estimated forest loss in Sarawak was lower (23.1%) than that in Sabah (39.5%) and Kalimantan (30.7%) (Gaveau *et al.* 2014). Nevertheless, rapid landscape changes in Sarawak have altered bird species distribution and species assemblages, especially where forest patch sizes fall below the critical area limits of individual species (Lambert & Collar 2002). Many tropical birds are restricted to rainforest and are particularly sensitive to forest fragmentation due to the fact that they have low population densities, patchy distributions, and poor dispersal abilities (Whitmore & Sayer 1992, Sodhi *et al.* 2004). Loss of habitat is known to be the major reason for local extirpation and the extinction of bird species (Sodhi *et al.* 2008). However, the response of different species to forest cover disruption varies (Fahrig 2001, Lambert & Collar 2002).

Many bird surveys have been conducted in Sarawak over the last two decades, including unpublished reports and theses (Sreedharan 1998, Dino 2005, Razali 2007, Mansor *et al.* 2008, Boon 2010) and published lists (Croxall 1976, Smith 1999, Rahman *et al.* 2002, Anwarali *et al.* 2008, Arif & Mohd-Azlan 2014). However, the first studies of the seasonality, ecology and population dynamics of birds in a typical rainforest in Sarawak were by Fogden (1972, 1976) from fieldwork conducted almost 50 years ago. From October 1964 to November 1965, Fogden (1976) mist-netted birds within a 20 ha plot in Semenggoh Nature Reserve (referred to hereafter as Semenggoh), about 22 km from Kuching, the state's capital. Using 20 to 30 mist-nets (12 m long x 2.5 m high) each field day, he sampled 200 sites, which were rotated every two months over the 14 months of the study. An additional 50 mist-nets were deployed in surrounding areas, including the buffer zone, resulting in a total trapping effort of about 500 net-days per month. Nets were set at ground level, apart from an occasional net set in the canopy. Although Fogden's final estimate of the densities of birds relied mainly on data obtained by mist-netting, he also used spot-mapping of unringed birds and nests to estimate the density of species that were rarely caught in mist-nets, such as those largely confined to the canopy and emergent trees.

Few long-term data (i.e. >50 years) are available on avifaunal change in tropical forest fragments (Castelletta *et al.* 2000, Sodhi *et al.* 2006) and, despite Fogden's (1976) prediction that extinctions were likely to occur in Semenggoh in the future because of the reserve's small size and isolation, there have been no published studies of the birds of Semenggoh since Fogden's (1976) study was published nearly 50 years ago. The aim of our study was to determine whether there had been any significant changes to the avifauna of Semenggoh since Fogden's study, given its further isolation from contiguous forest and increased human population density in surrounding areas. To address this aim we (1) conducted a mist-netting study over a similar period to that of Fogden (1976), and (2) analysed online records of all birds recorded in Semenggoh up to May 2021.

Mist-nets are used widely in studies of understorey bird assemblages (Blake & Loiselle 1991), especially in Indo-Malaya (Wong 1986, Sodhi *et al.* 2005, Waltert *et al.* 2005, Novarino *et al.* 2006, Noske *et al.* 2011, Woxvold & Noske 2011, Arif & Mohd-Azlan 2014), where there are many skulking understorey species which are difficult to detect when using standard transects or point counts (Karr 1981). Moreover, mist-netting permits comparisons of data from different researchers with varying levels of skills and experience in detecting forest birds, especially skulking understorey birds, thus minimising misidentifications (Waltert *et al.* 2005).

METHODS

Semenggoh Nature Reserve (1.400°N 110.324°E; 26–52 m asl) comprises an area of 653 ha, dominated by mature mixed dipterocarp forest and patches of secondary forest in various stages of regeneration (E. Lit, pers. obs.). In the early 20th century, the area of the reserve was used for shifting cultivation by the Dayak and Javanese planting of rubber, gambier, tea and herbs (Sarawak Forestry Corporation 2020). The cultivation area was gazetted as

the first forest reserve in 1920 and used as a botanical research centre. In 1975, it became a sanctuary to rehabilitate orangutans that were injured or orphaned. Semenggoh Forest Reserve was finally declared as Semenggoh Nature Reserve on 20 February 2000. Since then, it has become home to the Sarawak Forestry's Botanical Research Centre (BRC), Seed Bank and Nursery, Semenggoh Wildlife Centre (SWC) and Sarawak Biodiversity Centre (SBC). The reserve is now completely surrounded by villages and amenities, including shops and a hospital.

We mist-netted at six sites within Semenggoh, two of which were situated inside pristine dipterocarp forest (Sites B & D), while three others were in and around gardens planted with edible fruit trees (A), bamboo (C), or palms (E) (Table 1; Figure 1). The last site (F) was secondary forest surrounding the Wildlife Centre. Mist-netting was conducted over 10 days in March 2015, then over five days in each month until April 2016, using 25 mist-nets (12 m long x 2.5 m high, 36 mm^2 mesh) erected at 20–30 m intervals along forest edges and within the forest. The mist-nets were operated from 06:00 to 18:00 during the 75 sampling days, and each net was checked every two hours while open. Each bird was identified using Phillipps & Phillipps (2014), measured, ringed and subsequently released. The total sampling effort was 1,875 net-days or 22,500 net-hours.

In order to calculate the upper and lower limits of expected species richness, the mist-net data were analysed using Paleontological Statistics (PAST) version 3.12 (Hammer *et al.* 2001), based on the rate of accumulation of newly recorded species with survey effort. Sampling completeness (C) of mist-netted birds was calculated using the completeness ratio (number of observed species/estimated number of species) based on Soberon *et al.* (2000). Species diversity was calculated using the Shannon-Wiener species diversity index (H') in the Vegan Package in R version 1.8 (Oksanen *et al.* 2017).

We compared our data on the birds caught using mist-nets with Fogden's (1976) estimates of abundance for each species. To assess differences between the two studies in the relative abundance of each species, we compared the proportions that each species contributed to the total catch in each study. In addition, we extracted eBird (2021) records from Semenggoh up to May 2021 to compile a list of species seen since Fogden's study. Duplicate records and unidentified species were removed from the eBird dataset. We also excluded records of waterbirds (herons, rails, ducks) and swifts (Apodidae) due to their non-dependence on forests and, in the latter case, the difficulty of field identification, as well as the many taxonomic changes since Fogden's time. For consistency with eBird data, taxonomy and nomenclature were based on Billerman *et al.* (2022).

As body size, diet and forest-dependence have been identified as predictors of species extinction (Gaston & Blackburn 1995, Sodhi *et al.* 2004, 2006, Hamer *et al.* 2015), we assessed their roles in the apparent extirpation of bird species from Semenggoh by comparing species that have not been recorded since Fogden's (1976) study with those that had been recorded more recently, using Chi-squared tests. Categories for which the calculated expected frequency fell below 5 were lumped with other categories, and Yates' Correction was applied when the comparison was between only two categories (df = 1). Body length data (in cm) were sourced from Eaton *et al.* (2016) and, where a range was given, the median was calculated. Each species was also assigned to one or more of five dietary categories (carnivores, frugivores, granivores, insectivores and nectarivores), based on information in Billerman *et al.* (2022). For species with two dietary categories, each category scored 0.5, while for species with three categories, each category scored 0.33. Finally, we assigned forest-dependence to each species based on information in Billerman *et al.* (2022) and Phillipps & Phillipps (2014). Forest-dwelling species that commonly occurred in anthropogenic habitats such as plantations, grasslands, parks and/or gardens were considered non-dependent on forests.

Table 1. Vegetation, sampling effort and daily capture rates (excluding recaptures) of six mist-netting sites in Semenggoh Nature Reserve in 2015–2016.

Sites	Name	Net-hours	Capture rate†	Vegetation
A	Wild Fruit Garden	375	16.0	Secondary forest, planted with 64 species of edible fruit trees
B	Masing Trail	375	11.5	Pristine forest dominated by dipterocarps
C	Bamboo Garden Trail	375	14.9	Planted with over 20 species of bamboos, adjacent to secondary forest
D	Arboretum	500	12.2	Pristine forest dominated by dipterocarps
E	Palm Garden	125	12.8	Planted with 90% of palm species in Sarawak, adjacent to secondary forest
F	Wildlife Centre	125	8.8	Secondary forest surrounding parking area

† (Number of individuals ringed/net-days) x 100.

RESULTS

In total, we captured 247 individual birds comprising 55 species (Appendix 1). Species accumulation curves suggested that sampling saturation was achieved in the eighth month, and rarefaction curves suggest that more intensive sampling was unlikely to yield many additional species (Figure 2). The calculated completeness ratio was 0.90, suggesting that most of the species in the sampling area had been mist-netted at least once. Species richness was highest among bulbuls (Pycnonotidae), comprising 10 species, followed by spiderhunters and sunbirds (Nectariniidae: eight species) and babblers (Timaliidae: five species). The most abundant species were Little Spiderhunter *Arachnothera longirostra* (14.2% of all ringed individuals), Yellow-breasted Flowerpecker *Prionochilus maculatus* (7.7%), Rufous-backed Dwarf-kingfisher *Ceyx rufidorsa* (5.7%) and Rufous-winged Philentoma *Philentoma pyrhoptera* (4.5%). Of the six dietary guilds recognised, insectivorous species dominated (48.2%), followed by insectivore/frugivores (25%) and nectarivores (16.1%). Insectivore/carnivores, obligate frugivores and granivores were poorly represented.

Daily capture rates varied twofold, being highest at Wild Fruit Garden and lowest at the Wildlife Centre (Table 1). Discounting individuals recaptured in the same month at the same site, 34 individuals representing 16 species were recaptured on a combined total of 56 occasions, giving a total recapture rate of 10.6%. The most frequently recaptured species were the Little Spiderhunter (seven individuals recaptured 13 times) and Cream-vented Bulbul *Pycnonotus simplex* (five individuals recaptured six times) (Appendix 1). Eighteen individuals representing 12 species were recaptured at sites that were not the original ringing site and, of these 18, five birds were recaptured at three or four sites, including the ringing site. Two birds (one each of Rufous-winged Philentoma and Purple-naped Spiderhunter *Kurochkinegramma hypogrammica*) were recaptured 12 months after ringing, and three were recaptured 10 months afterwards. Of the 12 species, four were primarily frugivorous and two nectarivorous.

Fogden (1976) counted 592 individuals comprising 105 species in his 20 ha plot, although he was unable to estimate the abundance of an additional 34 species. Excluding the latter group, the species diversity index of birds recorded by Fogden (H' = 4.55) was considerably higher than in our mist-netting study (H' = 3.56). Of the combined total of 148 species, 46 (31.1%) were recorded in both studies, but 93 (62.8%) species were recorded only by Fogden. The remaining nine species (6.1% of the total) were mist-netted during our study and, although not recorded by Fogden, all have