

Comparing Bird Assemblages in Catchment Areas of Two Hydroelectric Dams in Terengganu, Malaysia

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ABSTRACT

The impact of dam construction on bird assemblages has been widely investigated in some regions, but bird diversity in catchment areas of hydroelectric dams during operation has been less studied. A high rate of forest regeneration around the affected area is expected to increase bird diversity. From September 2017 to February 2018, this study examined bird species richness and abundance in the Puah catchment area (PCA) and Tembat catchment area (TCA) in the Hulu Terengganu Hydroelectric Complex. PCA may be regarded as disturbed forest, while TCA comprises regenerating forest. This study conducted mist-netting and observations throughout the study period. This study recorded 204 individuals consisting of 62 bird species from 27 families. The Shannon diversity index for the birds captured was higher for TCA than for PCA, but the difference was insignificant. However, insectivorous bird diversity was significantly higher in TCA than in PCA, suggesting that feeding guilds are sensitive to habitat disturbance. Therefore, bird species diversity in both areas is expected to increase following habitat regeneration.

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INTRODUCTION

The tropical forests of Southeast Asia support high species richness and endemism (Sodhi et al., 2010). However, these forests

are vulnerable to degradation primarily from agricultural activities and commercial logging (Ong et al., 2006). As a developing country, Malaysia's development is expected to be rapid and paralleled by rising forest destruction rates (Hansen et al., 2013). Since 1957, Malaysia has shown enormous economic and infrastructural growth. To achieve the goal of being a developed country, the demand for energy supplies will increase to fulfill the needs of industry, households, and commercial trade (Pratiwi & Juerges, 2020). Therefore, a reliable energy supply is vital for the developing economy. However, energy consumption in Malaysia is excessive, causing the country to rely ever more on fossil fuels as the primary energy source (Petinrin & Shaaban, 2015).

The dependence on conventional energy sources, such as coal, petroleum, and gas, as the primary energy supply can harm the environment and rural development (Erdiwansyah et al., 2019). Consequently, renewable energy sources are an acceptable option. Moreover, renewable energy is sustainable and economical for Malaysia, considering that it is produced from natural sources such as geothermal, solar, biomass, wind, and hydropower resources (Adams et al., 2018).

Malaysia has been ranked among the top nine countries that generate electricity from hydropower (Faizal et al., 2017), with gross electricity generation increasing by around 2.8% in a single year, from 143,497 GWh in 2013 to 147,480 GWh in 2014 (Hossain et al., 2018). Hydropower stations can be found in various locations and are present in almost every state in Malaysia (Hossain et al., 2018). However, while dams can help prevent flooding (Luis et al., 2013), they have a significant environmental impact by diminishing forest cover (Tang et al., 2010) as their construction can result in habitat loss and fragmentation (Andriolo et al., 2013). For instance, the inundation phase of dam building causes the fragmentation of once continuous forests to form land-bridge islands (i.e., former hilltops). In addition, changes in forest structure caused by the construction of hydropower dams make the fauna and flora vulnerable to reduced habitat complexity and result in population decline (Castaño-Villa et al., 2014).

The impacts of tropical forest fragmentation are usually concentrated on taxa such as small mammals (Gibson et al., 2013; Niu et al., 2021) and birds (Messina et al., 2021; Simamora et al., 2021; Slattery & Fenner, 2021; Watson et al., 2004). Additionally, forest-dependent bird communities can be easily affected by habitat loss and degradation (Peh et al., 2005). Moreover, specialized forest species are more concentrated in larger forest patches than in smaller patches (Mohd-Taib et al., 2016), given their extreme sensitivity to habitat disturbance and destruction (Maas et al., 2009; Sodhi et al., 2005). For example, insectivorous birds are the most vulnerable to habitat degradation due to their specialized niches (Mansor et al., 2019). In addition, certain bird species affected by disturbance dispersed away to other suboptimal habitats to maintain their survival (Bakx et al., 2020).

Studies that assessed the dam's impact in Peninsular Malaysia have primarily been carried out in the state of Terengganu. For example, birds (Mohd-Taib et al., 2018), dung

beetles (Qie et al., 2011), and butterflies (Yong et al., 2011). Due to the high sensitivity of birds to habitat disturbance (Peh et al., 2005; Yong, 2009), the construction of dams and subsequent habitat loss may be detrimental to bird assemblages. Yong et al. (2011) showed that the size of land-bridge islands formed subsequently to the dam inundation significantly affected insectivorous birds. However, to this study's knowledge, no study has hitherto examined the effect of dam inundation on bird assemblages during the operating stage.

This study explored the effects of dam inundation on bird assemblages. This study evaluated the abundance and richness of bird species in the surrounding catchment of the two areas within the reservoirs with a different history of logging activities. Additionally, this study's findings will help determine the feeding guilds that are particularly vulnerable to the inundation process that also aids in managing bird assemblages in the catchment areas of newly built hydroelectric dams.

MATERIAL AND METHODS

Location of Study Areas

The Hulu Terengganu Hydroelectric Project (HTHEP; 5° 9' 1.4256" N, 102° 21' 35.3196" E) is located roughly 120 kilometers northwest of Kuala Terengganu in Peninsular Malaysia (Figure 1). There are two hydroelectric dams, Puah Dam and Tembat Dam, which generate 250 MWh and 25 MWh of electricity, respectively, and have a combined catchment area of 50,611 hectares. The study area in the Hulu Terengganu Hydroelectric Complex (HTHC) included the catchments of two dams: the Puah Catchment Area (PCA) (5° 9' 36.7956" N, 102° 35' 47.7132" E) that were recently logged in 2014 (disturbed forest); and the historically-logged forest approximately 30 years ago, Tembat Catchment Area (TCA) (5° 13' 38.586" N, 102° 36' 37.2636" E) (regenerating forest). The two sites are located 30 km apart from each other. There is much anthropogenic activity in PCA near the human settlement, whereas the TCA were located far from human activities. These catchments include the Tembat and Petuang Forest Reserves. Before logging began for the Hulu Terengganu Hydroelectric Project, the Department of Wildlife and National Parks Peninsular Malaysia (PERHILITAN) assessed wildlife, including avifauna, in 2007 (PERHILITAN 2007). Selective logging around the Puah Reservoir took about four years, and approximately 190 km² of forested land was logged between 2010 and 2014 (Magintan et al., 2019). The construction phase began in 2012, and the inundation phase took place from October 2014 to September 2015, resulting in the establishment of a 61 km² reservoir and 27 land-bridge islands by 2015. The water level progressively rose during the inundation period, allowing animals to relocate out of the catchment region and onto newly formed islands within it. The operation phase began once the water level reached the necessary depth (± 290 meters above sea level).

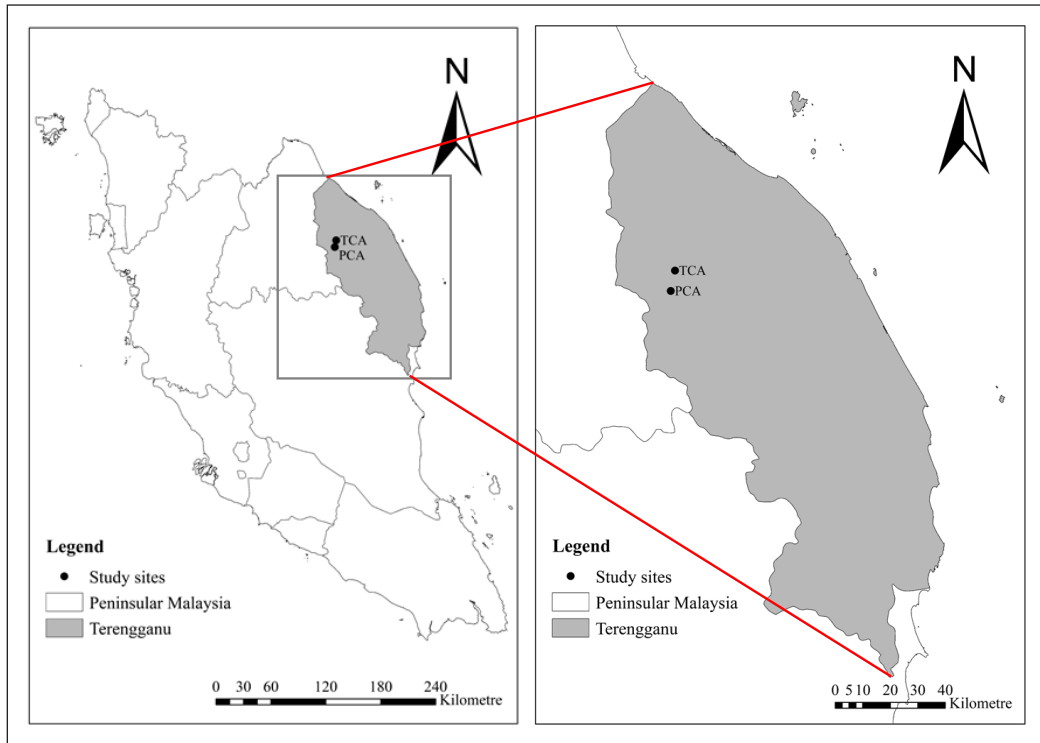


Figure 1. The location of the study sites in the Hulu Terengganu Hydroelectric Complex, Terengganu, Peninsular Malaysia

Field Methods

This study conducted mist-netting and point-count observations during the migrating seasons from September 2017 to February 2018. Each designated area, i.e., PCA (disturbed forest) and TCA (regenerating forest) was set up with 10 mist nets. Each net was 2.5 m × 9 m × 4 m with a mesh size of 36 mm. This study assessed the location within the dam by boat and foot. Each mist net was deployed along the trail approximately 100 m apart in the forest surrounding the dam. The nets were opened at 0700 h and closed at 1900 h, and monitored every hour. For the point-count observations, any bird species seen or heard within a 30-m radius of the center point were recorded. The observation site was established using ad hoc bird surveys with a random starting point. The observations were carried out between 0700 and 1900 h every day. A total of 15 observation points were made at TCA and 10 in PCA due extreme topography of the area. The total duration spent for every point was 20 min each. The observations were carried out by three experienced bird watchers (i.e., N.A.I, A.N.R, and U.N.S.D) using a pair of binoculars (10x42) for each person. The birds were identified by Robson (2014) and sorted and classified according to their feeding guild by using information from published sources obtained from Nasruddin-Roshidi et al. (2021), Wells (1999, 2007), Wong (1986), and Yong et al. (2011).

Data Analysis

This study used the non-parametric rank abundance curve (RAC) technique to define the distribution patterns of bird species at the two sites (Magurran, 2004; Tokeshi, 1993). Species were ordered from the most to the least abundant on the x-axis, while log abundance was plotted on the y-axis. The model with the lowest p -value was considered the optimal model type.

This study also computed several diversity indices: (1) the Shannon index that measures site diversity and is influenced by species number and uniformity; (2) the dominance index that provides an insight into the abundance of the commonest species; (3) the evenness index that expresses how evenly the individuals in a community are distributed among the different species; (4) Simpson's index that represents the probability that two individuals randomly selected from a community will belong to different species; and (5) the Chao-1 index that provides an estimate of species richness if sampling is prolonged.

The Mann–Whitney U test was used to evaluate whether there were significant differences in bird abundance according to their feeding guild between the two study sites. All analyses were carried out using the PAST program (Paleontological Statistics, v2.17; Hammer et al., 2001).

RESULTS AND DISCUSSION

This study recorded 204 individuals consisting of 62 bird species from 27 families and nine orders. Passeriformes was the most abundant order, with 166 individuals from 47 species and 18 families. The Pycnonotidae was represented by the highest number of species (eight species), followed by the Timaliidae (seven species) and Muscicapidae (six species). However, only one species each was recorded for 13 families: the Campephagidae, Chloropseidae, Columbidae, Estrildidae, Indicatoridae, Irenidae, Monarchidae, Phasianidae, Pittidae, Podargidae, Sturnidae, Tephrodornithidae, and Vireonidae.

In TCA, 84 individuals were recorded, consisting of 34 species from 23 families from eight orders. The Pycnonotidae and Timaliidae were the most dominant families, each with six species; the most dominant species were *Arachnothera longirostra* (8.3%), *Chalcophaps indica* (7.1%), *Gracula religiosa* (6%), and *Buceros bicornis* (6%). In PCA, 120 individuals were recorded, consisting of 44 species from 22 families and five orders; the Pycnonotidae was the most dominant bird family with eight species, followed by the Timaliidae (seven species) and Muscicapidae (six species). The most dominant species in the study area were *Arachnothera longirostra* (24.2%), *Alophoixus phaeocephalus* (5%), *Malacopteron magnirostre* (5%), and *Dicaeum trigonostigma* (4.3%).

Four families, the Bucerotidae, Corvidae, Indicatoridae, and Podargidae, were found only in TCA, while another four families, the Campephagidae, Alcedinidae, Pittidae, and Chloropseidae, were found only in PCA. Eighteen species were unique to TCA and 28 species to PCA, while the remaining 16 species were found in both study sites.

The rank abundance curve (RAC) for the mist-netting method shows two different relative abundance patterns for these two study sites (Figure 2). Bird relative abundance at TCA exhibited a log-normal model with Chi-square and p-value of 0.148 and 0.700, respectively. On the other hand, a broken-stick model was observed for bird relative abundance pattern in PCA ($\chi^2 = 23.16$, $p=0.058$).

As shown in Table 1. Although fewer bird species were captured in TCA, its Shannon diversity index was higher ($H' = 2.915$) than PCA ($H' = 2.735$). In addition, the dominance index was higher for PCA (0.124) compared to TCA (0.068). In contrast, the evenness index was lower for PCA (0.550) than for TCA (0.802). The Chao-1 index estimated that species richness could reach up to 46 in PCA and 30 in TCA. The Mann–Whitney analysis showed no significant difference ($Z = 0.323$, $p > 0.005$) in species diversity between the two study sites, although they had different levels of habitat disturbance. However, insectivorous species were significantly more diverse in TCA than in PCA (Mann-Whitney: $Z = 0.016$, $p < 0.005$) in the diversity of insectivorous species between the two study sites.

This study found that the TCA with regenerating forest had higher species richness than PCA with disturbed forest. This result was consistent with previous studies that found

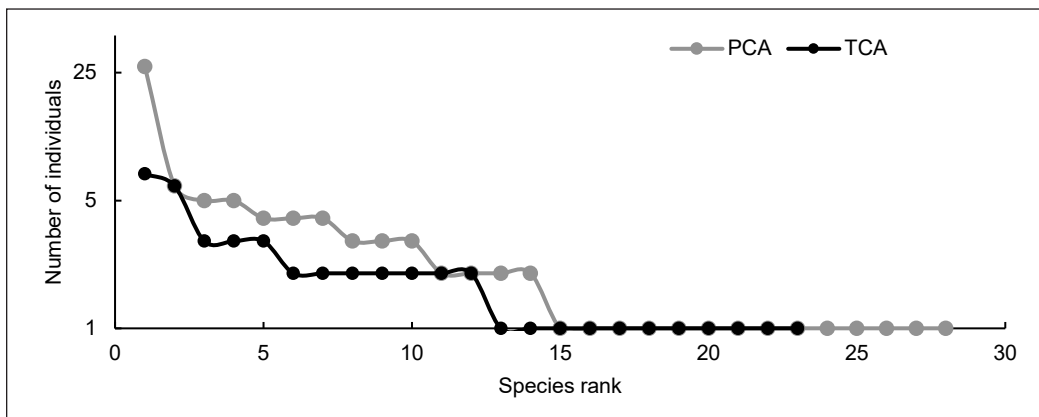


Figure 2. Rank abundance curve for mist-netting sampling in both study sites

Table 1
Species diversity indices for mist-net samples from the two study sites

Index	Tambat Catchment Area (TCA)	Puah Catchment Area (PCA)
Species	23	28
Individuals	47	86
Shannon_(H')	2.915	2.735
Dominance (D)	0.0684	0.1244
Evenness (E')	0.8019	0.5501
Simpson_(1-D)	0.9316	0.8756
Chao-1	29.88	46.20

that regenerating forests have higher species richness than disturbed habitats (Addisu & Girma, 1970; Nasruddin-Roshidi et al., 2021). Anthropogenic activities in PCA causing lower abundances and visitation rates of bird species could also have led to this result (Velho et al., 2012). Extensive deforestation could be a major threat to bird diversity, with habitat loss being the primary threat to species and the cause of the local extinction of wildlife (Sodhi et al., 2010).

Based on RAC analysis, the historically logged forest fitted well with the log-normal model indicated a mature community with an ideal species distribution model (Magurran 2004). On the other hand, PCA sites illustrated a broken-stick model, which indicated the community where all species colonize simultaneously and partition a single resource axis randomly (De Vita, 1979).

This study found differences in bird families recorded between study sites. Four families, the Campephagidae, Alcedinidae, Pittidae, and Chloropseidae, were only found in PCA, while the Bucerotidae, Corvidae, Indicatoridae, and Podargidae were found only in TCA. Different bird species may not have the same risk of extinction due to different characteristics (Sodhi et al., 2004). Changes in forest communities caused by habitat disturbance and degradation can have an indirect impact on forest bird survival (Sodhi et al., 2010). However, birds will perish as a result of the vast expansion in deforestation (Harris & Pimm, 2004). In addition, increased forest overexploitation can lead to increased impacts of resource competition and predation on wildlife (Yap & Sodhi, 2004). Therefore, rare or specialized birds are more susceptible to extinction due to habitat loss (Işik, 2011).

Despite having a diverse range of habitat possibilities, some species can adapt to and thrive in secondary forests. The forest floor in newly logged areas supports pioneer plant species that have replaced the mature and old trees. The development of species such as small-seeded shrubs in forested areas may increase the number of species in the Pycnonotidae (Johns, 1996). Furthermore, the presence of flowering plants in the secondary forest may attract species from the Nectariniidae, which may establish nests in secondary vegetation (Zakaria & Rahim, 1999). The significant difference in the diversity of insectivores between the two study sites suggests that they were the group most sensitive to habitat disturbance. It is supported by Canaday (1996) and Mansor et al. (2018), who found that insectivorous birds are susceptible to habitat change. For instance, most babbler species are confined to the forest interior and have relatively limited distributions as they are one of the specialized forest species; therefore, they are likely to be sensitive to habitat disturbance (Mansor et al., 2015; Styring et al., 2016). Insectivorous birds are sensitive to habitat disturbance, and human activity can negatively affect the movements of these species (de Oliveira et al., 2011; Mansor & Ramli, 2017). In contrast to TCA, which is located far from human activity and is less disturbed, in PCA, human activity, such as human settlements and vehicle noise, is high. In addition, PCA was recently subjected to selective logging. These could be reasons for the findings of this study.

CONCLUSION

This study found that bird species diversity did not differ between the two study hydrodam catchment areas. However, there was a significant difference between the sites in the abundance of the insectivore feeding guild. This study provides further information on and understanding the effect of habitat disturbance caused by recent construction and logging activities on bird assemblages, especially insectivorous birds. The findings suggest that the disturbed and regenerating forests within the catchment areas of hydroelectric dams can still serve as habitats for many bird species, particularly forest-dependent birds. This study predicts that bird species will increase in such areas following the regeneration of habitats with minimal human activity.

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