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Research Article

Population Estimates and Site Occupancy of Purple Swamphen and White-Breasted Waterhen in the Natural and Artificial Urban Wetlands of Peninsular Malaysia

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Purple swamphen, White breasted waterhen, Site occupancy, Wetlands, Distribution model, Density

Abstract | The study aimed at estimating the population and modelling the site occupancy of the *Porphyrio porphyrio indicus* (PPI) and *Amaurornis phoenicurus* (AP) populations in the Paya Indah (PIW) and Putrajaya (PW) wetlands, Peninsular Malaysia. The distance sampling point count technique using stratified random design was employed to survey (from November 2016 to December 2018) and choose 57 and 54 point stations around 14 and 24 lakes of PIW and PW respectively. Significant differences ($p<0.05$) existed in the encounter rate and effective detection radius of PPI and AP between PIW and PW. Both wetlands had low site occupancy, an unevenly distributed and non-significantly relative abundance ($p>0.05$) of PPI and AP. PW recorded the higher estimates of site occupancy, naïve occupancy and detection probability by PPI and AP. The findings implied that PW is more abundant in PPI and AP as compared to PIW. Also, it ascertained that the homogenous sites due to proximity (10km) with different wetland types (natural and artificial) could convey varied population estimates and site occupancy of the two species.

Novelty Statement | This is the first study that estimated the population and model the site occupancy of Porphyrio porphyrio indicus (PPI) and Amaurornis phoenicurus (AP) in the urban wetlands of Malaysia.

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Introduction

Purple Swamphen (*Porphyrio porphyrio indicus*) and White-breasted Waterhen (*Amaurornis phoenicurus*) are important species of the family Rallidae (Rails, Gallinules, and Coots) in Peninsular Malaysia. Globally, a lot of research had been undertaken most especially in the areas of their estimated population, habits, habitats, foods, nesting and reproduction, and potential ecological impacts in different habitats (del Hoyo *et al*., 1996; Taylor and Van Perlo, 1998; Gopakumar and Kaimal, 2008; Pearlstine and Ortiz, 2009; Buden and Retogral, 2010; BirdLife International, 2012; Taylor, 2016; Moreno-Opo and Pique, 2018; Chen *et al*., 2019). These different habitats of Purple Swamphen and White-breasted Waterhen include natural and man-made wetlands, rivers, lakes, reservoirs, ponds, freshwater swamps, mangroves and tidal mudflats, coral reefs, rice fields, grasslands, sewage farms, etc. Given

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the uncertainty in the population trends of the two species within severely fragmented areas in recent times (BirdLife International, 2015, 2016b), it is highly expedient to consider their current estimated populations in different urban wetlands despite their present "least concern" status on the IUCN Red data list (BirdLife International, 2016a, b).

PPI is widely distributed in southern and southeastern Asia, Oceania, the Middle East, sub-Saharan Africa, Australia and the Mediterranean basin (Bara *et al*., 2014; Taylor, 2016; Mundkur *et al*., 2017). This waterbird is associated with wetlands and dense marsh vegetation containing mainly *Phragmites* spp. and *Typha* spp. (Taylor and Van Perlo, 1998). The accurate estimation of their declining population has been difficult due to the cryptic behaviour of its individuals (Pearlstine and Ortiz, 2009). On the other hand, AP occurs in swamps across some parts of Asia including Malaysia, India, Myanmar, Southeast China, Thailand, Cambodia, Sri Lanka, Indonesia, Philippines, etc. It is native and vagrant to 29 and 4 Asian countries respectively (BirdLife International, 2016a). Generally, three subspecies (*Amaurornis phoenicurus phoenicurus, Amaurornis phoenicurus insularis, Amaurornis phoenicurus leucomelana*) are recognized, with a less known fourth species (*Amaurornis phoenicurus midnicobaricus*) (Ashima and Sahi, 2017). This species has an extremely large range with a declining or fluctuating range size, habitat extent/quality, or population size and a small number of locations or severe fragmentation (BirdLife International, 2016a).

According to Pearlstine and Ortiz (2009), PPI are usually shy and have a high tendency to migrate from human activity such as urbanization. Even, the establishment of artificial wetlands had been utilized as a protection mechanism and recovery approach for these species in some countries in Europe (Spain and Portugal). However, the scope of this study focused on estimating the population and modelling the site occupancy of PPI and AP in an urban setting, and then makes the comparison of these parameters between the natural and artificial wetlands. Wetlands in an urban setting are prone to shrinkage due to human pressure such as urban water supply, agricultural activities, road construction, human settlement expansion, etc.

In Peninsular Malaysia, Selangor State is the populous and most developed as well as the transportation and industrial hub (MDIMCM, 2015). Also, Putrajaya is one of the three Federal territories located along the Multimedia Super Corridor (the fastest growing region in Malaysia) and contains the largest integrated urban development project in Malaysia (Ho, 2006). PIW and PW are the largest natural and artificial wetlands located within this highly urbanized regions (Selangor State and Putrajaya Federal territory) respectively. It is pertinent to ascertain if the homogenous sites (Paya Indah and Putrajaya wetlands) due to proximity (10km) could convey a varied population distribution and site occupancy of the two species, concerning the limited habitat usage.

Thus, bird population studies aid to understand the interaction between avian ecology and their conservation planning (Butchart *et al*., 2016; Fraixedas, 2017). Also, site occupancy estimates and models have become useful tools to depict the detection probability, population distribution and site dynamics of waterbird species (Barbraud *et al*., 2003; Mackenzie *et al*., 2003; Altwegg and Nichols, 2019). Presently, no information existed on the site occupancy and detection probabilities of Purple Swamphen and White-breasted Waterhen. This makes it pertinent to develop a coherent strategy for the conservation and monitoring of the two studied species. Therefore, this study specifically focused on estimating the populations and modelling the site occupancy of the PPI and AP in the PIW and PW, Peninsular Malaysia.

Materials and Methods

Study areas

The study was undertaken at the Paya Indah and Putrajaya wetlands in Peninsular Malaysia (Figure 1). Paya Indah natural wetland is located within 101°36.39′E to 101°36.85′E longitude and 2°51.35′N to 2°51.59N latitude, adjacent to the administrative area of Putrajaya (Rajpar *et al*., 2017). It covers a landmass of 450 ha managed by the Department of Wildlife and National Parks, Peninsular Malaysia (Salari *et al*., 2014). It has five predominant land use/land cover classes marshy swamps, a lotus swamp, a lake, an open area with scattered trees, and scrublands (Rajpar *et al*., 2017). Approximately, 20 waterbird species have been recorded in the wetland (Zakaria and Rajpar, 2010). Putrajaya artificial wetland is located within 101°41.90′E to 101°42.43′E longitude and 2°57.71′N and 2°57.81′N in Putrajaya at Peninsular Malaysia. It covers a landmass of 200 ha with five land use/ land cover areas planted area, open water, islands, inundated area, and walking trails. The wetland comprises of 24 cells which primarily controls the water level and trap the pollutants derived from upstream source flowing into the catchment areas of the Chua and Bisa rivers. It consists of four vegetation classes aquatic plants including emergent plants, fruiting trees, flowering trees and bushes, and shrubs (Rajpar and Zakaria, 2013).

Methods

Preliminary surveys were undertaken at PIW and PW in October 2016. Also, the exercise aided to determine the appropriate sampling strategy and field method based on the topography and visibility in the sites. The waterbird survey spanned through the period from November 2016 to December 2018. The distance sampling point count

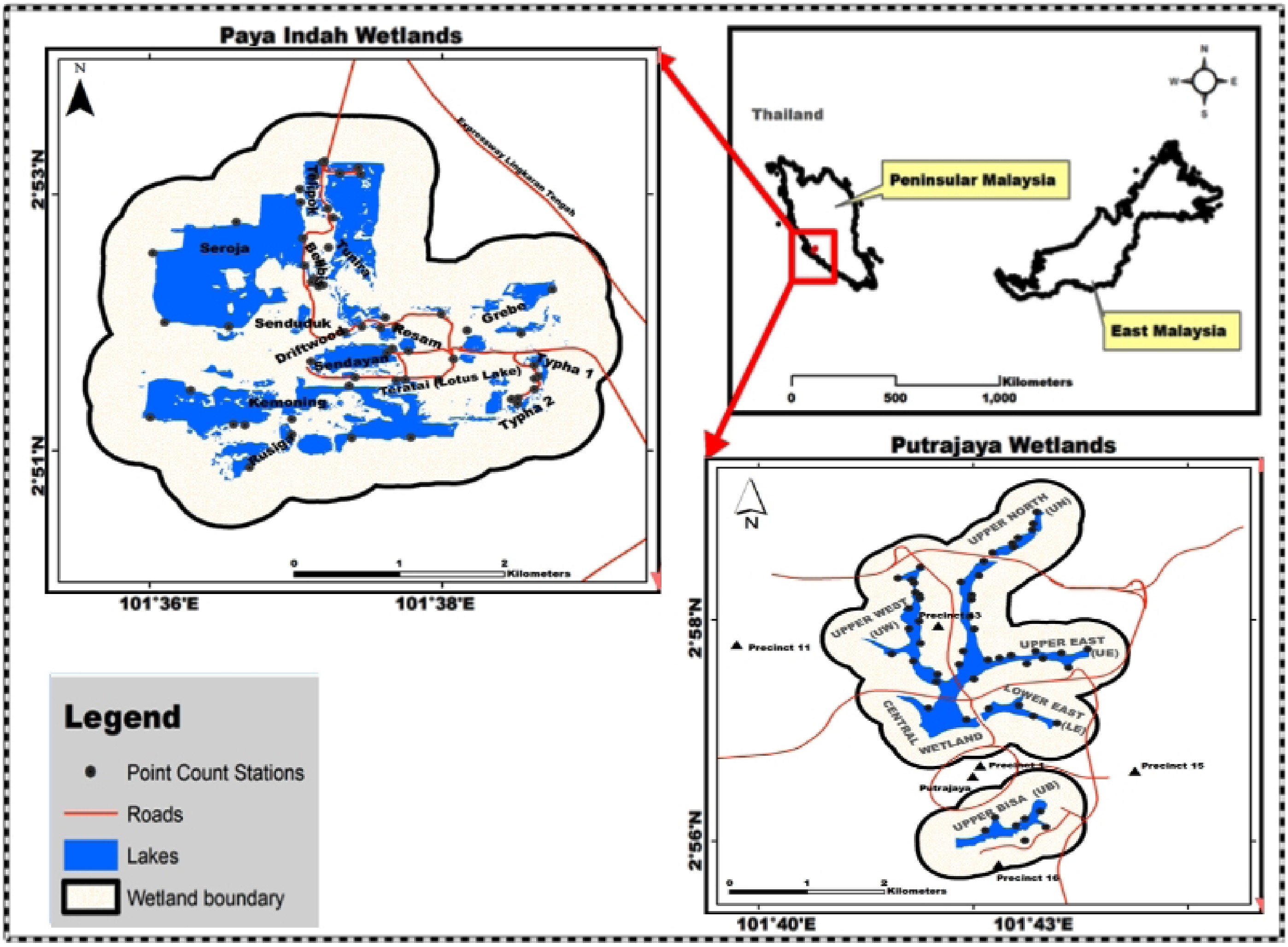

Figure 1: The Paya Indah and Putrajaya wetlands in Peninsular Malaysia with the survey point count stations.

technique was employed to determine the abundance, density and detection probabilities of PPI and AP according to Bibby *et al.* (2000), Ellingson and Lukacs (2003), Hutto and Young (2003) and Lloyd and Doyle (2011). The technique suited situations where access is restricted (wetlands), and cryptic, shy and skulking species such as PPI.

The stratified random design was used to identify and choose 57 and 54 point stations around 14 and 24 lakes in PIW and PW, respectively based on their visibility using binoculars. The design is efficient to ensure bias reduction with improved data accuracy and precision (Dunn *et al.*, 2006). Surveys were carried out 4 times within a week (16 times in a month) at each point station for 26 consecutive months, and each point count station surveyed for 10 minutes from 0730–1100 h (Nadeau *et al.*, 2008; Rajpar and Zakaria, 2010; Mohamed and Anjana, 2017). Hutto and Young (2002) recommended ten-minute counts to reduce the numbers of birds ignored. The information collected were lake, species observed on the lake, the total number observed, coordinates of the survey points, and sighting distance (the distance between observer and the two waterbird species) measured using the Hypsometer (TruePulse R 200x model).

Data analysis

The abundance distribution models were developed using Vegan Version 2.5.3 packages in R Software Version 3.5.2 (Gonzalez, 2018; Oksanen *et al.*, 2018). The distance software Version 7.2 was used to determine the population densities, encounter rate (per meter), effective detection radius and detection functions of PPI and AP in the study area (Thomas *et al.*, 2010; Sebastian-Gonzalez *et al.*, 2018). According to Buckland *et al.* (2001), the distribution of the observed distances was used to estimate the "detection function," g(y) - the probability of detecting a bird at distance y. This function can be used to estimate the average probability of detecting a bird (denoted Pa) given that it is within mean radial distance to the point.

A single species-single season occupancy modelling (MacKenzie *et al.*, 2002; Williams *et al.*, 2002; Howell *et al.*, 2009; MacKenzie *et al.*, 2018) was employed to estimate the site occupancy and detection probability of PPI and AP in the PIW and PW using PRESENCE 12.21 software. It revealed the occupancy estimates for constant detection models [Psi (.), P (.)] for the presence of IHA fitted using single species-single season (Hines et al., 2010). The independent T-test was used to determine if significant differences ($p<0.05$) existed in the density, encounter rate and effective detection radius of both species between PIW and PW.

Results and Discussion

Population densities of PPI and AP in PIW and PW, Peninsular Malaysia are presented in Table 1. The result showed that PW had the higher observed individuals (n = 248), density (3.84 ± 0.04 bird's ha^{-1}), encounter rate (0.02 ± 0.01 per effort) and effective detection radius (4.24 ± 0.00m) of PPI than PIW with the least observed individuals (n = 197), density (3.01 ± 0.05 bird's ha^{-1}), encounter rate (0.01 ± 0.00 per effort) and effective detection radius (3.74 ± 0.00m). Furthermore, PIW recorded the higher detection probability (0.29 ± 0.00) of PP1, while PW recorded the least detection probability (0.22 ± 0.00).

Significant differences ($p<0.05$) existed in the encounter rate (t= -3.09E+16, p= 0.00) and effective detection radius (t= -4.90, p= 0.00) of PPI between PIW and PW. As it relates to AP, PW recorded the higher observed

Table 1: Population estimates of *Porphyrio porphyrio indicus* and *Amaurornis phoenicurus* in Paya Indah and Putrajaya Wetlands, Peninsular Malaysia.

Estimates/ species	*Porphyrio porphyrio indicus*				*Amaurornis phoenicurus*			
	Paya Indah	Putrajaya	t value	p	Paya Indah	Putrajaya	t value	p
Observed bird individual	197	248			297	714		
Density (bird's ha^{-1})	3.01 ± 0.05	3.84 ± 0.04	0.21	0.84^{ns}	9.91 ± 2.83	18.44 ± 0.97	-12.31	0.00*
Encounter rate (per meter)	0.01 ± 0.00	0.02 ± 0.01	-3.09E+16	0.00*	0.04 ± 0.03	0.08 ± 0.07	-3.09E+16	0.00*
Detection probability	0.29 ± 0.00	0.22 ± 0.00	-0.18	0.32^{ns}	0.15 ± 0.09	0.29 ± 0.00	-21.16	0.00*
Effective detection radius (m)	3.74 ± 0.00	4.24 ± 0.00	-4.90	0.00*	3.44 ± 0.43	3.74 ± 0.00	-1.21	0.27^{ns}

p= Significant level; * implies significant difference ($p<0.05$); ns implies non-significant difference ($p>0.05$).

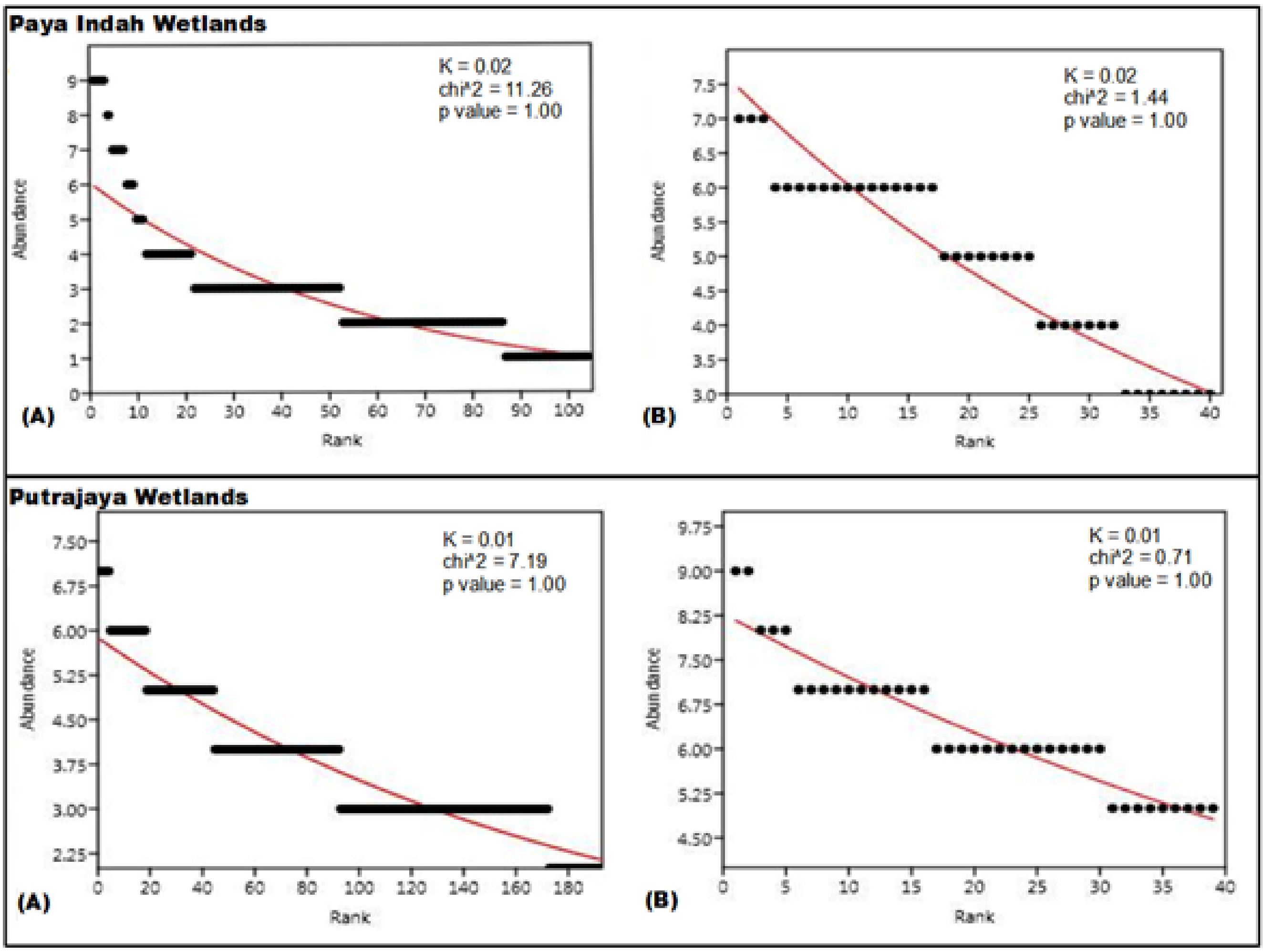

Figure 2: Abundance distribution models of (A) *Amaurornis phoenicurus* and (B) *Porphyrio porphyrio indicus* in Paya Indah and Putrajaya Wetlands.

individuals (n= 714), density (18.44±0.97 bird's ha^{-1}), encounter rate (0.08±0.07 per effort), detection probability (0.29 ± 0.00) and effective detection radius (3.74 ± 0.00m). But, PIW had the least observed individuals (n = 297), density (9.91 ± 2.83 bird's ha^{-1}), encounter rate (0.04 ± 0.03 per effort), detection probability (0.15 ± 0.09) and effective detection radius (3.44 ± 0.43m) of AP. Significant differences ($p<0.05$) existed in the density, encounter rate and effective detection radius of AP between PIW and PW.

Moreover, the abundance distribution models of AP and PPI in PIW and PW are presented in Figure 2. The PIW had an unevenly distributed and non-significantly related ($p>0.05$) abundance of AP (K= 0.02, x^2= 11.26, p= 1.00), and likewise the abundance of AP in PW (K = 0.01, x^2= 7.19, p= 1.00). Also, PIW depicted an unevenly distributed and non-significantly related ($p>0.05$) abundance of PPI (K= 0.02, x^2= 1.44, p= 1.00), and as well as the abundance of PPI in PW (K= 0.01, x^2= 0.71, p= 1.00). Estimates of site occupancy and detection probability for PPI and AP in PIW and PW are presented in Table 2. The result revealed that PW recorded the higher estimates of site occupancy by PPI (Ψ = 0.06 ± 0.03) and naïve occupancy (NO= 0.06). PIW recorded the lower estimates of site occupancy by PPI (Ψ= 0.05 ± 0.03) and naïve occupancy (NO= 0.05). However, PIW recorded the higher detection probability of PPI (P= 0.83 ± 0.05) with CI (0.70 – 0.91), while PW recorded the lower detection probability (P= 0.81±0.06) with CI (0.68–0.90). Furthermore, PW recorded the higher estimates of site occupancy (Ψ = 0.26 ± 0.06), naïve occupancy (NO = 0.26) and detection probability (P = 0.86±0.02) of AP. Also, PIW recorded the lower estimates of site occupancy (Ψ = 0.14 ± 0.05), naïve occupancy (NO = 0.14) and detection probability (P= 0.81±0.03) of AP.

Table 2: Estimates of site occupancy and detection probability for *Porphyrio porphyrio indicus* and *Amaurornis phoenicurus* in Paya Indah and Putrajaya Wetlands, Peninsular Malaysia.

Estimates/ species	*Porphyrio porphyrio indicus*		*Amaurornis phoenicurus*	
	Paya Indah	**Putrajaya**	**Paya Indah**	**Putrajaya**
NO	0.05	0.06	0.14	0.26
Ψ ± SE	0.05 ± 0.03	0.06 ± 0.03	0.14 ± 0.05	0.26 ± 0.06
CI	0.02 – 0.15	0.02 – 0.16	0.07 – 0.26	0.16 – 0.39
P ± SE	0.83 ± 0.05	0.81 ± 0.06	0.81 ± 0.03	0.86 ± 0.02
CI	0.70 – 0.91	0.68 – 0.90	0.74 – 0.87	0.80 – 0.90

NO, naïve occupancy; Ψ, occupancy estimate; SE, standard error; CI, 95% confidence interval (specified by Program PRESENCE output) and P, detection probability.

Despite the higher detection probability of PPI in PIW, it was quite evident that its populations in PW were more abundant and dense than PIW based on the population attributes of density, encounter rate, abundance distribution and site occupancy models. Similarly, AP witnessed the same population variation pattern in both wetlands except its effective detection radius. This abundance pattern negated the submissions of Hassen-Aboushiba (2015) that the PIW attracted more populations of PPI and AP than PW. Also, the number of PPI individuals was quite lower to that observed by Bara *et al*. (2014) at the wetland complex of Guerbes-Sanhadja, north-east Algeria within the same study span.

However, the varied abundance pattern of these waterbirds in PW and PIW could be attributed to the differences in habitat heterogeneity, shallow water depth, foraging behaviour, vegetation composition and structure. Also, these could have been responsible for the low site occupancy, an unevenly distributed and non-significantly relative abundance of PPI and AP in both wetlands. Although both wetlands are situated within an urban setting, PW possess greater potential for vegetation regeneration, slow-flowing waters, ground and surface water recharge. The good habitat protection mechanism is very essential for the natural regeneration of wetlands' vegetation and recovery of wildlife populations (Pitchford *et al*., 2012; Lopoukhine *et al*., 2012). The security system in PW is well-organized and equipped with consistent patrol than PIW. Catford *et al*. (2017) opined that anthropogenic pressure poses a serious threat to the population growth of waterbirds. The characterized slow-flowing waters of PW could have contributed to its suitability for PPI populations. This assumption was based on the findings of Pearlstine and Ortiz (2009) that PPI thrived better in wetlands characterized by slow-flowing or stagnant waters.

Moreover, PW is bounded by the catchment of river Chua and Baisa and characterized by shallow water depth according to Rajpar and Zakaria (2013). But, PIW is multi-land use bounded with oil palm plantation, settlements, farmlands, peat swamp forest and old excavating lands (Hassen-Aboushiba, 2015). Despite the dense aquatic vegetation in PIW, the majority of the lakes in PW have shallow water depth (Rajpar and Zakaria, 2013) due to the lake design and siltation. The lakes in PW were purposely designed for water purification and supply. Therefore, the lakes' attribute could have provided suitable breeding and foraging sites for PPI and AP. On the other hand, the dense aquatic vegetation apart from the shallow water depth determines the distribution of these species in both wetlands. For instance, PPI were distributed and commonly sighted in Teratai (Lotus), Typha 1 and Typha 2 lakes of PIW due to their dense aquatic vegetation.

Similarly, these same species are commonly sighted in the lakes situated at the upper east and upper north regions of PW. However, these lakes are dominated by *Typha* spp. and *Lotus* spp. This supported the submissions of Taylor

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and Van Perlo (1998), Blumstein (2006), Johnson and McGarrity (2009) and Moreno-Opo and Pique (2018) that PPI are commonly associated to wetlands dominated with *Phragmites* spp., *Lotus* spp. and *Typha* spp. As regards AP, they had more wide distributions than PPI in PIW and PW. Specifically, the species were mostly sighted at Teratai and Tunira lakes of PIW. It occupied mostly the upper west, upper north, upper east and the woody densely vegetated areas of the central wetland regions in PW. Its wide distribution can be linked to the species' high adaptability and resilience to inhabiting wetlands with proximity to human habitation which supported the views of del Hoyo *et al*. (1996).

Furthermore, the lower effective detection radius of PPI and AP in PIW could be attributed to the dense aquatic vegetation within their distribution i.e. Teratai (*Lotus*), Tunira, Typha 1 and Typha 2 lakes. Muchmore, the cryptic behaviour of PPI (Pearlstine and Ortiz, 2009) could have been responsible for its preference of densely vegetated areas of PW. These areas are mostly around the lakes situated at the northern edge of the wetland i.e. the upper east, upper north and upper west regions. Aside from the dense terrestrial and aquatic vegetation of these regions, their lakes are also characterized by shallow water depth.

Conclusions and Recommendations

The findings revealed that PW is abundant and dense in PPI and AP as compared to PIW. It ascertained that the homogenous sites due to proximity (10km) with different wetland types (natural and artificial) could convey a varied population estimates and site occupancy of the two species. This might be due to the greater potential for vegetation regeneration, slow-flowing waters, ground and surface water recharge, well-organized habitat protection mechanism, dense aquatic vegetation and shallow water depth. Contrary to past literature, the lakes at the northern edge of PW still contain relics of dense aquatic vegetation characterized with shallow water depth. These attributes might have made PW advantageous to attract more PPI and AP than PIW. Also, they could have determined the distribution and site occupancy of these species in both wetlands. Generally, both species were observed to have very low site occupancy.

Nevertheless, AP are more widely distributed than PPI in PIW and PW. And, this could be associated to the species' high adaptability and resilience to inhabiting wetlands with proximity to human habitation. However, further research on the factors (climatic, landscape, waterscape and hydrological) influencing the distribution and site occupancy of PPI and AP in these homogenous sites (PIW and PW) is highly expedient. Also, a robust population monitoring database for these species should be developed to ensure the management effectiveness towards their ecological sustainability within the urban setting.

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Conflict of interest

The authors have declared no conflict of interest.

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