Assessing the Effects of Aquatic Vegetation Composition on Waterbird Distribution and Richness in Natural Freshwater Lake of Malaysia

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Abstract: Aquatic vegetation structure and composition is a major driven factor which plays a significant role in waterbird foraging sites and habitat selection. Assessing the effects of aquatic vegetation composition on the distribution and richness of waterbird in a freshwater lake is a useful tool to understand the habitat requirement and preference of waterbird species for future better conservation and management. A total of 19 aquatic plants was recorded in the Paya Indah lake using 10 X 10 m quadrant method. *Eleocharis variegata* (13.0%), *E. dulcis* (12.0%), *Scirpus mucronatus* (11.0%), and *Fimbristylis globulosa* (10.0%) were the most dominant aquatic plants which cover around 46.0% of the lake area. Likewise, a total of 1492 bird individuals represnting 24 waterbird species and 8 families was recorded through direct observation using 10X50 binocular. *Porphyrio porphyrio* (17.02%), *Amaurornis phoenicurus* (15.82%), and *Ardea purpurea* (8.31%) were three most common waterbird species in the study area. In contrast, three waterbird species, namely *Hydrophasianus chirurgus* (0.8%), *Tachybaptus ruficollis* (0.6%), and *Gallirallus striatus* (0.54%) were the rarest i.e., recorded only a few individuals. Pearson's Correlation Coefficient test illustrated that aquatic vegetation species have strong positive correlationship (i.e., r = 0.9259, P > 0.05) with waterbird species distribution and richness in the lake area. This showed that higher waterbird richness could be due to the diversity of aquatic vegetation species composition. Overall, the finding of this study highlighted that Paya Indah Lake is rich in aquatic vegetation structure and composition that had attracted a wide array of waterbird to perform various activities such as food, water, habitat and reproduce.

Keywords: Lake, Aquatic Vegetation, Waterbird, Richness, Distribution

1. Introduction

Wetlands are the most productive and diverse aquatic ecosystems, due to vegetation heterogeneity, unpredictable rainfall patterns, occurrence of different surrounded landscape and productivity. They characterized by shallow water overlying waterlogged soil, dominated by a variety of aquatic vegetation such as submerged, emergent, reedbeds, sedges, grasses and even shrubs and trees along the edges. The diversity of vegetation plays a significant role and effects on the distribution, diversity and richness of avian species especially wetland dependent bird species. It has been illustrated that the structure and composition of aquatic vegetation may vary dramatically even within the same habitat among the years (Winter *et al.* 2005).

Avian richness and diversity may vary across the different wetland habitats, depending on habitat structures, vegetation species composition and richness, occurrence of diversity of food resources, and adjacent surrounded landscapes. Bird species composition, richness and diversity are associated with aquatic vegetation structure and composition (Bersier and Meyer, 1995; Hurlbert, 2004) and occurrence of food resources. The heterogeneity of vegetation offer suitable loafing, foraging, nesting and refuge site that protect them from predators and harsh weather. Henning and Remsburg (2009) reported that higher avian richness may occur in wetland dominated by a wide array of aquatic vegetation and rich in food resources. Cunningham *et al.* (2008) and Barrett et al. (2003) illustrated that diversity of vegetation such as blocks of woodlands and scattered trees has an important interaction on bird species richness and diversity.

However, the role of the aquatic vegetation structure on avian richness and diversity is poorly documented in freshwater lakes. Detailed information on the effects of the

vegetation structure and composition on the richness and diversity of avian species is still lacking. Therefore, this study was carried out to determine the effects of aquatic vegetation composition on waterbird distribution and richness in natural freshwater lakes of Malaysia to understand the importance of aquatic vegetation for waterbird species for better future conservation and management.

2. Materials and Methods

2.1. Study Area

The Paya Indah lake area is situated within 101°10′ to 101°50′ longitude and 2°50′ and 3°00′ latitude, covers an area of 450ha (Figure 1). This lake is dominated by diverse aquatic such as Water Chestnut, Bulrush, Fimbry, Needle Leaf Plant, Giant Bulrush, Lotus, Common Reed, Sedges, Cattail Plant, Joint Weed, Barnyard Grass etc.
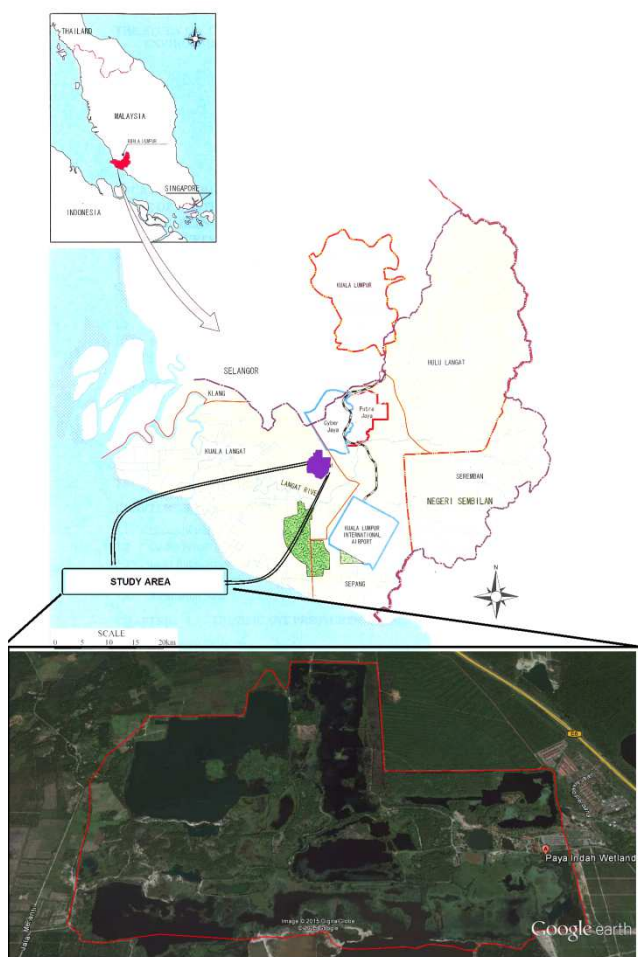

Figure 1. Location map of the study area.

2.2. Aquatic Vegetation Composition Survey

The aquatic vegetation composition of Paya Indah lake was examined using quadrant method (10m x 10m). This method has been extensively employed to survey the variety of vegetation across the different habitats (Mumby *et al.*, 1997; Fernandez-Alaez *et al.*, 2002). Fifty quadrant plots were sampled along the edges and in shallow water to examine the aquatic vegetation composition in the lake area. In each sample plot, vegetation cover % (i.e., the proportion of the water surface covered with aquatic vegetation), vegetation type (i.e., emerged and submerged vegetation, sedges, reeds, ferns and grasses). The aquatic vegetation variables in deep water were recorded using the visual estimation while the temperature and relative humidity were recorded using the Psychrometer. The methodology was followed as described by Isacch *et al.* (2005).

2.3. Waterbird Survey

Waterbird was surveyed at 50 point count stations simultaneously at the same sites where the aquatic vegetation composition and micro–climate variables were sampled. The presence of waterbird was recorded using binoculars (with 20X50 magnifications) from 0730 hours and ended at 1100 hours once in a month. Multiple visits (i.e., 12 visits) were made during the one year from November 2011 to January 2012. The methodology was followed by Kunz *et al.* (2007), Magrath *et al.* (2008) and Hamel *et al.* (2009).

2.4. Data Analysis

The relative abundance (%) was determined using the following expression: n/N x 100 where n is the number of a particular species and N is the total observations of detected species.

The effects of aquatic vegetation composition on waterbird distribution and richness were determined using Pearson's Correlation Coefficient in order to understand either aquatic vegetation composition may influence on the distribution and richness in the lake area employing following formula:

$$r = \frac{\sum_{i=1}^{n} (X - M_x)(Y - M_y)}{\sqrt{\sum_{i=1}^{n} (X - M_x)^2} \sqrt{\sum_{i=1}^{n} (Y - M_y)^2}}$$

Where; X = X Values (waterbirds), Y = Y Values (aquatic vegetation), M_x = Mean of X Values and M_y = Mean of Y Values

X − M_x & Y − M_y: Deviation scores,
$(X - M_x)(Y - M_y)^2$: Deviation Squared,
$(X - M_x)(Y - M_y)$: Product of Deviation Scores

3. Results

3.1. Aquatic Vegetation Species Composition and Relative Abundance

A total of 19 aquatic plants was sampled in the lake area using 10m x 10m quadrant method at the Paya Indah lake. The results illustrated that Chinese Water Chestnut–

Eleocharis variegata (13.0%), followed by Ground-chestnut/Water nut–*E. dulcis* (12.0%) and Rice Field Bulrush–*Scirpus mucronatus* (11.0%), and Globe Fimbry–*Fimbristylis globulosa* (10.0%) were four dominant aquatic plants which cover around 46.0% of the lake area. On the contrary, three aquatic plants, namely; Yefen–*Fuirena umbellata*, Knot Grass/Joint Weed–*Polygonum barbatum*, and Ludwig–*Ludwigia* spp., considered as a rare species (i.e., each covered only 1.0%) were recorded in the study area (Table 1).

Table 1. List of aquatic plants with percentage, recorded in the lake area.

Scientific Name	Common English Name	Percentage
Eleocharis variegata	Chinese Water Chestnut	13.0%
Eleocharis dulcis	Ground-chestnut/Water nut	12.0%
Scirpus mucronatus	Bog Bulrush/Rice Field Bulrush	11.0%
Fimbristylis globulosa	Globe Fimbry	10.0%
Eriocaulon sexanglare	Needle Leaf Plant	8.0%
Scirpus grossus	Giant Bulrush/Greater Club Rush	8.0%
Lepironia articulata	Blue Rush/Twig Rush	6.0%
Nymphaea nouchali	Blue Lotus	5.0%
Rhynchospora corymbosa	Matamat	5.0%
Crinum defixum	Wild Garlic	4.0%
Phragmites karka	Common Reed/Giant Reed Grass	4.0%
Centella asiatica	Asiatic Penny-wort	3.0%
Cyperus halpan	Dwarf Papyrus Sedge	3.0%
Scleria sumatrensis	Nut rush	3.0%
Typha angustifolia	Cattail Plant	2.0%
Echinochloa crus-galli	Barnyard Grass	2.0%
Fuirena umbellata	Yefen	1.0%
Polygonum barbatum	Knot Grass/Joint Weed	1.0%
Ludwigia spp.	Ludwig	1.0%

3.2. Waterbird Species Composition With Relative Abundance

A total of 1492 individuals, belongs to 24 waterbird species, representing 8 families were recorded through direct observation using 10X 50 binocular. Purple Swamphen–*Porphyrio porphyrio* (17.02%), White-breasted Waterhen–*Amaurornis phoenicurus* (15.82%), and Purple Heron–*Ardea purpurea* (8.31%) were three most common waterbird species in the study area. In contrast, three waterbird species, namely Pheasant-tailed Jacana–*Hydrophasianus chirurgus* (0.8%), Little Grebe–*Tachybaptus ruficollis* (0.6%), and Slaty-breasted Crake–*Gallirallus striatus* (0.54%) were the rarest in the study area (Table 2).

Table 2. List of waterbird species recorded in the lake area.

| Family Name	Common Name	Scientific Name	Point Count Method	
			No of Observations	Percentage
Rallidae	Purple Swamphen	*Porphyrio porphyrio*	254	17.02
Rallidae	White-breasted Waterhen	*Amaurornis phoenicurus*	236	15.82
Ardeidae	Purple Heron	*Ardea purpurea*	124	8.31
Charadriidae	Red-wattled Lapwing	*Vanellus indicus*	104	6.97
Ardeidae	Yellow Bittern	*Ixobrychus sinensis*	98	6.57
Rallidae	Common Moorhen	*Gallinula chloropus*	97	6.50
Anatidae	Cotton Pygmy Goose	*Nettapus coromandelianus*	86	5.76
Anatidae	Lesser Whistling Duck	*Dendrocygna javanica*	84	5.63
Rallidae	White-browed Crake	*Porzana cinerea*	53	3.55
Ardeidae	Grey Heron	*Ardea cinerea*	52	3.49
Ardeidae	Little Egret	*Egretta garzetta*	44	2.95
Alcidinidae	White-throated Kingfisher	*Halcyon smyrnensis*	36	2.41
Ardeidae	Little Heron	*Butorides striatus*	33	2.21
Ardeidae	Cinnamon Bittern	*Ixobrychus cinnamoneus*	28	1.88
Ardeidae	Great Egret	*Chasmerodius albus*	24	1.61
Scolopacidae	Common Sandpiper	*Tringa hypoleucos*	23	1.54
Rallidae	Water Cock	*Gallicerx cinerea*	22	1.47
Scolopacidae	Pintail Snipe	*Gallinago stenura*	22	1.47
Ardeidae	Schrenck's Bittern	*Ixobrychus eurhythmus*	15	1.01
Alcidinidae	Common Kingfisher	*Alcedo atthis*	14	0.94
Rallidae	Ballion's Crake	*Porzana pusilla*	14	0.94
Jacanidae	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	12	0.80
Podicipedidae	Little Grebe	*Tachybaptus ruficollis*	9	0.60
Rallidae	Slaty-breasted Crake	*Gallirallus striatus*	8	0.54
		Total	1492	

3.3. Effects of Aquatic Vegetation Composition on Waterbird Distribution and Richness

Pearson's Correlation Coefficient test illustrated that aquatic vegetation species have strong positive correlationship (i.e., $r = 0.9259$, $P > 0.05$) with waterbird species distribution and richness in the lake area. This showed that higher waterbird richness could be due to the diversity of aquatic vegetation species composition (Table 3 & Figure 2).

Table 3. *Test results of Pearson's Correlation Coefficient between aquatic vegetation composition and waterbird richness in the lake.*

X Values	Y Values	X and Y Values	R Calculation
$\sum = 96.17$	$\sum = 102$	N = 19	$r = \sum(X - My)(Y - Mx)/\sqrt{(SSx)(SSy)}$
Mean = 5.062	Mean = 5.368		
$\sum(X - Mx)2 = SSx = 379.124$	$\sum(Y - My)2 = SSy = 270.421$	$\sum(X - Mx)(Y - My) = 296.459$	$r = 296.459/\sqrt{(379.124)(270.421)} = 0.9259$
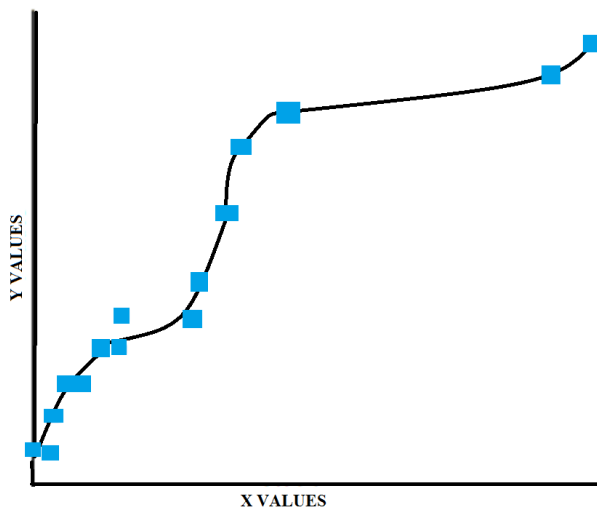
Figure 2. *Biplot diagram of Pearson's Correlation Coefficient indicating the effects of aquatic vegetation composition on the distribution and richness of waterbird species in the lake habitat.*

4. Discussion

Information on the aquatic vegetation species composition and habitat characteristics on the occurrence of waterbird richness is critically important for lake management and protection of the wide array of waterbird species inhabiting in a wide range of aquatic habitats. This detailed information will help in future conservation and management activities of waterbird species inhabited various aquatic habitats. The recording of 19 aquatic plant species and 24 waterbird species illustrated that Paya Indah Lake is rich in aquatic vegetation and waterbird species. This might be that, diversity of aquatic plants has created different micro-habitats and rich in food resources that offer suitable habitats that had attracted a wide array of waterbird species to utilize this study area (Watson et al. 2004; Cousin and Phillips, 2008; Dami and Manu, 2008), in order to perform multiple activities i.e., foraging, perching, nesting, shelter and chick rearing sites.

The vegetation structure and floristic composition are a key factor that affected the habitat selection of the waterbirds, and indicated where and how they used the lake resources (Block and Brennan, 1993). Waterbird species positively correlated with lake area, habitat heterogeneity and vegetation cover percentage (Berg, 1997), i.e., variety of invertebrate communities occur in thick mats of aquatic vegetation (Bromham *et al.* 1999). Habitat variables, for instance, the aquatic vegetation cover percentage plays an important role in the distribution of prey and waterbird species in different lakes (Zharikov and Skilleter, 2002). Waterbird species may respond to aquatic vegetation structure and diversity that offers an adequate invertebrate food supply (Marshall and Cooper, 2004).

It was observed that waterbird distribution and richness may vary from lake to lake depending on the heterogeneity of vegetation structure and richness, foliage height, habitat size and ground vegetation cover (Gabbe *et al.,* 2002; Goetz *et al.,* 2007; Pidgeon *et al.,* 2007; Brown, 2008). This might be that the variation in aquatic vegetation structure may affect the distribution and waterbird communities i.e., aquatic vegetation composition, richness, and cover percentage provide suitable foraging, roosting, and nesting sites for a wide array of waterbird species to fulfill their biological needs and increase their population (Abrams and Rodewald, 2002; Lee and Rotteberry, 2005; Augenfeld *et al.,* 2008). Variation in vegetation attracted a variety of animals such as insects, reptiles and small mammals which is a major dietary component of different bird species. Hence it indicates that richness of food is a major factor that effect on the distribution and richness of waterbird species.

Furthermore, micro–climatic factors such as the temperature, rainfall, relative humidity and habitat variables, for instance, vegetation cover, had played important roles in the distribution of prey and bird species in the wetland ecosystem (Yates *et al*., 1993). In addition, other factors such as the weather (rainfall), social interactions (Erwin, 1983) and predators also played important roles in the distribution and habitat use of the wetland birds in the study area (Rivers, 2000; Zakaria *et al.,* 2009). Strong and Sherry (2000) stated that food availability is one of the most key factors which effects on avian distribution, relative abundance and diversity across the different habitats. Habitat complexity may harbor higher resources such as food, perch, shelter and nest due to availability of different microhabitats (Hulbert, 2004). Hauser *et al.* (2006) reported that macro-fauna diversity and richness increased with an increase in habitat complexity.

5. Conclusion

Aquatic vegetation structure and composition is a major driven factor which plays a significant role in waterbird foraging sites and habitat selection. The results of this study illustrated that aquatic vegetation composition influenced on the distribution and richness of waterbird species in the lake area. Furthermore, the results indicated that the aquatic vegetation species composition has strong positive correlationship on the distribution and richness of waterbird species in the lake area. Overall, the finding of this study highlighted that Paya Indah Lake is rich in aquatic vegetation structure and composition that had attracted a wide array of waterbird to perform various activities such as food, water, habitat and reproduce.

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