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Research Article

Effects of Water Level Fluctuation on Waterbirds Distribution and Aquatic Vegetation Composition at Natural Wetland Reserve, Peninsular Malaysia

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The effects of water level fluctuations on waterbirds distribution and aquatic vegetation composition was determined using distance sampling point count method and direct visual observation at Paya Indah Natural Wetland Reserve, Peninsular Malaysia. A total of 2563 waterbird individual of 28 species and 8 families were detected in three habitats, that is, marsh swamp (68.59%), open water body (18.42%), and lotus swamp (12.99%). *Porphyrio porphyrio* was the most dominant species in marsh swamp (45.39%), and lotus swamp (23.42%), whereas *Dendrocygna javanica* (42.16%) was the most abundant in open water body. The highest water level for marsh swamp (2.313 m) and lotus swamp (2.249 m) was recorded in January, 2008 and for open water body (2.572 m) in January and April, 2008. In contrast, the lowest water level for marsh swamp (2.048 m) and lotus swamp (1.834 m) was determined in October, 2008 and for open water body (2.398 m) in January, 2009. Pearson test indicates weak linear correlationship between water level and waterbird abundance in lotus swamp habitat ($r^2 = 0.120, P > 0.05$) and in marsh swamp ($r^2 = 0.100, P > 0.05$) and negative linear correlationship ($r^2 = -0.710, P > 0.05$) in open water body habitat. Canonical correspondence analysis indicated strong correlationship between waterbird abundance and vegetation (73.0%) in open water body, and weaker association (29.8%) in lotus swamp. The results of this study indicate that water level is a major factor that influences the relative abundance and distribution of ducks, swamphen, crakes, herons, jacanas, and moorhens directly and indirectly. In addition, it also effects on the dynamics of aquatic vegetation composition such as, emergent, submerged, and grasses in this wetland reserve.

1. Introduction

Malaysia is rich in aquatic resources such as rivers, lakes, reservoirs, swamps, mangroves, estuaries, lagoons, and the sea. These aquatic resources provide diverse habitats for wildlife species particularly waterbirds and are lifeline for Malaysian people that supply diverse food resources and water for domestic, agriculture, and industrial uses. Majority of people live within the vicinity of aquatic resources. Despite their crucial role, these aquatic resources are facing overwhelming pressure such as siltation, water pollution, loss of mangrove, and degradation of coral reef [1].

"Waterbirds" refers to the bird species that entirely depend on wetlands for a variety of activities such as foraging, nesting, loafing, and moulting [2]. They are bioindicators of wetland ecosystems, because they quickly respond to any changes in vegetation composition and water level fluctuation as compared to other animals [3, 4]. Water level among wetlands always fluctuates from time to time depending upon location, precipitation, and incoming water resources. Single wetlands will not have similar attraction to waterbirds throughout the year or among years due to unpredictable fluctuation in water level that causes changes in aquatic vegetation composition.

It has been reported that fluctuation in water level influenced the distribution of waterbirds such as from total drought [5–7] to major flooding [8, 9]. The highest species richness and density of waterbirds occurs in reed beds of aquatic vegetation, where the water level is 20–65 cm in depth [10].

Determining the population fluctuation of waterbirds in wetland habitats is highly important to understand the waterbird community structures and population status of existing species in the dwelling areas [11] For this reason, the distance sampling point count method is one of the most common quantitative survey techniques that have been widely used in order to monitor the correlationship of the avian species with water level and vegetation composition [12]. This method involves the visual and auditory detection of birds at a preselected spot for specific period of time [13–15].

Very little information is available on the effects of water level fluctuation on waterbird distribution and aquatic vegetation composition in Malaysia. The main objective of this study was to determine and understand the effects of water level fluctuations on waterbirds distribution and aquatic vegetation composition in Paya Indah Natural Wetland Reserve, Peninsular Malaysia.

2. Materials and Methods

2.1. Study Site. Paya Indah Natural Wetland Reserve encompasses 3050 ha out of which 450 ha are under the administration of the Department of Wildlife and National Parks, Peninsular Malaysia. The study area is located within the quadrant of 101°10′ to 101°50′ longitude and 2°50′ and 3°00′ latitude (see Figure 1). This natural wetland reserve comprises three major aquatic habitats that may vary in vegetation composition and structure, namely, (i) marsh swamp (ii) lotus swamp, and (iii) open water body.

2.2. Marsh Swamp. These are shallow watery areas densely covered by emergent aquatic vegetation, that is, *Eleocharis dulcis, Lepironia articulata, Scirpus olneyi, Carex sp., Elodea, Spartina alterniflora, Scleria purpurascens, Philydrum lanuginosum*, *Panicum maximum*, and *Lycopodium cenum*. The marsh swamps are rich in fishes, amphibians, and aquatic invertebrate assemblages (Figure 2).

2.3. Lotus Swamp. The water surface is dominated by *Nelumbo nucifera,* and *N. nouchali, N. pubescens* and edges covered by *E. Dulcis* and *L. articulate* and somewhere by *Phragmites karka* and *Typha angustifolia* (Figure 3).

2.4. Open Water Body. These are deep water areas dominated by submerged vegetation (i.e., *Myriophyllum spicatum*, *Salvinia minima*, *Potamegoton* sp., *Salvinia* sp., *S. purpurascens*, and *S. alterniflora*) and are rich in food resources such as fishes, amphibians and aquatic invertebrates, as it provides suitable breeding sites for them (Figure 4).

2.5. Waterbird Surveys. Waterbird surveys were carried out using the distance sampling point count method to determine the species composition, relative abundance, and habitat preference from November, 2007 to January, 2009. One hundred and twenty-one point count stations at 300 m interval apart from each other were established within marsh swamp (43 stations), lotus swamp (38 stations) and open water body (40 stations) (Figure 5). The main reason of using 300 m interval apart was to avoid double counting of the same waterbirds at more than one station. The survey was done fifteen times at monthly interval in order to obtain reliable results and avoid bias. The repetition increased the precision and provided accurate estimates. The survey was carried out early in the morning, that is, 0730–1100 hrs. The detections of birds within each point count station were done for 10 minutes. During each survey, all waterbird species and individuals seen or heard were recorded. The flushed waterbirds with unknown original position were not included in the analysis. The methodology was followed as described by Smith et al. [16], Petit et al. [17], Buckland et al. [18], Aborn [19], and Nadeau et al. [20].

2.6. Water Level. The water levels in the three habitats, namely, marsh swamp, open water body, and lotus swamp for a period of 15 consecutive months from November, 2007 to January, 2009, was obtained from Department of Irrigation, Malaysia, in order to determine and understand the fluctuation of water level and its effects on the waterbird distribution and aquatic vegetation at Paya Indah Wetland Reserve, Peninsular Malaysia. The water level was recorded in feet; later on, feet were converted into meters.

2.7. Vegetation Survey. The vegetation proportion (%) and type such as emergent, submerged, grasses, shrubs, and trees in marsh swamp, lotus swamp, and open water body was determined by direct observation within the consistency of the point count stations.

2.8. Data Analysis. The relative abundance (%) of waterbird species was determined using the following expression:

$$\frac{n}{N} \times 100, \quad (1)$$

where n = number of a particular waterbird species and N = total observations detected for all species.

The effects of water level fluctuation on waterbird distribution and aquatic vegetation composition were determined by direct observation. In addition, the correlationship between water level and waterbird relative abundance was determined using Pearson's correlation coefficient in order to understand the effects of water level on waterbird distribution

$$r = \frac{\sum_{i=1}^{n}\left(X_i - \overline{X}\right)\left(Y_i - \overline{Y}\right)}{\sqrt{\sum_{i=1}^{n}\left(X_i - \overline{X}\right)^2}\sqrt{\sum_{i=1}^{n}\left(X_i - \overline{Y}\right)^2}}, \quad (2)$$

where X_i = standard score, $\overline{X}$ = sample mean, and S_X = standard deviation.

The correlationship between waterbirds and vegetation was examined using multiple regressions, that is, canonical correspondence analysis (CCA) software (version 4.5) by Ter Braak and Smilauer [21] to understand the correlationship between aquatic vegetation composition and waterbird abundance.

Figure 1: Location map of Paya Indah Natural Wetland Reserve, Selangor, Peninsular Malaysia.

The results were compared using analysis of variance (ANOVA) and Tukey's (HSD) test to determine the significant difference of water level and species abundance among three habitats, that is, marsh swamp, lotus swamp, and open water body.

3. Results

A total of 2563 waterbird individual of 28 species and 8 families were recorded in three habitats, namely marsh swamp (68.59%), open water body (18.42%), and lotus swamp

Figure 2: Marsh swamp habitat at Paya Indah Natural Wetland Reserve, Peninsular Malaysia.

Figure 3: Lotus swamp habitat at Paya Indah Natural Wetland Reserve, Peninsular Malaysia.

Figure 4: Open water body habitat at Paya Indah Natural Wetland Reserve, Peninsular Malaysia.

(12.99%) using distance sampling point count method at Paya Indah Natural Wetland Reserve, Peninsular Malaysia.

3.1. Relative Abundance of Waterbirds in Marsh Swamp. Marsh swamp habitat was most attractive habitat for waterbirds, that is, a total of 1758 waterbird individuals of 22 species and 8 families were recorded using distance sampling point count method. Purple swamphen—*Porphyrio porphyrio* (45.39%), white-breasted waterhen—*Amaurornis phoenicurus* (11.38%), purple heron—*Ardea purpurea* (9.33%), and yellow bittern—*Ixobrychus sinensis* (9.22%) were four of the most abundant waterbird species with highest relative abundance. On the contrary, pheasant-tailed jacana—*Hydrophasianus chirurgus* was the rarest waterbird species observed only once (0.06%) during survey period (Table 1).

3.2. Relative Abundance of Waterbirds in Lotus Swamp. Point count method detected 333 waterbird individuals of 17 species and 8 families in the lotus swamp habitat. Three waterbird species, namely, purple swamphen—*Porphyrio porphyrio* (23.42%), purple heron—*Ardea purpurea* (15.62%), and white-throated kingfisher—*Halcyon smyrnensis* (15.32%) were the most dominant in lotus swamp habitat. In cotrast, common kingfisher (*Alcedo atthis*), cotton pygmy goose (*Nettapus coromandelianus*), and water cock (*Gallicerx cinerea*) were the rarest waterbird species, which were recorded only once (0.30% each) (Table 2).

3.3. Relative Abundance of Waterbirds in Open Water Body. A total of 472 waterbird individuals that belong to 15 bird species and 7 families were recorded in the open water body habitat using the point count method. The results indicated that lesser whistling duck—*Dendrocygna javanica* (42.16%), cotton pygmy goose—*Nettapus coromandelianus* (17.16%), and white-throated kingfisher—*Halcyon smyrnensis* (8.90%) were the three most dominant waterbird species in the open water body area. On the contrary, Grey heron (*Ardea cinerea*) and schrenck's bittern (*Ixobrychus eurhythmus*) were the two rarest waterbirds, which were recorded only once (0.21% each) (Table 3).

The significant difference for waterbird abundance among the three habitats, that is, marsh swamp, open water body, and lotus swamp, was compared by applying the one-way analysis of variance (ANOVA) and Tukey's (HSD) test. The ANOVA test indicated that the waterbird abundance of marsh swamp habitat during 15 consecutive months was significantly different from lotus swamp and open water body habitats, that is, $F_{2,42} = 226.20$, $P < 0.05$ (Table 4 and Table 13).

3.4. Water Level in Marsh Swamp. The results showed that the water level in the marsh swamp habitat varied among 15 consecutive months due to the variation in rainfall volumes and discharge water from the catchment areas of Sungai Chua and Sungai Bisa. Notably, the highest water level was recorded in January, 2008 (i.e., 2.313 m), and the lowest was detected in October, 2008 (i.e., 2.048 m) (Table 5).

3.5. Water Level in Open Water Body. Higher water level, that is, 2.572 m, was recorded in during January and April, 2008. In contrast, lower water level, that is, 2.398 m, was observed in January, 2009 due to low rainfall (Table 6).

3.6. Water Level in Lotus Swamp. Apparently, the highest water level (i.e., 2.249 m) for lotus swamp habitat was recorded in January, 2008, and the lowest (i.e., 1.834 m) was recorded in October, 2008 (Table 7).

The significant difference for mean water level among the three habitats, that is, marsh swamp, open water body, and lotus swamp, was compared by applying the one-way analysis of variance (ANOVA) and Tukey's (HSD) test. The ANOVA analysis indicated that the water level of the three habitats

Table 1: List of waterbird species with relative abundance recorded in Marsh Swamp at Paya Indah Natural Wetland Reserve, Peninsular Malaysia.

Rank	Family name	Common name	Scientific name	No. of observations	%
1	Rallidae	Purple swamphen	*Porphyrio porphyrio*	798	45.39
2	Rallidae	White-breasted waterhen	*Amaurornis phoenicurus*	200	11.38
3	Ardeidae	Purple heron	*Ardea purpurea*	164	9.33
4	Ardeidae	Yellow bittern	*Ixobrychus sinensis*	162	9.22
5	Alcidinidae	White-throated kingfisher	*Halcyon smyrnensis*	128	7.28
6	Charadriidae	Red-wattled lapwing	*Vanellus indicus*	93	5.29
7	Rallidae	Common moorhen	*Gallinula chloropus*	61	3.47
8	Anatidae	Lesser whistling duck	*Dendrocygna javanica*	37	2.10
9	Ardeidae	Cinnamon bittern	*Ixorbychus cinnamoneus*	28	1.59
10	Ardeidae	Little heron	*Butorides striatus*	20	1.14
11	Ardeidae	Black-crowned nightheron	*Nycticorax nycticorax*	13	0.74
12	Anatidae	Cotton pygmy goose	*Nettapus coromandelianus*	11	0.63
13	Scolopacidae	Pintail snipe	*Gallinago stenura*	10	0.57
14	Ardeidae	Grey heron	*Ardea cinerea*	7	0.40
15	Ardeidae	Schrenck's bittern	*Ixobrychus eurhythmus*	6	0.34
16	Ardeidae	Great egret	*Egretta albus*	4	0.23
17	Ardeidae	Little egret	*Egretta garzetta*	4	0.23
18	Rallidae	Water cock	*Gallicerx cinerea*	4	0.23
19	Rallidae	Ballion's crake	*Porzana pusilla*	3	0.17
20	Alcidinidae	Common kingfisher	*Alcedo atthis*	2	0.11
21	Podicipedidae	Little grebe	*Tachybaptus ruficollis*	2	0.11
22	Jacanidae	Pheasant-tailed jacana	*Hydrophasianus chirurgus*	1	0.06
		Total		1758	

Table 2: List of waterbird species with relative abundance recorded in Lotus Swamp at Paya Indah Natural Wetland Reserve, Peninsular Malaysia.

Rank	Family name	Common name	Scientific name	No. of observations	%
1	Rallidae	Purple swamphen	*Porphyrio porphyrio*	78	23.42
2	Ardeidae	Purple heron	*Ardea purpurea*	52	15.62
3	Alcidinidae	White-throated kingfisher	*Halcyon smyrnensis*	51	15.32
4	Ardeidae	Yellow bittern	*Ixobrychus sinensis*	42	12.61
5	Rallidae	White-breasted waterhen	*Amaurornis phoenicurus*	38	11.41
6	Rallidae	Common moorhen	*Gallinula chloropus*	28	8.41
7	Rallidae	Ballion's crake	*Porzana pusilla*	11	3.30
8	Charadriidae	Red-wattled lapwing	*Vanellus indicus*	8	2.40
9	Jacanidae	Pheasant-tailed jacana	*Hydrophasianus chirurgus*	6	1.80
10	Rallidae	White-browed crake	*Porzana cinerea*	5	1.50
11	Ardeidae	Grey heron	*Ardea cinerea*	4	1.20
12	Ardeidae	Little heron	*Butorides striatus*	3	0.90
13	Scolopacidae	Common sandpiper	*Tringa. hypoleucos*	2	0.60
14	Podicipedidae	Little grebe	*Tachybaptus ruficollis*	2	0.60
15	Alcidinidae	Common kingfisher	*Alcedo atthis*	1	0.30
16	Anatidae	Cotton pygmy goose	*Nettapus coromandelianus*	1	0.30
17	Rallidae	Water cock	*Gallicerx cinerea*	1	0.30
		Total		333	

Table 3: List of waterbird species with relative abundance recorded in Open Water Body at Paya Indah Natural Wetland Reserve, Peninsular Malaysia.

Rank	Family name	Common name	Scientific name	No. of observations	%
1	Anatidae	Lesser whistling duck	*Dendrocygna javanica*	199	42.16
2	Anatidae	Cotton pygmy goose	*Nettapus coromandelianus*	81	17.16
3	Alcidinidae	White-throated kingfisher	*Halcyon smyrnensis*	42	8.90
4	Charadriidae	Red-wattled lapwing	*Vanellus indicus*	41	8.69
5	Rallidae	Purple swamphen	*Porphyrio porphyrio*	25	5.30
6	Rallidae	White-breasted waterhen	*Amaurornis phoenicurus*	25	5.30
7	Ardeidae	Purple heron	*Ardea purpurea*	22	4.66
8	Ardeidae	Yellow bittern	*Ixobrychus sinensis*	11	2.33
9	Podicipedidae	Little Grebe	*Tachybaptus ruficollis*	7	1.48
10	Ardeidae	Cinnamon bittern	*Ixorbychus cinnamoneus*	6	1.27
11	Rallidae	Common moorhen	*Gallinula chloropus*	6	1.27
12	Rallidae	Water cock	*Gallicerx cinerea*	3	0.64
13	Scolopacidae	Pintail snipe	*Gallinago stenura*	2	0.42
14	Ardeidae	Grey heron	*Ardea cinerea*	1	0.21
15	Ardeidae	Schrenck's bittern	*Ixobrychus eurhythmus*	1	0.21
		Total		472	

Table 4: Comparison of waterbird abundance in marsh swamp, open water body, and lotus swamp habitats at Paya Indah Natural Wetland Reserve, Peninsular Malaysia.

Habitat name	Mean waterbird abundance (%)	Standard error (SE)
Marsh swamp	118.27 a	0.37
Open water body	31.67 b	1,06
Lotus swamp	21.40 b	1.12

(The mean values in columns with same letter are not significant at P = 0.05).

was significantly different; that is, $F_{2,42} = 68.42$, $P < 0.05$ (Table 8 and Table 14).

3.7. Proportion and Type of Vegetation in Three Habitats. Marsh swamp habitat was densely covered with water chestnuts—*E. dulcis* (59.12%), and lotus swamp habitat was densely covered with emergent vegetation that is water lilies—*N. nucifera* (55.40%) while, open water body was with spike water-milfoils—*M. spicatum*, and common duck weeds—*S. minima* (61.50% both). The edges were covered with grasses (*Imperata cylindrical, S. olneyi, P. maximum* and *Distichlis spicata*). However, some shrub that is, *Melastoma malabathrcium,* and *Dillenia suffruticosa* and tree species, that is, *Acacia auriculiformis, Melicope glabra, Cinnamomum iners, Fragraea fragrans*, and *Macaranga tanarius* were recorded along the edges of marsh swamp, open water body, and lotus swamp (Table 9).

3.8. Correlationship between Water Level and Waterbird Abundance. Pearson's correlation coefficient (PCC) was used to determine the correlationship between water level and waterbird abundance. The results of PCC test showed a weak linear correlationship between water level and waterbird abundance in lotus swamp habitat ($r^2 = 0.120$, $P > 0.05$) and in Marsh Swamp habitat ($r^2 = 0.100$, $P > 0.05$). In contrast, negative linear correlationship ($r^2 = -0.710$, $P > 0.05$) was recorded between water level and waterbird abundance in open water body habitat.

3.9. Correlation between Waterbirds and Vegetation in Marsh Swamp Habitat. Canonical correspondence analysis (CCA) was used to examine the correlationship between waterbird abundance and vegetation type in marsh swamp habitat. The CCA analysis indicated that the correlationship between waterbird abundance and vegetation was (45.1%) (Table 10).

The CCA ordination biplot diagram of marsh swamp habitat showed that purple swamphens, purple herons, yellow bitterns, and cinnamon bitterns have strong association with emergent vegetation, white-breasted waterhens and white-throated kingfishers had close relationship with grasses while, lesser whistling ducks, little grebes, and cotton pygmy geese had strong associated with submerged vegetation. In contrast, common moorhens and red-wattled lapwings showed negative association with emergent and submerged vegetation (Figure 6).

3.10. Correlation between Waterbirds and Vegetation in Lotus Swamp Habitat. The canonical correspondence analysis test indicated a weak correlationship between waterbird abundance and vegetation (29.8%). This suggested that waterbird abundance in lotus swamp habitat a was little bit influenced by different vegetation namely, emergent vegetation, submerged vegetation, grasses, shrubs, and trees (Table 11).

The CCA ordination biplot diagram of lotus swamp habitat showed that common moorhen, grey heron, and pheasant-tailed jacanas have association with emergent vegetation, white-breasted waterhens, yellow bitterns, ballion's crakes, and purple swamphens have positive correlationship

Table 5: Monthly water level (m) data in marsh swamp at Paya Indah Natural Wetland Reserve, Peninsular Malaysia.

Months	Minimum water level (meters)	Mean water level (meters)	Maximum water level (meters)
November, 2007	2.218	2.249	2.273
December, 2007	2.206	2.222	2.237
January, 2008	2.197	2.243	**2.313↑**
February, 2008	2.176	2.197	2.218
March, 2008	2.197	2.215	2.231
April, 2008	2.246	2.218	2.237
May, 2008	2.167	2.182	2.222
June, 2008	2.139	2.151	2.167
July, 2008	2.127	2.148	2.167
August, 2008	2.084	2.103	2.127
September, 2008	2.075	2.097	2.115
October, 2008	**2.048↓**	2.090	2.124
November, 2008	2.087	2.112	2.154
December, 2008	2.142	2.167	2.185
January, 2009	2.151	2.170	2.182

Note: ↑ Arrow show maximum water level and ↓ arrow shows minimum water level.

Table 6: Monthly water level (m) data in open water body at Paya Indah Natural Wetland Reserve, Peninsular Malaysia.

Months	Minimum water level (meters)	Mean water level (meters)	Maximum water level (meters)
November, 2007	2.514	2.535	2.554
December, 2007	2.502	2.529	2.557
January, 2008	2.526	2.548	**2.572↑**
February, 2008	2.478	2.499	2.523
March, 2008	2.502	2.542	2.569
April, 2008	2.532	2.523	**2.572**
May, 2008	2.499	2.526	2.554
June, 2008	2.459	2.526	2.493
July, 2008	2.453	2.465	2.475
August, 2008	2.426	2.438	2.453
September, 2008	2.417	2.438	2.456
October, 2008	2.432	2.438	2.462
November, 2008	2.401	2.420	2.444
December, 2008	2.420	2.441	2.459
January, 2009	**2.398↓**	2.423	2.441

Note: ↑ Arrow shows maximum water level and ↓ arrow shows minimum water level.

with grasses. On contrary, white-browed crakes and red-wattled lapwings had negative association with shrubs, submerged vegetation, grasses, and trees (Figure 7).

The results of canonical correspondence analysis (CCA) of open water body habitat showed that waterbird abundance had strong association with vegetation (73.0%). Hence, this revealed that vegetation types, that is, emergent vegetation, submerged vegetation, grasses, shrubs, and trees, influence waterbird distribution (Table 12).

The CCA ordination biplot diagram of open water body habitat indicated that white-breasted waterhens, cinnamon bitterns, white-throated kingfisher and yellow bittern had close association with emergent vegetation and trees. Likewise, lesser whistling ducks and little grebe had strong correlationship with submerged vegetation and shrubs. in contrast, red-wattled lapwing and common moorhens showed negative association with submerged vegetation, shrubs, and emergent vegetation. Furthermore, cotton pygmy geese showed positive correlationship with grasses (Figure 8).

4. Discussions

The attraction and response of waterbirds in relation to water level is conspicuous and reflects the status of habitat at a given time of a particular area. Apparently, this wetland reserve straddles the water resources from Sungai Chua and

Table 7: Monthly water level (m) data in lotus swamp at Paya Indah Natural Wetland Reserve, Peninsular Malaysia.

Months	Minimum water level (meters)	Mean water level (meters)	Maximum water level (meters)
November, 2007	2.188	2.215	2.237
December, 2007	2.182	2.203	2.228
January, 2008	2.185	2.215	**2.249**↑
February, 2008	2.090	2.130	2.182
March, 2008	2.118	2.179	2.222
April, 2008	2.185	2.026	2.228
May, 2008	2.060	2.145	2.215
June, 2008	1.865	1.966	2.072
July, 2008	1.859	1.883	1.889
August, 2008	1.841	1.853	1.868
September, 2008	1.837	1.856	1.868
October, 2008	**1.834**↓	1.868	1.895
November, 2008	1.874	1.895	1.935
December, 2008	1.932	1.978	2.005
January, 2009	1.978	1.993	2.008

Note: ↑ Arrow shows maximum water level and ↓ arrow shows minimum water level.

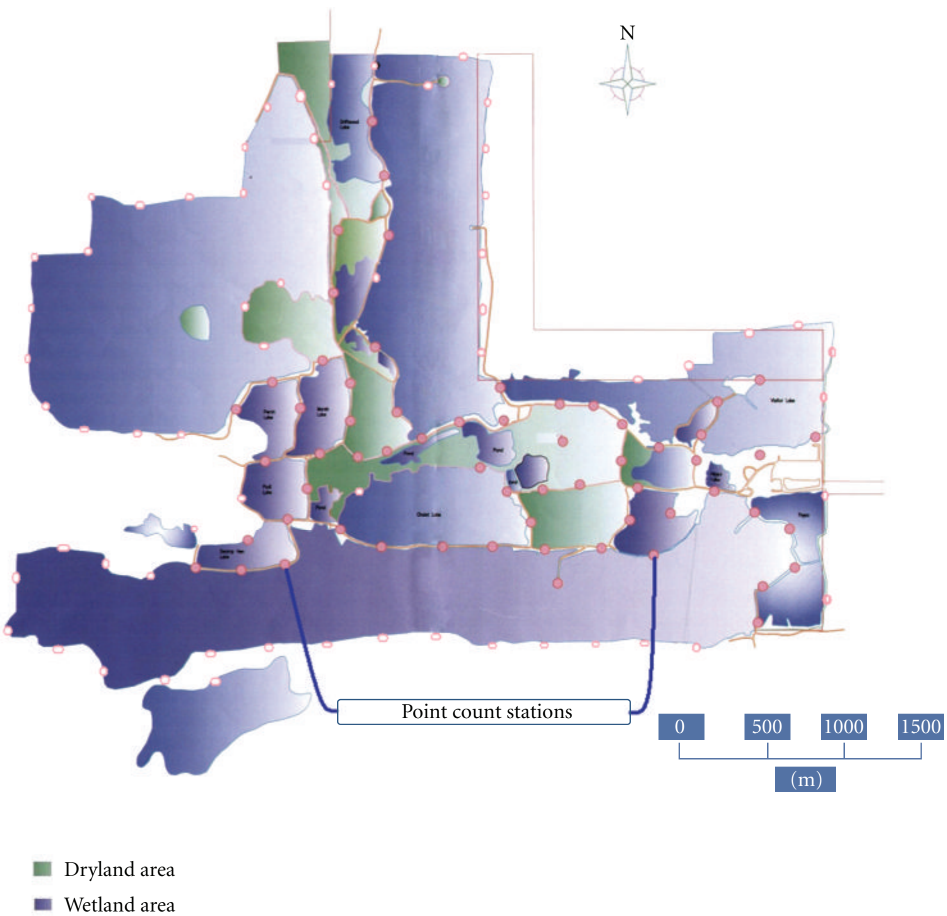

Figure 5: Map location of the distance sampling point count stations at Paya Indah Natural Wetland Reserve, Peninsular Malaysia.

Table 8: Comparison of mean water level of marsh swamp, open water body, and lotus swamp at Paya Indah Natural Wetland Reserve, Peninsular Malaysia.

Habitat name	Mean water level (meters)	Standard error (SE ±)
Marsh swamp	2.48 a	0.06
Open water body	2.19 b	0.05
Lotus swamp	2.03 c	0.16

(The mean values in columns with same letter are not significant at $P = 0.05$,).

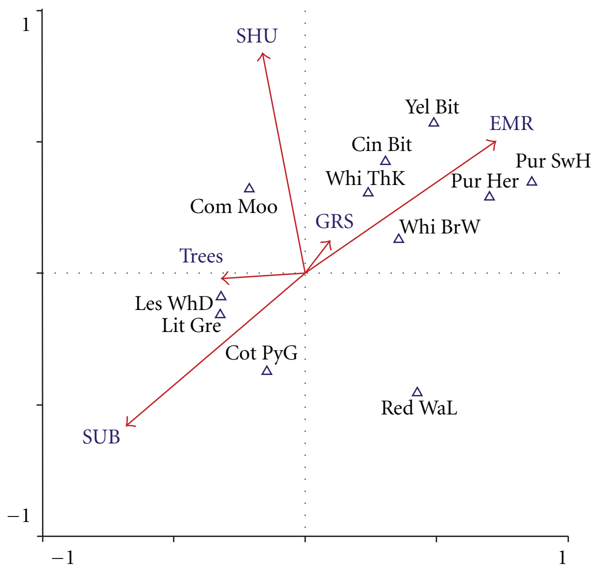

Figure 6: Ordination plot from a canonical correspondence analysis of waterbirds abundance of Marsh Swamp in relation to vegetation type. The biplot of axes 1 and 2 is presented; the orientation of each vegetation type in relation to waterbird is presented by an arrow, and the length of arrow indicates the degree of correlation.

Sungai Bisa. It was observed that the water levels in this natural wetland reserve might vary during 15 consecutive months due to unpredictable hydrological events such as rainfall and incoming water resources from the watershed areas of Sungai Chua and Sungai Bisa. It also has been reported that water level in wetlands might vary depending upon incoming water resources and precipitation [22–24].

It was observed that the changes in water level had eventually caused a shift of aquatic vegetation in the study area for instance, and when the water level went down, the shallow water areas which were dominated by water chestnuts (*E. dulcis*), marsh sedges (*S. purpurascens*), woolly water lilies (*P. lanuginosum*), spike water-milfoils (*M. spicatum*), and smooth cord grass (*S. alterniflora*) became dry and suppressed by grasses such as cogon grass (*I. cylindrical*), three square bulrushes (*S. olneyi*), buffalo grass (*P. maximum*), spike grass (*D. spicata*) and carpet grass (*Cynodon dactylon*). Due to decrease in water level, the lotus (*N. nucifera*) became dry and was replaced by emergent vegetation that is, *E. dulcis* and *S. purpurascens*. Mortsch [25]

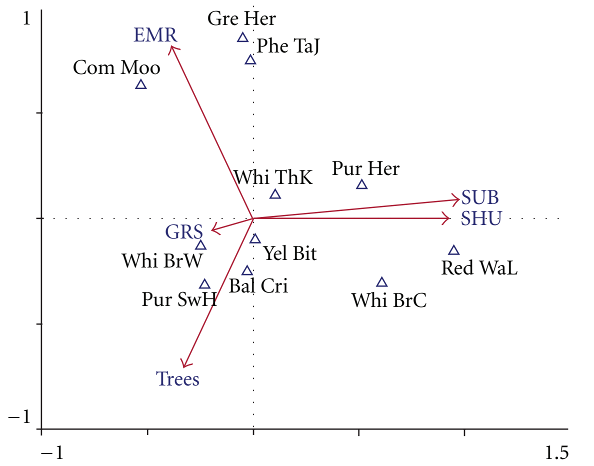

Figure 7: Ordination plot from a canonical correspondence analysis of waterbirds abundance of lotus swamp in relation to vegetation type. The biplot of axes 1 and 2 is presented; the orientation of each vegetation type in relation to waterbird is presented by an arrow, and the length of arrow indicates the degree of correlation.

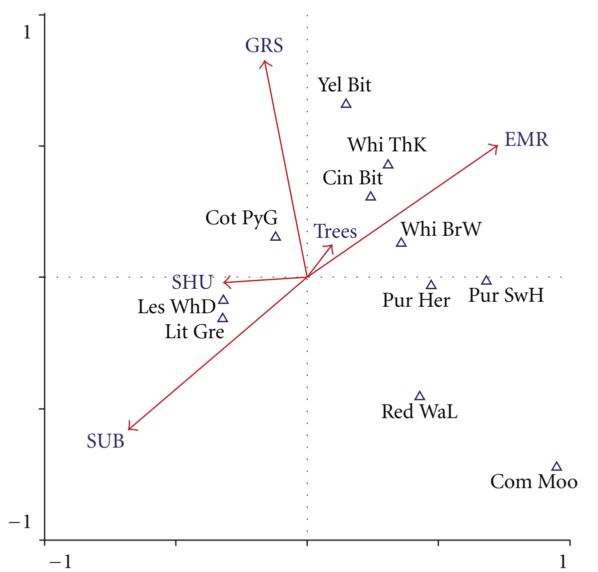

Figure 8: Ordination plot from a canonical correspondence analysis of waterbirds abundance of open water body in relation to vegetation type. The biplot of axes 1 and 2 is presented; the orientation of each vegetation type in relation to waterbird is presented by an arrow, and the length of arrow indicates the degree of correlation.

and Poiani et al. [26] has also reported that lower water level caused the changes in aquatic vegetation composition and structures and as a result, affected the grass and shrub communities.

In addition, when water level rose, the areas that were dominated by emergent vegetation sank and the lotus plants became dominant species. These changes in vegetation composition had caused the shift of ducks, swamphens, crakes, herons, jacanas, and moorhens from deeper areas

Table 9: The proportion and type of vegetation occurring in three habitats at Paya Indah Wetland Reserve, Peninsular Malaysia.

Type of vegetation	Marsh swamp	Lotus swamp	Open water body
Emergent vegetation (EMR)	59.12%	55.40%	30.80%
Submerged vegetation (SUB)	13.61%	15.40%	61.50%
Grasses (GRS)	4.82%	5.00%	4.54%
Shrubs (SHU)	3.74%	1.20%	3.16%
Trees	67	17	6

Table 10: Summary table of CCA coordination for waterbird abundance and vegetation type in marsh swamp habitat at Paya Indah Wetland Reserve, Peninsular Malaysia.

Term	Axis				
	1	2	3	4	Total
Eigen values	0.226	0.093	0.075	0.043	1.069
Species-environmental correlations	0.938	0.817	0.687	0.706	—
Cumulative percentage variance of species data	21.2	29.8	36.9	40.9	—
Cumulative percentage variance of species-environment relation	50.1	70.7	87.4	97.0	—
Sum of all eigen values	—	—	—	—	1.069
Sum of all canonical eigen values	—	—	—	—	0.451

to shallow waters such as edges dominated by emergent vegetation. Birds often relate to vegetation community, thus, shifts in vegetation may influence the distribution of bird species [27]. In the study, it was also observed that due to the rise in water level, the swamphens moved to shallow areas covered with emergent vegetation such as water chestnuts, sometimes flew to the deep-water area to pluck the seeds of water lilies, and then flew to the dryland and consumed there. Furthermore, ducks also moved to water bodies having emergent vegetation along the edges, because they provide suitable loafing sites for them. The shallow vegetated areas are rich in food sources such as fishes, amphibians, and aquatic invertebrates. The rise in water level affects the abundance and distribution of invertebrate, amphibian, and fish compositions which were the main sources of food for the waterbirds. This shows that fluctuation in water level within wetland indicates where and when waterbird species can access their foods.

However, lapwings, waterhens, kingfishers, geese, grebes, and water cocks were less affected such as lapwing mostly utilized moist soil in ditches and along edges for foraging and dry land for breeding, waterhen and water cock preferred both water body edges and dry grassland adjacent to water bodies, kingfisher hunted on fishes and insects through sallying and consumed on trees, and grebes and geese often preferred deeper water for foraging. Seemingly, high water level can make invertebrate food resources less available for many waterbirds [28–30].

In contrast, when water level fall down, the leaves of water lilies became dry that caused shift in waterbird such as jacanas, bitterns, and moorhen moved to shallow waters dominated by water lilies and water chestnut vegetation. Jacanas foraged on snails and aquatic insects attached with floating leaves of water lilies, and bitterns sit on stems of water lily leaves and prey on aquatic insects resting or moving on aquatic vegetation or attached with leaves. This indicates that water level changes influence the physical structure of habitats (zonation of vegetation), the availability and accessibility of food, and the presence of safe roosting or breeding sites. Similar findings were also recorded by Green and Robins [31], Guillemain et al. [32], and Clausen [33]. Eventually, the fluctuation in water level might alter the habitat characteristics that could cause prompt changes in fish, amphibians, invertebrates and waterbird communities [34–38].

The results of this study indicated that water level is a major factor that influenced the waterbird species composition and relative abundance directly and indirectly in this wetland reserve. In addition, it was observed that waterbird abundance is influenced by water level and richness of aquatic vegetation, that is, water chestnut (*E. dulcis*), lotus (*N. nucifera*), marsh sedge (*S. purpurascens*), wooly water lily (*P. lanuginosum*), spike water-milfoil (*M. spicatum*), common duck weed (*S. minima*), and smooth cord grass (*S. alterniflora*). Undeniably, it was also recorded that water level is a crucial factor that influenced the dynamics of aquatic vegetation composition.

It has been reported that the higher waterbird species diversity occurred at 0–20 cm water depths due to availability of diverse foraging sites, which might vary from exposed mud to deeper water with submerged aquatic plants [29, 30, 39–41] and correlates to hydrological variation [22, 42–44]. Causarano and Battisti [24] examined the effects of a seasonal water level on five water-obligated birds, that is, *Tachybaptus ruficollis, Anas platyrhynchos, Rallus aquaticus, Gallinula chloropus*, and *Fulica atra* and reported that the

Table 11: Summary table of CCA coordination for waterbird and vegetation types in lotus swamp habitat at Paya Indah Wetland Reserve, Peninsular Malaysia.

Term	Axis				
	1	2	3	4	Total
Eigen values	0.142	0.111	0.035	0.010	0.298
Species-environmental correlations	1.000	1.000	1.000	1.000	—
Cumulative Percentage variance of species data	47.7	84.9	96.6	100.0	—
Cumulative Percentage variance of species-environment relation	47.7	84.9	96.6	100.0	—
Sum of all eigen values	—	—	—	—	0.298
Sum of all canonical eigen values	—	—	—	—	0.298

Table 12: Summary table of CCA coordination for waterbird abundance and vegetation type in open water body at Paya Indah Wetland Reserve, Peninsular Malaysia.

Term	Axis				
	1	2	3	4	Total
Eigen values	0.414	0.199	0.072	0.030	0.730
Species-environmental correlations	1.000	1.000	1.000	1.000	—
Cumulative Percentage variance of species data	56.7	83.9	93.9	98.0	—
Cumulative Percentage variance of species-environment relation	56.7	83.9	93.9	98.0	—
Sum of all eigen values	—	—	—	—	0.730
Sum of all canonical eigen values	—	—	—	—	0.730

Table 13: Analysis of variance (ANOVA) of waterbird abundance of three habitats, namely, marsh swamp, open water body, and lotus swamp at Paya Indah Natural Wetland Reserve, Peninsular Malaysia.

DF	SS	MS	*F*	*P*
2	84940.6	42470.3	226.20	0.0000
42	7885.87	187.759	—	—
44	92826.4	—	—	—

Table 14: Analysis of variance (ANOVA) of mean water levels of three habitats, namely, marsh swamp, open water body and lotus swamp at Paya Indah Natural Wetland Reserve, Peninsular Malaysia.

DF	SS	MS	*F*	*P*
2	1.54	0.77	68.42	0.0000
42	0.47	0.01	—	—
44	2.01	—	—	—

reduction in water depth dried out the reed beds and rush beds that consequently reduced the habitat suitability. In addition, Boertmann and Riget [45] studied the effects of water level fluctuation on dabbling ducks and found that eurasian wigeons (*Anas PenelopeI*), eurasian teals (*Anas crecca*), and mallards (*Anas platyrhynchosI*) positively correlated with the water level while northern shovelors (*Anas clypeata*) and northern pintails (*Anas acuta*) showed less evidence of correlationship with the water level.

Additionally, DesGranges et al. [46] examined the wetland birds' response to water level fluctuation and revealed that wetland bird species were significantly associated with hydrological context. Additionally, Hamabata [47] and Sugawa [48] also reported that the waterbird species richness was usually high in shallow waters less than 3 m deep with gentle slopes. Furthermore, Epstein and Joyner [49] and Colwell and Taft [41] reported that maximum waterbird abundance occurred at zero water depth. On the other hand, Hands et al. [50] and Frederick and McGehee [51] compared the bird relative abundance among wetlands and found confounding effects of variation in water depth.

5. Conclusion

The results of this study indicate that water level is a major factor that influenced the relative abundance and distribution of ducks, swamphen, crakes, herons, jacanas, and moorhens directly and indirectly. In addition, it also affects the dynamics of aquatic vegetation composition such as emergent, submerged, and grasses in this wetland reserve.

Appendix

For more details, see Tables 13 and 14.

Contribution of the Main Author

M. N. Rajpar developed the experimental design, collected and analyzed the data, and also wrote of the paper. M. Zakaria reviewed and edited the paper.

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