A DISSERTATION FOR THE MASTER DEGREE OF FOREST SCIENCES

Characteristics of Wintering Bird Communities in Different Habitat Types in the Moeyungyi Wetland Wildlife Sanctuary, Myanmar

미얀마 모엔지 습지 야생동물 보호구역의 서식지 유형과 월동 조류 군집의 특성

By

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DEPARTMENT OF FOREST SCIENCES

GRADUATE SCHOOL

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Abstract

Understanding the bird communities in different habitat types is essential for the conservation of important habitats. Wetlands possess different types of habitats, are important for wintering waterbird community. However, there is only a handful of studies, dealing habitat-bird relationship, done in the wetlands of tropical Southeast Asia. The aim of this study is to compare bird community characteristics at different habitat types and find the relationships between bird community composition and environment characters at different habitat types at Moeyungyi wetlands, and conduct species analysis to identify indicator species for each representative habitat types in Moeyungyi wetland. Bird and habitat data collection was made among five representative habitat types (short grasslands, tall grasslands, lotus fields, open water areas, and rice fields) during December, January, and the first week of February of 2014-15, at the Moeyungyi Wetland Wildlife Sanctuary, Myanmar.. A total of 52 different bird species belonging to 11971 total individuals were encountered during the survey season with 50 point count stations of 7 minutes observation per plot. Natural wetlands hosted high species richness, abundances and diversity of birds while rice fields showed lowest species richness, abundances and diversity of birds. The canonical correspondence analysis revealed the habitat preferences of each bird species.Marsh Sandpipers (*Tringa stagnatilis*) and Oriental Darters (*Anhinga melanogaster*) were strongly related to short grasslands. Purple Herons (*Ardea purpurea*) and Purple Swamphens (*Porphyrio porphyrio*) preferred tall grasslands while

Bronze-winged Jacanas (*Metopidius indicus*) and Garganeys (*Anas querquedula*) tend to occur at lotus fields. Little Terns (*Sternula albifrons*) and White-winged Terns (*Chlidonias leucopterus*) were widely distributed in open water areas, and Pacific Golden Plovers (*Pluvialis fulva*) and Pintail Snipes (*Gallinago stenura*) belonged rice fields. Among the 52 bird species observed during the survey, 35 species were recognized as indicator species for each five habitat types, which was in accordance with canonical correspondence analysis results that supported with the relationships between each representative habitat types. In conclusion, The composition of bird communities was different between five habitats and more importantly, that the rice fields had lower indices for bird communities than any other natural habitat types. Natural marshes were more beneficial in maintaining of high species richness, abundances and diversity of waterbirds than in rice fields during the wintering period. Thus, the further management strategies should target the conservation of natural marshes, as an important habitat for the conservation of wintering waterbird communities at Moeyungyi Wetland. Also. indicator species found in this study can be a useful measure for the management of Moyungyi wetland, and even can be applied to broader geographic region including tropical South and Southeast Asia which holds similar wetland habitats and waterbird communities during winter.

Keywords: indicator species analysis, natural marshes, rice fields, tropical Southeast Asia, waterbirds

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I. Introduction

Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters (Ramsar 1971). Wetlands can highly provide biological diversity and possess ecological values. One of the best known functions of wetlands is to provide habitats for birds (Wetland International 2013, Isola et al. 2000). Furthermore, many of the globally threatened avian species depend on wetlands (Green 1996).

The global wetland areas are generally estimated to be 7 to 9 millions km^2 (4-6 percent of the land surface of the earth) (Mitsch and Gosselink 2000, Dahl 1990). Waterbird populations are adversely affected due to wetland degradation and losses. Providing high quality habitats are quite important for waterbird conservation and it is a difficult issue how to provide high quality habitat through effective management practices (Weber and Haig 1996, Erwin 2002). Human activities can cause wetland degradation and losses. Extension of agricultural practices and development activities can have an affect on wetland areas and wetlands' quality (Barbier 1993, Barbier 1994).

Bird species utilize different resources and microhabitats in available ways throughout the wetlands, depending on their feeding niches. Some waterfowl, such as grebes, have adapted to wetlands to such an extent that their survival as individual species depends on the availability of certain types of wetlands within their geographic range (Nudds et al. 1994, Green 1998, Isola et al. 2000).

Species richness, abundance and diversity of birds in each habitat type are basic information used to identify the characteristics of bird communities (Ma et al. 2007). Studies of the relationships between birds and their habitats are needed to formulate management strategies, especially for globally threatened bird species (Green 1996). And also, there is a need for the identification of indicator species for monitoring, conservation and management of areas and target species (Caceres and Legendre 2009). If one habitat has more individuals of indicator species with higher indicator value, this habitat is more likely to belong to a particular group (Dufrene and Legendre 1997). The indicator value method is important to conservation biology because it allows researchers to identify bioindicators for any habitat types or areas (McGeoch and Chown 1998).

In Myanmar, Moeyungyi Wetland Wildlife Sanctuary is an important bird area, the first and the only Ramsar site, and a Flyway Network Site of the East Asian- Australasian Flyway Partnership (EAAFP) in Myanmar. From October to March, it hosts over 20,000 migratory waterbirds. These include the globally threatened Baer’s Pochard (*Aythya baeri*), Sarus Crane (*Grus* *antigone*), Greater Spotted Eagle (*Clanga clanga*) and more than one percent of the regional population of Northern Pintail (*Anas acuta*) (Thaw 2013). 70 species of migratory birds (both land birds and waterbirds) and 59 species of resident birds are recorded in the Moeyungyi area by Forest Department (FD 2013).

Migratory birds reach Myanmar from October to May along two flyways, the Central Asian Flyway and the East Asian Australasian Flyway. Wetlands in Myanmar attract migratory birds from the Arctic Region for wintering, which provide a good indicator of site significance (Thaw 2013). Understanding of the relationships between bird communities and their habitats is quite important for the conservation and management activities (Chettri et al. 2005).

In Myanmar, construction of dams and harmful agricultural practices (e.g., use of chemical fertilizers and pesticides) can cause negative impacts on the regular flow of water into wetlands. Increased depositions of silt in wetlands are due to inappropriate land use methods in upland areas (FD 2013). Furthermore, at Moeyungyi Wetland, illegal hunting of waterbirds by the local people, supply of fresh water to agriculture by the Irrigation Department and extension of agricultures by local people may be harmful for the long term existence of wetlands and bird communities (FD 2013). The drying parts of wetland are used for growing rice and this leads to degradation of the natural marshland vegetation in the Moeyungyi area (Davies et al. 2004). Studies on bird communities and their habitats are quite important to protect and conserve Moeyungyi Wetland and associated bird communities.

Nevertheless, at Moeyungyi Wetland, there are no previous studies about the characteristics of community of wintering birds in different habitat types. No information about the relationship between the bird communities and their habitats is available either. Consequently, the main objectives of my studies are;

a) to compare species richness, abundances and diversity of birds in different habitat types;

b) to identify the relationships between bird communities and their habitats and

c) to identify indicator species representing each habitat type at Moeyungyi Wetland, Myanmar.

II. Literature Review

1. Relationship between bird communities and habitats

Birds are the valuable indicators of ecosystem changes because they often respond to both direct and indirect environmental influences (Adamus and Brandt 1990, Sekercioglu 2006). Birds have been also considered as good predictors of habitat quality (Chettri et al. 2001, Raman 2001, Chettri et al. 2005). Habitat fragmentation or other habitat parameters affect the distribution of many bird communities (O'Connell et al. 2000) since birds commonly respond to altered habitat structures (MacArthur and MacArthur 1961, MacArthur et al. 1966,), changes in vegetation patterns and structures (Mills et al. 1991) and also water depth (Colwell and Taft 2000).

Generally, the vertical diversity, canopy height, cover, and total vegetation volume explain the avian richness and diversity (Finch 1989, Mills et al. 1991). MacArthur and MacArthur (1961) found that bird species diversity was positively related to vertical diversity of vegetation and Losito and Baldassarre (1995) stated that there were strong correlations between vegetation structures and bird diversity. Vegetation height and species composition were major structural habitats to explain the habitat selection of grassland birds (Bryan and Best 1991). Vegetation height, as an important structural feature, influences habitat selection by grassland birds that can change the suitability of a particular area over time (Wiens 1969, Bryan 1990). Mills et al. (1991) mentioned that an index of total vegetation volume was strongly correlated with breeding bird density in shrub and desert habitats.

Similar to these cases in terrestrial environments, the use of wetland habitats by waterbirds were affected by multiple environmental components such as vegetation and water level (Velasquez 1992, Colwell and Taft 2000). Rajpar and Zakaria (2011) found that the dynamics of aquatic vegetation composition such as emergent, submerged and grasses were affected by the water level directly and indirectly, as well as the relative abundance and distribution of ducks, swamphen, crakes, herons, jacanas and moorhens. The distribution of waterbirds were influenced by fluctuation in water level such as from drought to flooding (Kushlan 1986, Pyrovetis and Papastergiadou 1992).

Hattori and Mae (2001) showed that the highest species richness and density of waterbirds occurred in the reed beds of aquatic vegetation, where the water level is 20-60 cm in depth. Hattori and Mae (2001) described also that the reed bed habitats with shallow water (<1 m depth) may be crucial in the determination of high waterbird diversity. Kushlan (1986) reported that wading birds (Ciconiiformes) may use diverse strategies to cope with the seasonal fluctuations of water level characteristics of large tropical wetlands.

Along with the diversity and density, the most notable interspecific differences in habitat use, that characterize communities (Wiens 1992) is the use of different water depth among waterbirds (e.g., waterfowls and shorebirds). Interspecific patterns of habitat use by waterfowls and shorebirds were mostly related to water depth and these patterns were also correlated with species' morphologies. Larger species with longer necks, bills and legs feed in deeper habitats than smaller taxa (Baker 1979, Colwell and Oring 1988, Colwell and Taft 2000).

The other factors including wetland size and distribution, vegetation structures, and water chemistry also affect bird distribution and species composition in wetlands. For instance, multi-species duck communities have shown niche separation between species in horizontal dimensions with different habitat characteristics such as wetland size, vegetation, and water chemistry (Nudds et al. 1994). Bryan and Best (1991) reported that temporal patterns in bird abundance were attributed primarily to aspects of the waterways and surrounding cropland that changed overtime, such as vegetation height. These environmental components are not independent, for example, water depth and vegetation structure were frequently correlated in wetlands (Nudds et al 1994).

2. Review on Asian Waterbird Census and other bird surveys in Myanmar

Monitoring the status of waterbird populations, their distribution and the status of wetlands in Asia was initiated by the Asian Waterbird Census (AWC) in 1987. AWC is an integral part of the international waterbird census and has been coordinated by Wetland International (Li and Mundkur 2007). The AWC provides the most comprehensive monitoring programs for waterbirds in the Asia-Pacific region.

More than 6,100 sites in 27 countries have been counted at least once by AWC. The thousands of active volunteers are involved in AWC (Wetland International 2014). For waterbirds and wetland conservation, a strategy to guide for the development of AWC have been developed during the period 2004-2006 (Wetland International 2013).

A total of 408 sites in Southeast Asia (Brunei Darussalam, Cambodia, Indonesia, Loa PDR, Malaysia, the Philippines, Singapore, Thailand, Timor Leste and Vietnam) including Myanmar was counted at least once (Li and Mundkur 2007). As a part of AWC, 122 species of waterbirds comprising 19 families were recorded in Myanmar between 2000 and 2003. Twenty-one globally threatened species (2 endangered, 9 vulnerable and 10 near-threatened) were recorded in Myanmar (Davies et al. 2004). Many of Myanmar's globally threatened bird species were characteristics of wetland ecosystems and included some of the most threatened bird species in the country (MOECAF 2014). Habitat loss was suggested as the main threats for most globally threatened bird species (Birdlife International 2003).

The nationwide comprehensive census had not been possible due to the lack of resources, bird surveys have been regularly conducted in wetland protected areas in Myanmar. There were no dramatic changes in bird numbers between 2012 and 2013 in two protected wetland areas, Inlay Lake and Moeyungyi Wetland Wildlife Sanctuary. Indeed the number of migratory birds increased in 2013 at Inlay Lake, while resident birds increased at Moeyungyi Wetland Sanctuary over the same period (MOECAF 2014).

3. Indicator Species

A species is an indicator species when it characterizes a group of sites. It is mostly found in a single group and present in the majority of the sites belonging to that group**.** Indicator species give ecological meaning to groups of sites and represent specific environmental conditions whose presence, absence or abundance can reflect a specific environmental conditions (Dufrene and Legendre 1997).

Identification of indicator species can be used in the field of monitoring, conservation and management of habitats. Studies based on field works, describing sites or habitats usually mention one or several indicator species characterizing each habitat type (Caceres and Legendre 2009).

Verner (1984) found that an indicator species may be used to predict response of other species in the same guild to changes in the environment according to the guild indicator hypothesis. Roberge and Angelstam (2006) concluded that the indicator species approach may be useful for resident birds of deciduous forests in hemiboreal Europe for conservation and management.

McGeoch and Chown (1998) stated that indicator species can be used as indicators of the state of an ecosystem and of human-induced changes to the environment and biodiversity. The indicator value of waterbird species characterizing the different types of wetlands had been studied by Paton et al. 2009 and the results confirmed the distinct, species-rich nature of the wetland regions.

III. Materials and Methods

1. Study Area

Moeyungyi Wetland was originally created as a man-made dam constructed in 1885. For the last 100 years, it has gradually changed into a natural wetland area. It extends for an area of 103.6 km^2 (10359 hectares). It is located at 17° 32 ' 57″ N and 96° 36' 58″ E in Bago and Wow township, Bago Region (Figure 1). Moeyungyi Wetland Wildlife Sanctuary (MWWS) was notified as a gazette protected area by the Forest Department, Ministry of Environmental Conservation and Forestry in 1988 (FD 2013).

The Moeyungyi Wetland falls within the tropic and temperate region throughout the year with a mean annual temperature of 26.95°C. The mean monthly temperature is the highest in April with 30.5 °C and the lowest temperature in January with 23.72 °C and with the annual rainfall of 3543.05 mm (FD 2013).

Five major wetland types are generally recognized by the Ramsar Classification System for classification of wetland types (Cowardin et al. 1979). The wetland type of Moeyungyi Wetland is palustrine dominated by herbaceous plants such as grasses, reeds and rushes.

Habitat types within Moeyungyi Wetland are tall grasslands, short grasslands, lotus fields, open water areas, planted trees and seasonal rice fields (figure 2-3). Tall grassland is dominated by Wild Rice (*Oryza minuta*), and the height of vegetation is ranged from 80 cm to 130 cm. The height of short grassland dominated by Water Snowflake (*Nymphoides indicum*) and Umbrella Canegrass (*Leptochloa neesii*) is ranged from 15 cm to 33 cm. The lotus fields are covered by Indian Lotus (*Nelumbo nucifera*) while rice fields at Moeyungyi areas are dominated by irrigated and seasonal crop rices.

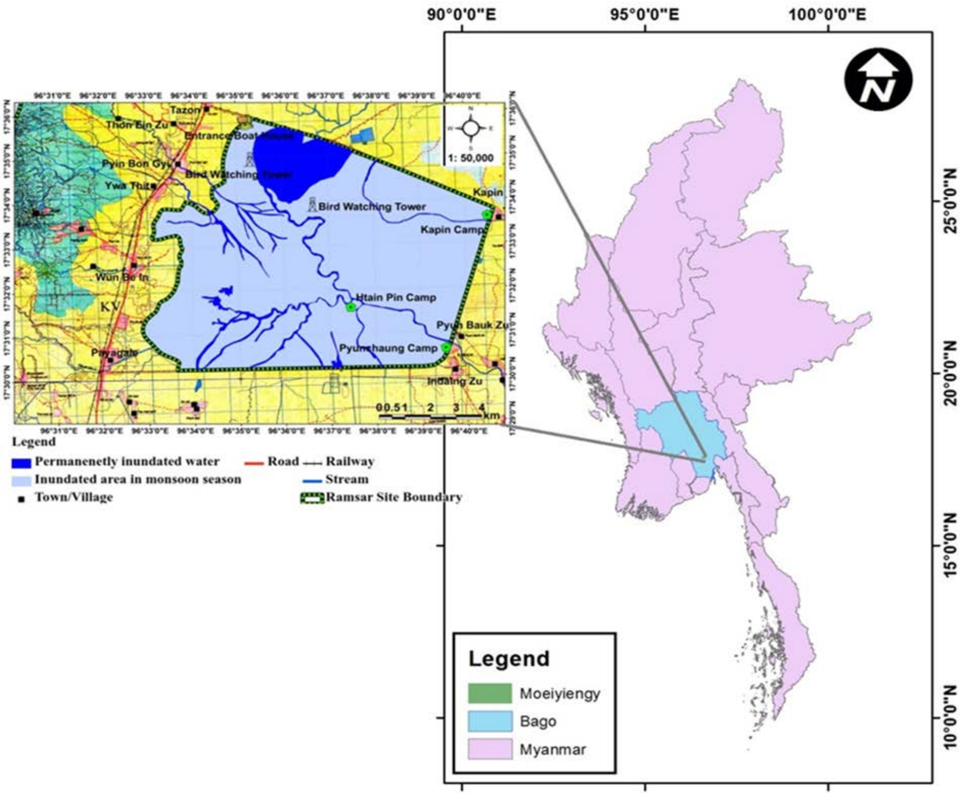

Figure 1. Map of Moeyungyi Wetland Wildlife Sanctuary

(courtesy of Wildlife Conservation Society)

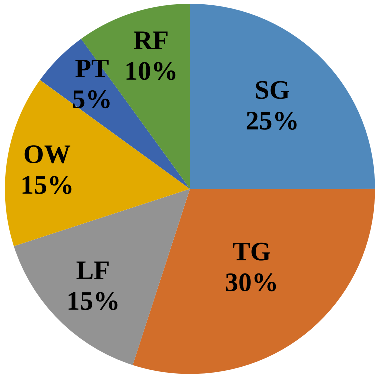

Figure 2. Area estimation of major habitat types at Moeyungyi Wetland in winter (SG:short grassland, TG:tall grassland, LF:lotus field, OW:open water, PT:planted tree, RF:rice field) (Moeyungyi Office, unpublished data)

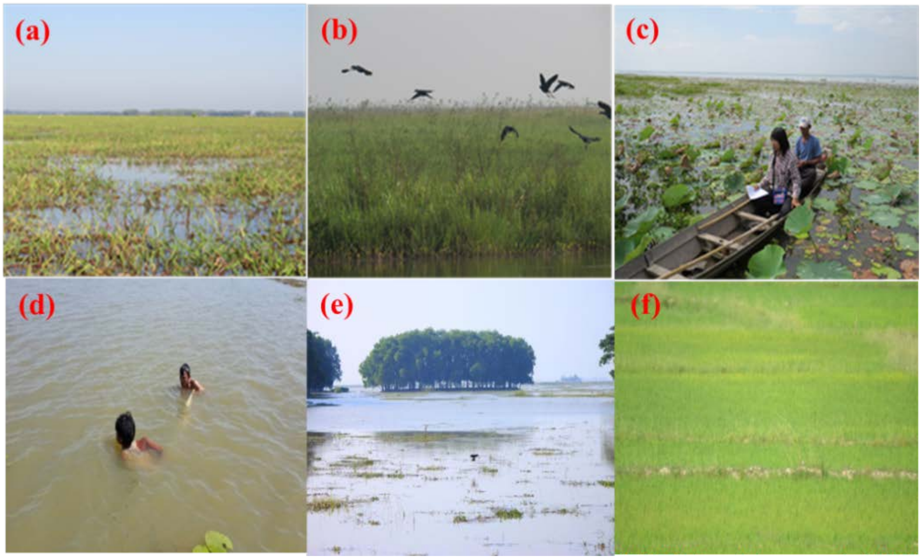

Figure 3. Habitat types at Moeyungyi Wetland (a) short grassland, (b) tall grassland, (c) lotus field, (d) open water area, (e) planted tree, and (f) rice field

2. Habitat surveys

I used the point quadrat method (Cockayne 1926, Brown 1954, Goodall 1952) for habitat studies in December, 2014. The size of one plot for vegetation survey was $1\times1\ m^2$. I took five plots within each bird sample plot (Figure 4). A total of 200 plots were selected for vegetation surveys in short grassland, tall grassland, lotus field and rice field habitat. I counted the number of individuals of each plant species and also measured water depth (cm), vegetation height (cm) and vegetation cover (percentage) (Figure 5). In open water areas, vegetation species were not recorded because the vegetation was not above the water surface. I measured only water depth in open water area. In the rice field, species diversity was not recorded since all rice fields in the Moeyungyi area are monoculture. The positions of each vegetation plot were marked with a Global Positioning System device (GPS map 62S, Garmin). Dominant plant species, vegetation cover, vegetation density, vegetation height, plant species diversity and average water depth were calculated during March, 2015.

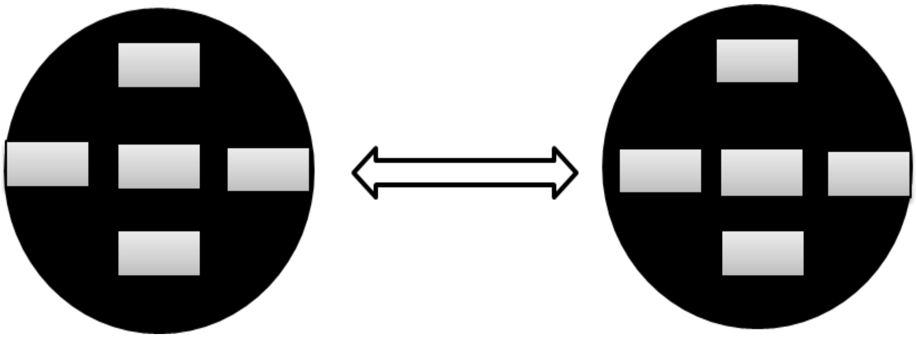

Figure 4. Design for bird survey plots (circle) and habitat survey plots (box) at each habitat type. Distance between each bird survey plot was 300 m at least to avoid double counting of the same birds.

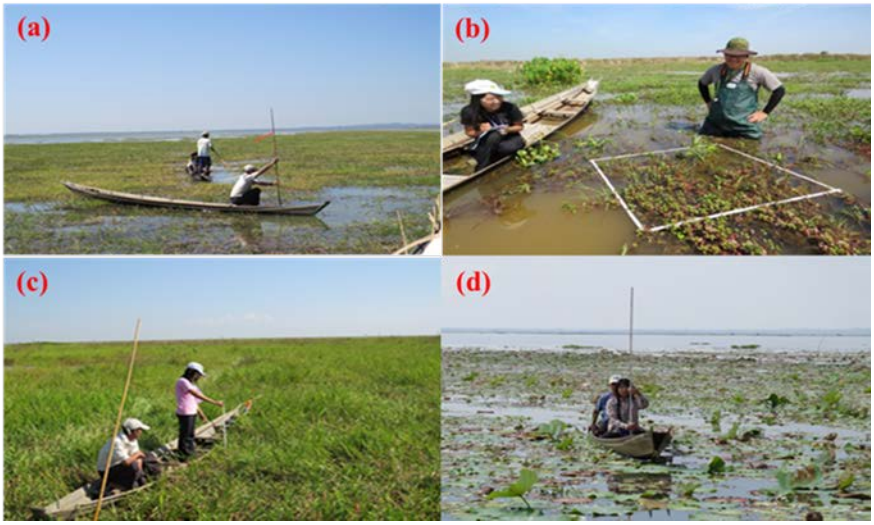

Figure 5. Habitat survey at Moeyungyi Wetland, Myanmar (December, 2014): (a) marking the center of the plot with a bamboo pole, (b) vegetation survey with point quadrat frame, (c) measuring water depth at tall grassland, and (d) measuring water depth at lotus field.

3. Bird Surveys

I selected five different habitat types according to habitat classification of the Moeyungyi office. These habitats are tall grasslands (height 80-130 cm), short grasslands (height 15-33 cm), lotus fields, open water areas and rice fields, and these are different habitat types for bird communities. Grasslands, lotus fields and open water areas are natural habitats for birds whereas rice fields are artificial habitats. Bird surveys were conducted from December 2014 to the first week of February 2015 in Myanmar. The point count method (Ralph and Sauer 1995, Hostetler and Main 2001) was used for bird surveys.

I set up 50 meter radius plots at each habitat type first and marked the center of each plot with a bamboo pole, marking tapes and measuring tapes. I took 10 sample plots for rice fields, 10 sample plots for short grasslands, 10 sample plots for tall grasslands and 10 sample plots for lotus fields. But, I took only 9 sample plots for open water areas according to field conditions (small housing within the wetland). Therefore, a total of 49 point count plots at five different habitat types were consequently selected (Figure 5).The distance between each plot was at least 300 meters to avoid double counting of the same birds. I used binoculars (Nikon 10 × 42) for bird identification and counts, and all bird counts were done outside the plots (at least 100 meters distance from birds) to minimize disturbances from an observer, we thus avoided disturbing birds and usually completed counts before the birds flew away as much as possible.

The survey was done in the morning from 7:00 AM to 12:00 PM. Bird counting lasted for 7 minutes at each plot, and 20-23 plots were surveyed per day. Each bird plot was visited 21 times. I visited bird survey plots and habitat types with different spatial and temporal schedules to avoid potential bias from time and date. Bird data were collected by recording the number of individuals of each species and the number of species (species richness). We did not conduct bird surveys in bad weather conditions (days with rain, mist and strong wind).

4. Data Analysis

4.1 Community analysis

4.1.1. Dominance index

To express dominant species, ecologists estimate species' percent cover in herbaceous plant communities. Percent cover in 1 m^2 plot (% of plot covered by species) is easily and reliably estimated (Kercher et al. 2003). The dominant cover percentage of plant species is calculated by the following formula.

$$\textbf{Average Percent Cover} = \frac{(\textbf{cover in plot 1}) + (\textbf{cover in plot 2}) + (\textbf{cover in plot X})}{\textbf{total number of plots}}$$

4.1.2 Species richness and abundances

Species abundance is the number of individuals per species (MacArthur 1960). Species richness (Menhinick's index D) is a measure of the number of species found in a sample (Gotelli and Colwell 2001, Davari et al. 2011). In a larger sample, we would expect to find more species, therefore, the number of species can be divided by the square root of the number of individuals in the sample as an index of species richness to account for sample size.

$$\mathbf{D} = \frac{s}{\sqrt{N}}$$

where s equals the numbers of different species represented in the sample and N equals the total number of individual organisms in the sample.

4.1.3 Species diversity

The Shannon-Weaver index is used to characterize species diversity in a community (Shannon and Weaver 1949, MacArthur and MacArthur 1961) and also accounts for both abundance and evenness of the species present. The index is calculated from the below formula:

$$\mathbf{H'} = -\sum_{\boldsymbol{n}}^{\boldsymbol{i}} \boldsymbol{pi} \times \mathbf{ln}\, \boldsymbol{pi}$$

Where p_i is the relative abundance of each species. ($P_i = n_i / N$); n_i denoted the total number of the organization belong to i-th species; N, denoted the total number of organizations of all species.

4.1.4 Species evenness

The Evenness index is used to measure biodiversity which quantifies how equal the population is. The index was denoted by the letter J. The formula is:

$$\mathbf{J = H' / H'_{max}}$$

Where H' is the number derived from the Shannon- Weaver index and H'_{max} = ln (s), which is the natural logarithm of the number of species’s, occurs when all species are present in equal numbers.

4.2 Indicator species analysis

The Dufrene and Legendre (1997) method of calculating indicator species value was used for indicator species analysis. The Indicator value (IndVal) combined a species's relative abundance (specificity) with its relative frequency of occurrence in a group of sites (fidelity) referred to as an "area". These two components were included because an indicator species that is defined as most characteristic of one area must be found mostly in this area and be present in the majority of the sites belonging to that area.

To take into account this duality, IndVal were calculated for each species j and for each area k according to the following formula (Dufrene and Legendre 1997).

$$\mathbf{IndVal}_{\text{Group k, Species j}} = \mathbf{100\times\ A_{kj} \times B_{kj}}$$

In that equation, A_{kj} is a measure of specificity and B_{kj} is a measure of fidelity.

According to the formula:

$$\mathbf{IndVal_j = max\ [\ IndVal_{kj}]}$$

$$\mathbf{A_{kj} = Nindividuals_{kj} / Nindividuals_{+k}}$$

$$\mathbf{B_{kj} = Nsites_{kj} / Nsites_{+k}}$$

In the formula for specificity (A_{kj}), $Nindividuals_{kj}$ is the mean abundance of species j across the sites pertaining to cluster k. $Nindividuals_{+k}$ is the sum of the mean abundances of species j within the various clusters. A_{kj} is maximum when species j is present in cluster k only.

B_{kj} is a measure of fidelity. In the formula for fidelity (B_{kj}), $Nsites_{kj}$ is the number of sites in cluster k where species j is present. N $sites_{+k}$ is the total number of sites in that cluster. B_{kj} is maximum when species j is present at all sites of cluster k.

The indicator value of species j for a partition of sites is the largest value of $IndVal_{kj}$ observed over all clusters k of that partition: $IndVal_j$ = max [$IndVal_{kj}$]. The significance of the indicator value of each species is assessed by a randomization procedure. A random permutation procedure of the sites among the site groups is used to test the significance of $IndVal_j$. The index can be computed for a given partition of the sites or for all levels of a hierarchical classification of the sites. I performed indicator species analysis in R software with the package ‘ labdsv’ (Robert 2015).

5. Statistical Analysis

The Kruskal-Wallis (non- parametric test) (Kruskal and Wallis 1952) was used to compare species richness, abundances and diversity of birds between different habitat types. Habitat variables (vegetation cover, vegetation density, vegetation height, plant species diversity and water depth) at five different habitat types were also compared by using the Kruskal-Wallis test. If significant, a post hoc test (Bonferroni, pairwise comparisons) was used for multiple comparisons in SPSS 21 software.

Canonical Correspondence Analysis (CCA) was performed to reveal the relationships between bird communities and their habitat variables by using R software (3.2.0) with vegan package. CCA is a multivariate method to elucidate the relationships between biological assemblages of species and their environments. The method is designed to extract synthetic environmental gradients from ecological data sets. The gradients are the basis for succinctly describing and visualizing the differential habitat preferences (niches) of taxa via an ordination diagram (Ter Braak 1986, Ter Braak and Verdonschot 1995, Blair 1996). A Monte Carlo permutation (999 repeats) was run to test the significance of the relationship between bird communities and their habitats. The 5 % level of significance ($p < 0.05$) was considered to be statistically significant.

IV. Results

1. Comparison of habitat variables among different habitats

During the vegetation survey in December, 2014, I collected 24 plant species of 17 families characterizing three habitat types: short grassland, tall grassland and lotus field. I detected 15 plant species in short grassland and the areas were densely covered by Water Snowflake *Nymphoides indium* (15.90%), Umbrella Canegrass *Leptochloa neesii* (14.16%), Grass *Saccolepis interrupta* (13.00%) and Wild Rice *Oryza minuta* (10.80 %) (Table 1). Totally, 11 plant species were found in tall grassland, three plant species, namely, Wild Rice *Oryza minuta* (34.94%) ,Umbrella Canegrass *Leptochloa neesii* (24.70%) and Torpedograss *Panicum repens* (4.96%) were dominant species in tall grassland (Table 2). Fifteen plant species were recorded in lotus field by using point quadrat method. The water surface was dominated by Indian Lotus *Nelumbo nucifera* (53.40%), Sea Purslane *Sesuvium portulacastrum* (7.60%) and Water Snowflake *Nymphoides indicum* (6.70%) in lotus field (Table 3).

Table1. Plant species and dominant cover percentage (DCP) detected in short grassland habitats at Moeyungyi Wetland, Myanmar

Rank	**Family Name**	**Common Name**	**Scientific Name**	**DCP**
1	Menyanthaceae	Water Snowflake	*Nymphoides indium*	15.90 %
2	Gramineae	Umbrella Canegrass	*Leptochloa neesii*	14.16 %
3	Poacece	Grass	*Sacciolepis interrupta*	13.00 %
4	Poaceae	Wild Rice	*Oryza minuta*	10.80 %
5	Nymphaeaceae	Blue lotus	*Nymphaea stellata*	5.94 %
6	Cyperaceae	Grass	*Eleocharis calva*	4.20 %
7	Araceae	Duckweed	*Lemna paucicostata*	3.34 %
8	Poaceae	Torpedograss	*Panicum repens*	3.20 %
9	Pontederiaceae	Water Hyacinth	*Eichhornia crassipes*	1.31 %
10	Araceae	Taro	*Colocasia esculenta*	0.80 %
11	Aizoaceae	Sea Purslane	*Sesuvium portulacastrum*	0.50 %
12	Fabaceae	Shrub	*Mimosa asperata*	0.40 %
13	Asteraceae	Water Cress	*Enhydra fluctuans*	0.36 %
14	Leguminosae	Sesbania Pea	*Sesbania cannabina*	0.20 %
15	Poaceae	Good fooder	*Hygroryza aristata*	0.20 %

Table 2. Plant species and dominant cover percentage (DCP) detected in tall grassland habitat at Moeyungyi Wetland**,** Myanmar

Rank	**Family Name**	**Common Name**	**Scientific Name**	**DCP**
1	Poaceae	Wild Rice	*Oryza minuta*	34.94 %
2	Gramineae	Umbrella Canegrass	*Leptochloa neesii*	24.70 %
3	Poaceae	Torpedograss	*Panicum repens*	4.96 %
4	Araceae	Taro	*Colocasia esculenta*	3.30 %
5	Poaceae	Grass	*Eulalia aurea*	2.12 %
6	Poacece	Grass	*Sacciolepis interrupta*	1.80 %
7	Poaceae	Cogon Grass	*Imperata cylindrica*	1.80 %
8	Convolvulaceae	Water Spinach	*Ipomoea aquatica*	1.74 %
9	Leguminosae	Sesbania Pea	*Sesbania cannabina*	1.60 %
10	Cyperaceae	Grass	*Eleocharis calva*	1.50 %
11	Thelypteridaceae	Marsh Fern	*Thelypteris palustris*	0.03%

Table 3. Plant species and dominant cover percentage (DCP) detected in lotus field habitat at Moeyungyi Wetland, Myanmar

Rank	Family Name	Common Name	Scientific Name	DCP
1	Nelumbonaceae	Indian Lotus	*Nelumbo nucifera*	53.40 %
2	Aizoaceae	Sea Purslane	*Sesuvium portulacastrum*	7.60 %
3	Memyanthaceae	Water Snowflake	*Nymphoides indicum*	6.70%
4	Pontederiaceae	Water Hyacinth	*Eichhornia crassipes*	3.00 %
5	Trapaceae	Water Chestnut	*Trapa bispinosa*	3.00 %
6	Poaceae	Torpedograss	*Panicum repens*	2.80 %
7	Poacece	Grass	*Sacciolepis interrupta*	2.30 %
8	Cyperaceae	Grass	*Eleocharis calva*	2.16 %
9	Araceae	Water grass	*Lemna paucicostata*	1.56 %
10	Poaceae	Wild Rice	*Oryza minuta*	1.00 %
11	Alismataceae	Yellow Sawah Lettuce	*Limnocharis flava*	0.60 %
12	Ploygonaceae	Knot Grass	*Polygonum barbatum*	0.56 %
13	Nymphaeaceae	Blue Lotus	*Nymphaea stellata*	0.50 %
14	Nymphaeaceae	Red Indian Lily	*Nymphaea rubra*	0.40 %
15	Poaceae	Water grass	*Hygroryza aristata*	0.10 %

The Kruskal-Wallis test highlighted that there was a significant difference in vegetation covers (H= 25.84, df=3, $p<0.001$) among different habitat types. The vegetation cover (percentage) of rice field was significantly higher than those in short grassland, tall grassland and lotus field ($p<0.001$), but no difference was detected in vegetation coverage (percentage) among the remaining three habitat types ($p>0.05$) (Figure 6).

Differences were detected in vegetation density among different habitat types (H=28.46, df=3, $p<0.001$). The vegetation density was lowest in lotus field, but highest in tall grassland showing a significant difference ($p<0.05$) (Figure 7).

The vegetation heights in different habitat types were also significantly different (H=33.02, df=3, $p<0.001$). The vegetation height of tall grassland was significantly higher than those of rice field, short grassland and lotus field, while the vegetation height in short grassland and lotus field were lowest ($p>0.05$) (Figure 8).

I also found that there was a statistically significant difference in plant species diversity (H=8.508, df=2, p=0.014) among different habitat types. The plant species diversity in lotus field was highest and was significantly higher than that of tall grassland ($p<0.05$) (Figure 9).

Statistically significant difference was found in water depth (H=42.26, df=4, $p<0.001$) among five different habitat types. The water depth of rice field is significantly lower than that of short grassland, tall grassland, lotus field and open water area, whereas those of lotus field and open water areas were deepest ($p>0.05$) (Figure 10).

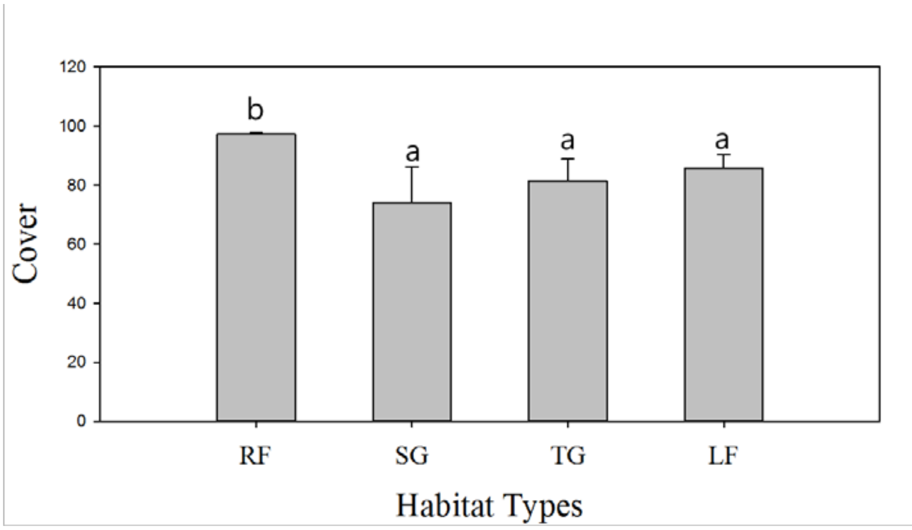

Figure 6. Result of post hoc test (Bonferroni) in vegetation cover (percentage) among different habitat types. (RF:rice field, SG:short grassland, TG:tall grassland, LF:lotus field)

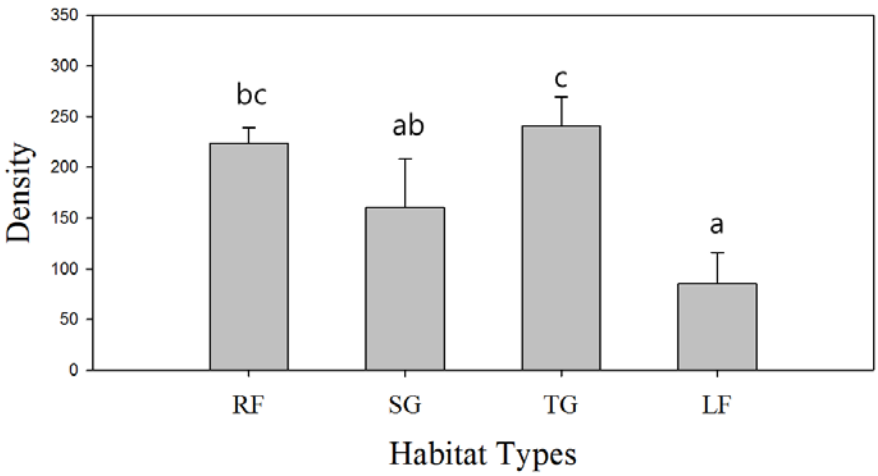

Figure 7. Result of post hoc test (Bonferroni) in vegetation density (number) among different habitat types (RF= rice field, SG= short grassland, TG= tall grassland, LF= lotus field)

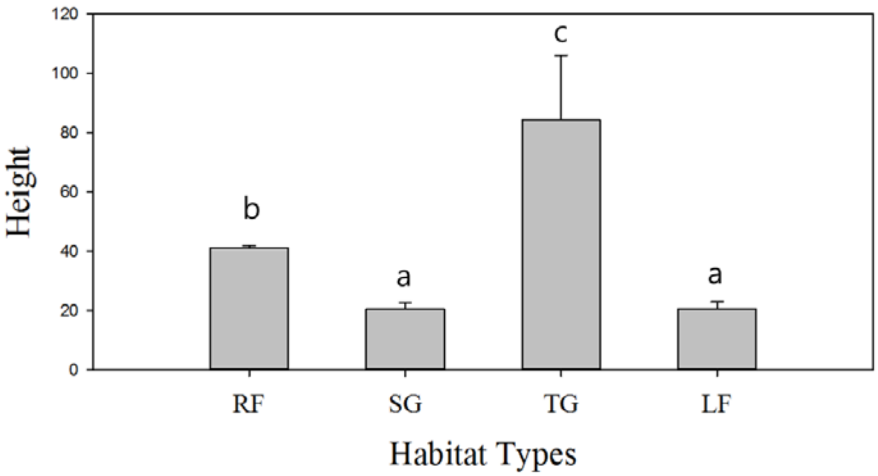

Figure 8. Result of post hoc test (Bonferroni) in vegetation height (cm) among different habitat types. (RF= rice field, SG= short grassland, TG= tall grassland, LF= lotus field)

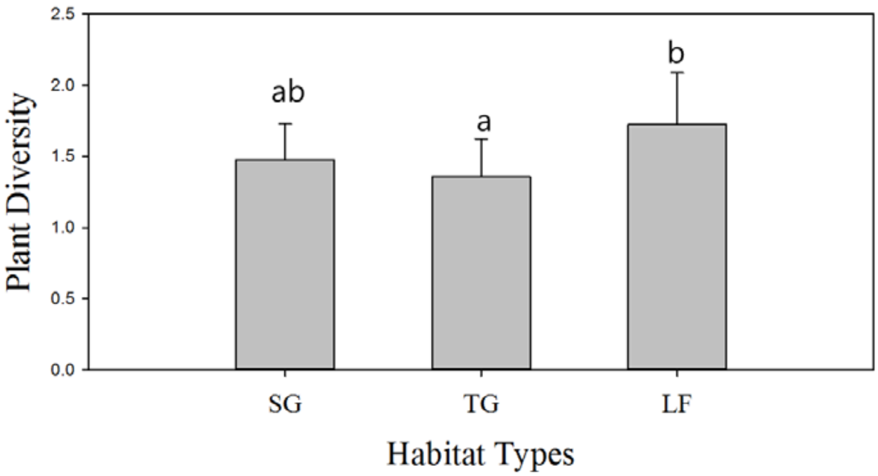

Figure 9. Result of post hoc test (Bonferroni) in plant species diversity (number) among different habitat types (SG:short grassland, TG:tall grassland, LF: lotus field)

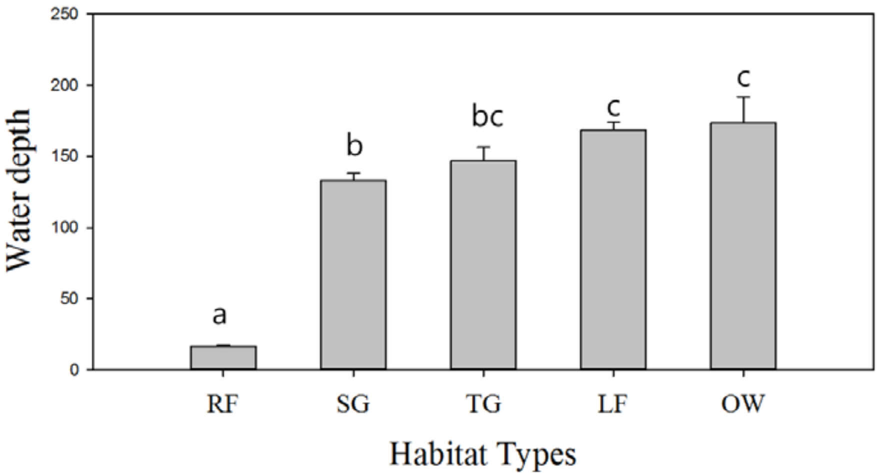

Figure 10. Result of post hoc test (Bonferroni) in water depth (cm) among different habitat types (RF:rice field, SG:short grassland, TG:tall grassland, LF: lotus field, OW:open water)

2. Comparison of species richness, abundances and diversity of birds among different habitats

A total of 11971 individuals comprised of 52 bird species were encountered during the survey. The globally threatened wetland bird species such as Black-headed Ibis (*Threskiornis melanocephalus*), Painted Stork (*Mycteria leucocephala*) and Oriental Darter (*Anhinga melanogaster*) were also found during this survey.

Rice fields hosted 13 different bird species and 1348 total individuals. Little Egret *Egretta garzetta* (68.10 %), Cattle Egret *Bubulcus ibis* (11.79 %), Intermediate Egret *Mesophoyx intermedia* (10.31 %) and Great Egret *Ardea alba* (4.23 %) were the most dominant species in rice field habitat (Table 4).

In short grassland, 30 different bird species belonging to 3229 total individuals were found. The most dominant species in short grassland habitat were Lesser Whistling-duck *Dendrocygna javanica* (20.38%), Little Egret *Egretta garzetta* (15.32%), Cattle Egret *Bubulcus ibis* (12.60%) and Cotton Pygmy-goose *Nettapus coromandelianus* (9.04%) (Table 5).

In tall grassland, 26 different bird species and 3535 total individuals were recorded. Purple Swamphen *Porphyrio porphyria* (31.34%), Cattle Egret *Bubulcus ibis* (12.70%), Asian Openbill *Anastomus oscitans* (12.24%) and Little Egret *Egretta garzetta* (11.20%) were the four most dominant species in tall grassland habitat (Table 6).

In lotus field, 33 different bird species and 1741 total individuals were observed. Lesser Whistling-duck *Dendrocygna javanica* (21.99%), Cotton Pygmy-goose *Nettapus coromandelianus* (18.03%), Pheasant-tailed Jacana *Hydrophasianus chirurgus* (9.65%), Barn Swallow *Hirundo rustica* (6.49) and Bronze-winged Jacana *Metopidius indicus* (5.11%) were the most dominant speices in lotus field habitat (Table 7).

In open water areas, 15 different bird species and 2118 total individuals were surveyed. Lesser Whistling-duck *Dendrocygna javanica* (34.37%), Northern Pintail *Anas acuta* (31.35%), Little Cormorant *Phalacrocorax niger* (10.62%) and Little Grebe *Tachybaptus ruficollis* (5.85%) were the most dominant species (Table 8).

Table 4. Bird species and relative abundance (%) recorded in rice field habitat at Moeyungyi Wetland, Myanmar from Dec 2014 to Feb 2015

Rank	Species Name	Scientific Name	No. of Observation	Relative Abundance
1	Little Egret	*Egretta garzetta*	918	68.10 %
2	Cattle Egret	*Bubulcus ibis*	159	11.79 %
3	Intermediate Egret	*Mesophoyx intermedia*	139	10.31%
4	Great Egret	*Ardea alba*	57	4.23%
5	Pacific Golden Plover	*Pluvialis fulva*	25	1.85%
6	Pin-tailed Snipe	*Gallinago stenura*	19	1.41%
7	Asian Openbill	*Anastomus oscitans*	16	1.19%
8	Green Sandpiper	*Tringa ochropus*	6	0.45%
9	Greater Sand Plover	*Charadrius leschenaultii*	4	0.30%
10	Common Snipe	*Gallinago gallinago*	2	0.14%
11	Northern Pintail	*Anas acuta*	1	0.07%
12	Little Cormorant	*Phalacrocorax niger*	1	0.07%
13	Marsh Sandpiper	*Tringa stagnat*	1	0.07%

Relative abundance (%) = (n/N)*100 (n= number of a particular species, N= total observations detected for all species)

Table 5. Bird species and relative abundance (%) recorded in short grassland habitat in Moeyungyi Wetland, Myanmar from Dec 2014 to Feb 2015

Rank	Species Name	Scientific Name	No. of Observation	Relative Abundance
1	Lesser Whistling-duck	*Dendrocygna javanica*	658	20.38 %
2	Little Egret	*Egretta garzetta*	495	15.32%
3	Cattle Egret	*Bubulcus ibis*	407	12.60 %
4	Cotton Pygmy-goose	*Nettapus coromandelianus*	292	9.04 %
5	Intermediate Egret	*Mesophoyx intermedia*	235	7.27%
6	Asian Openbill	*Anastomus oscitans*	197	6.10 %
7	IndianPond-heron	*Ardeola grayii*	109	3.37%
8	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	105	3.25 %
9	Barn Swallow	*Hirundo rustica*	95	2.94 %
10	Little Cormorant	*Phalacrocorax niger*	93	2.88 %
11	Little Grebe	*Tachybaptus ruficollis*	74	2.29 %
12	Glossy Ibis	*Plegadis falcinellus*	64	1.98%
13	Purple Heron	*Ardea purpurea*	64	1.98%
14	Great Egret	*Ardea alba*	63	1.95%
15	Black Drongo	*Dicrurus macrocercus*	51	1.58 %
16	Northern Pintail	*Anas acuta*	51	1.58 %
17	Purple Swamphen	*Porphyrio porphyrio*	28	0.88 %
18	Watercock	*Gallicrex cinerea*	27	0.84 %
19	Grey Heron	*Ardea cinerea*	23	0.71 %

Rank	Species Name	Scientific Name	No. of Observation	Relative Abundance
20	Oriental Darter	*Anhinga melanogaster*	21	0.65 %
21	Marsh Sandpiper	*Tringa stagnatilis*	20	0.62 %
22	Green Sandpiper	*Tringa ochropus*	11	0.34 %
23	Chinese Pond-heron	*Ardeola bacchus*	10	0.30 %
24	Pacific Golden- Plover	*Pluvialis fulva*	9	0.28%
25	Black-capped Kingfisher	*Halcyon pileata*	7	0.22%
26	Eurasian Coot	*Fulica atra*	6	0.19%
27	Common Snipe	*Gallinago gallinago*	5	0.15 %
28	Pin-tailed Snipe	*Gallinago stenura*	4	0.12 %
29	Green Bee- eater	*Merops orientalis*	3	0.09 %
30	Bronze winged Jacana	*Metopidius indicus*	2	0.06 %

Table 6. Bird species and relative abundance (%) recorded in tall grassland habitat at Moeyungyi Wetland, Myanmar from Dec 2014 to Feb 2015

No	Species Name	Scientific Name	No.of Observation	Relative Abundance
1	Purple Swamphen	*Porphyrio porphyrio*	1108	31.34 %
2	Cattle Egret	*Bubulcusibis*	449	12.70 %
3	Asian Openbill	*Anastomus oscitans*	433	12.24 %
4	Little Egret	*Egretta garzetta*	396	11.20 %
5	Purple Heron	*Ardea purpurea*	321	9.08%
6	Intermediate Egret	*Mesophoyx intermedia*	235	6.64 %
7	Black Drongo	*Dicrurus macrocercus*	210	5.94 %
8	Little Cormorant	*Phalacrocorax niger*	75	2.12%
9	Great Egret	*Ardea alba*	57	1.61 %
10	Grey Heron	*Ardea cinerea*	36	1.01 %
11	Indian Pond-heron	*Ardeola grayii*	36	1.01 %
12	Barn Swallow	*Hirundo rustica*	35	0.99 %
13	Siberian Stonechat	*Saxicola maurus*	21	0.59%
14	Hen Harrier	*Circus cyaneus*	17	0.48 %
15	Zitting Cisticola	*Cisticola juncidis*	16	0.45 %
16	Common Kingfisher	*Alcedo atthis*	15	0.42 %
17	Pied Harrier	*Circus melanoleucos*	14	0.39%

No	Species Name	Scientific Name	No.of Observation	Relative Abundance
18	Blacked-headed Ibis	*Threskiornis melanocephalus*	13	0.36 %
19	Eastern Marsh-harrier	*Circus spilonotus*	12	0.34%
20	Painted Stork	*Mycteria leucocephala*	6	0.16 %
21	Oriental Reed-warbler	*Acrocephalus orientalis*	6	0.16 %
22	Glossy Ibis	*Plegadis falcinellus*	6	0.16 %
23	Chinese Pond-heron	*Ardeola bacchus*	5	0.14 %
24	Oriental Darter	*Anhinga melanogaster*	5	0.14 %
25	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	5	0.14 %
26	Osprey	*Pandion haliaetus*	3	0.08%

Table **7**. Bird species and relative abundance (%) recorded in lotus field habitat at Moeyungyi Wetland, Myanmar from Dec 2014 to Feb 2015

Rank	**Species Name**	**Scientific Name**	**No. of Observation**	**Relative Abundance**
1	Lesser Whistling-duck	*Dendrocygna javanica*	383	21.99%
2	Cotton Pygmy-goose	*Nettapus coromandelianus*	314	18.03 %
3	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	168	9.65%
4	Barn Swallow	*Hirundo rustica*	113	6.49%
5	Garganey	*Anas querquedula*	89	5.11 %
6	Bronze-winged Jacana	*Metopidius indicus*	89	5.11 %
7	Little Grebe	*Tachybaptus ruficollis*	89	5.11%
8	Little Tern	*Sternula albifrons*	69	3.96%
9	Little Cormorant	*Phalacrocorax niger*	65	3.73 %
10	Indian Pond-heron	*Ardeola grayii*	55	3.15%
11	Black Drongo	*Dicrurus macrocercus*	50	2.87%
12	Little Egret	*Egretta garzetta*	33	1.90%
13	Purple Swamphen	*Porphyrio porphyrio*	32	1.83%
14	Cattle Egret	*Bubulcus ibis*	25	1.43%
15	Common Moorhen	*Gallinula chloropus*	19	1.09%
16	Watercock	*Gallicrex cinerea*	17	0.97%

Rank	Species Name	Scientific Name	No. of Observation	Relative Abundance
17	Oriental Reed-warbler	*Acrocephalus orientalis*	14	0.80%
18	Eurasian Coot	*Fulica atra*	14	0.80%
19	Purple Heron	*Ardea purpurea*	13	0.74 %
20	Asian Openbill	*Anastomus oscitans*	13	0.74%
21	Common Kingfisher	*Alcedo atthis*	12	0.68%
22	Pied Harrier	*Circus melanoleucos*	12	0.68%
23	Intermediate Egret	*Mesophoyx intermedia*	9	0.52%
24	White- winged Tern	*Chlidonias leucopterus*	8	0.45%
25	Eastern Marsh-harrier	*Circus spilonotus*	7	0.40%
26	Whiskered Tern	*Chlidonias hybrida*	6	0.34%
27	Zitting Cisticola	*Cisticola juncidis*	5	0.28%
28	Pacific Swallow	*Hirundo tahitica*	4	0.23%
29	Striated Swallow	*Cecropis striolata*	4	0.23%
30	Oriental Darter	*Anhinga melanogaster*	3	0.17%
31	Great Cormorant	*Phalacrocorax carbo*	3	0.17 %
32	Chinese Pond-heron	*Ardeola bacchus*	2	0.11%
33	Siberian Stonechat	*Saxicola maurus*	2	0.11%

Table 8. Bird species and relative abundance (%) recorded in open water habitat at Moeyungyi Wetland, Myanmar from Dec 2014 to Feb 2015

Rank	**Species Name**	**Scientific Name**	**No. of Observation**	**Relative Abundance**
1	Lesser Whistling-duck	*Dendrocygna javanica*	728	34.37%
2	Northern Pintail	*Anas acuta*	664	31.35%
3	Little Cormorant	*Phalacrocorax niger*	225	10.62%
4	Little Grebe	*Tachybaptus ruficollis*	124	5.85%
5	Little Tern	*Sternula albifrons*	81	3.82%
6	Ruddy Shelduck	*Tadorna ferruginea*	56	2.64%
7	Cotton Pygmy-goose	*Nettapus coromandelianus*	50	2.36%
8	Barn Swallow	*Hirundo rustica*	42	1.98%
9	White-winged Tern	*Chlidonias leucopterus*	38	1.79%
10	Eurasia Coot	*Fulica atra*	37	1.75%
11	Whiskered Tern	*Chlidonias hybrida*	34	1.60%
12	Brown -headed Gull	*Chroicocephalus brunnicephalus*	18	0.85%
13	Asian Palm-swift	*Cypsiurus balasiensis*	15	0.71%
14	Watercock	*Gallicrex cinerea*	4	0.18%
15	Oriental Darter	*Anhinga melanogaster*	2	0.09%

Avian species richness was different among five different habitat types (H= 65.12, df=4, p< 0.001). The avian species richness of rice field was lowest, showing significantly different from the highest richness in short grassland and lotus field (p<0.05) (Figure 11).

Bird abundances was significantly different among habitats (H= 37.13, df=4, p< 0.001). Bird abundances of rice field were the same with that of lotus field (p>0.05), but significantly lower than those of short grassland, tall grassland and open water area (p<0.05) (Figure 12).

The diversity of birds was also significantly different among five habitat types (H= 63.83, df=4, p<0.001). The avian species diversity of short and tall grasslands were significantly higher than the lowest diversity in rice field (p< 0.05), while the avian species diversity of tall grassland, lotus field and open water areas was in the same group (p>0.05) (Figure 13).

There was also a statistically significant difference in the avian evenness index among the five habitat types (H= 13.07, df=4, p= 0.011). The avian species evenness was highest in short grassland and lowest in open water areas, showing a clear difference (p<0.05) (Figure 14).

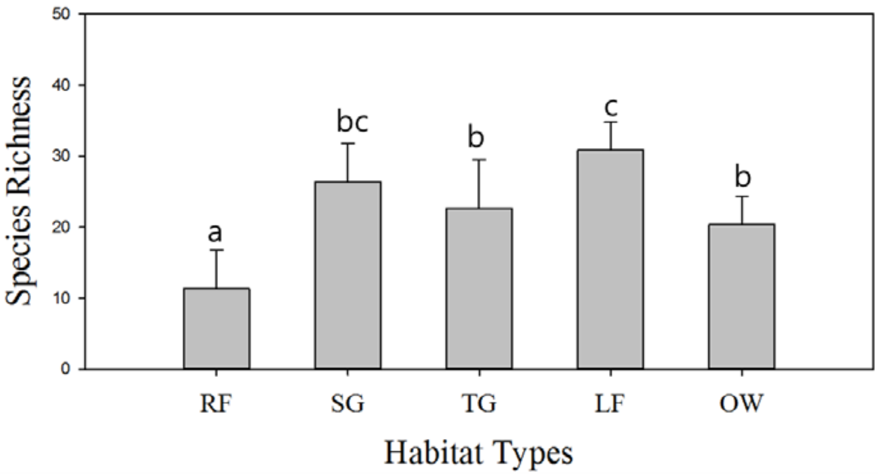

Figure 11**.** Result of post hoc test (Bonferroni) in avian species richness among different habitat types (RF: rice field, SG:short grassland, TG: tall grassland, LF: lotus field, OW: open water)

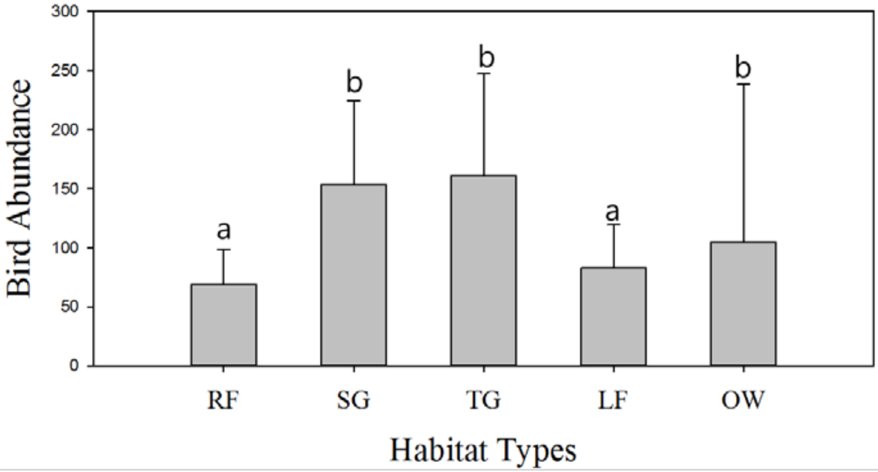

Figure 12**.** Result of post hoc test (Bonferroni) in avian species abundance among different habitat types (RF:rice field, SG:short grassland, TG:tall grassland, LF: lotus field, OW:open water)

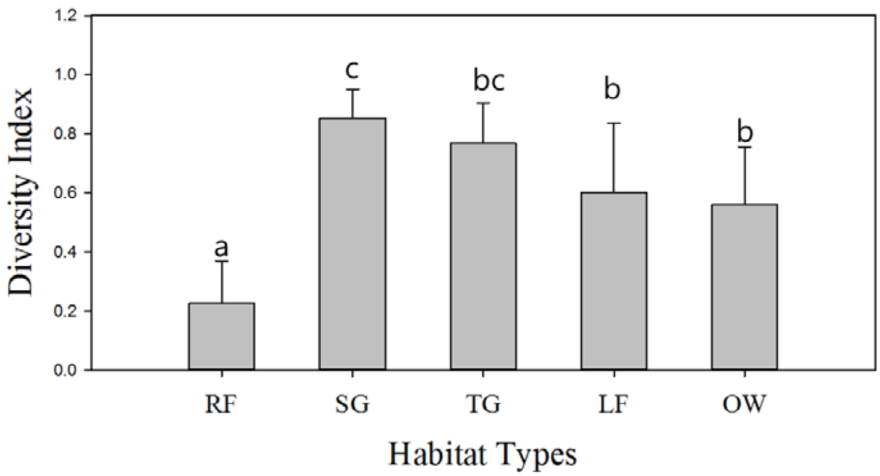

Figure 13**.** Result of post hoc test (Bonferroni) in avian species diversity among different habitat types (RF:rice field, SG:short grassland, TG:tall grassland, LF:lotus field, OW:open water)

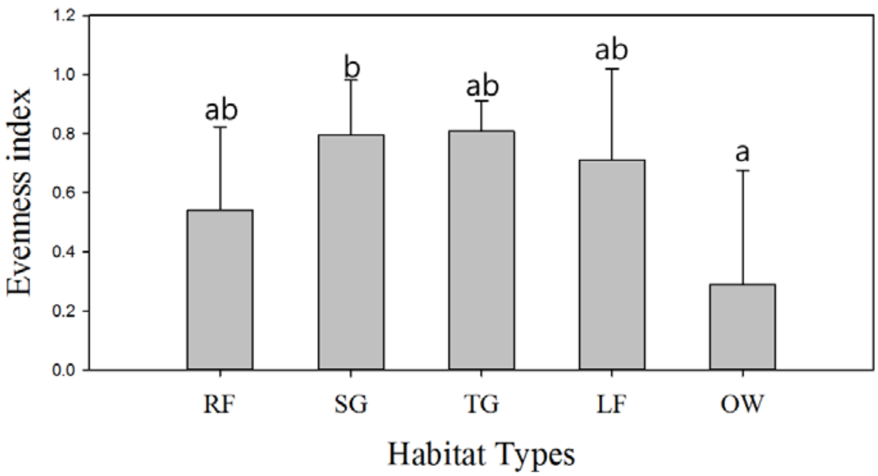

Figure 14**.** Result of post hoc test (Bonferroni) in avian species evenness among different habitat types (RF:rice field, SG:short grassland, TG:tall grassland, LF:lotus field, OW:open water)

3. Relationship between bird communities and habitat variables

Canonical Correspondence Analysis (CCA), a multivariate statistical technique, was used to interpret the relationship between bird communities and habitat variables (vegetation coverage, vegetation density, vegetation height, water depth and plant species diversity). The habitat variables were used as the predictor (independent variables) and bird communities were used as a response (dependent variables). At the 5% significance level for all statistical tests, there was a statistically significant correlation between bird communities and their habitat variables at the individual sampling points.

The result of CCA was shown in Table 9. For species-habitat relationship, 18.91% and 10.93% of the variation were explained by axis 1 (horizontal axis) and axis 2 (vertical axis). The first two axes showed canonical eigenvalues of 0.5702 and 0.3249 in comparison to the eigenvalues of 1.690 which was the sum of all unconstrained eigenvalues.

The CCA generates bird species, habitat variables and sample plots of different scales. Figure 15-16 demonstrate the results of this CCA analysis in two biplots: one of habitat variables arrows and sites (Figure 15) and one of habitat variables arrows and species (Figure 16). The arrows for habitat variables in Figure 15-16, together with the bird species' place, account for 43.03 % of the variance in the weighted averages of the bird species in connection with each of the habitat variables on the first axis and 24.86 % of the variance on the second axis.

Species-habitat variable correlations find out how well the extracted variation in community composition can be described by the habitat variables and how the variation is equal to the correlation between the site scores that are weighted average species and sites scores that are linear combinations of the habitat variables.

A Monte Carlo technique using 999 permutations found that the overall analysis and the two axes were significant (CCA; Axis I, $p<0.001$; Axis II, $p<0.001$). The most effective habitat variables for differentiating the sites and their bird communities were the amount of vegetation height, vegetation density, vegetation coverage and plant species diversity (Figure 15-16). They also indicate that the area covered by water depth is redundant measures.

Table 9. Correlation with canonical axes showing correlation coefficient with each CCA explanatory axis ($p<0.05$).

Habitat Variables	**CCA1**	**CCA2**	**CCA3**	**CCA4**	**CCA5**
Cover	0.728	-0.319	-0.600	-0.058	-0.056
Density	0.980	-0.068	-0.092	0.143	-0.077
Height	0.776	0.545	-0.229	-0.206	-0.085
Water depth	-0.689	0.596	-0.366	0.155	0.051
Plant diversity	0.162	0.039	-0.876	0.050	0.446
Eigenvalues	0.5702	0.3294	0.3076	0.0734	0.0445
% of variance	43.03 %	24.86%	23.22%	5.53%	3.35%

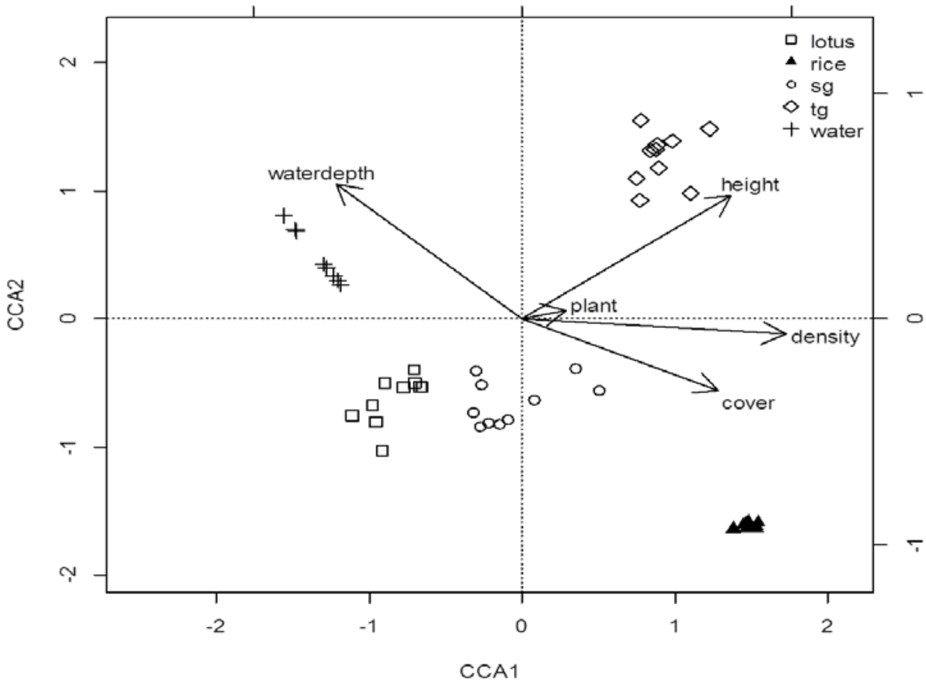

Figure 15. Ordination diagrams of canonical correspondence analysis. Sites as a linear combination of habitat measures. The abbreviation, lotus (lotus field habitat), rice (rice field habitat), sg (short grassland habitat), tg (tall grassland habitat), water (open water area) represents points within each site (n=10 for each site). Arrows represent the direction of highest change of habitat measures and are positioned toward the direction of the highest increase of the variable. The length of the arrow describes the significance of the habitat variable in the ideal, the direction of the arrow explains how well the habitat variable is correlated with the various axes, the angle between arrows points out the correlation between variables (a small angle says high correlation) and the situation of a site score corresponding to arrows shows the habitat characteristics of the site.

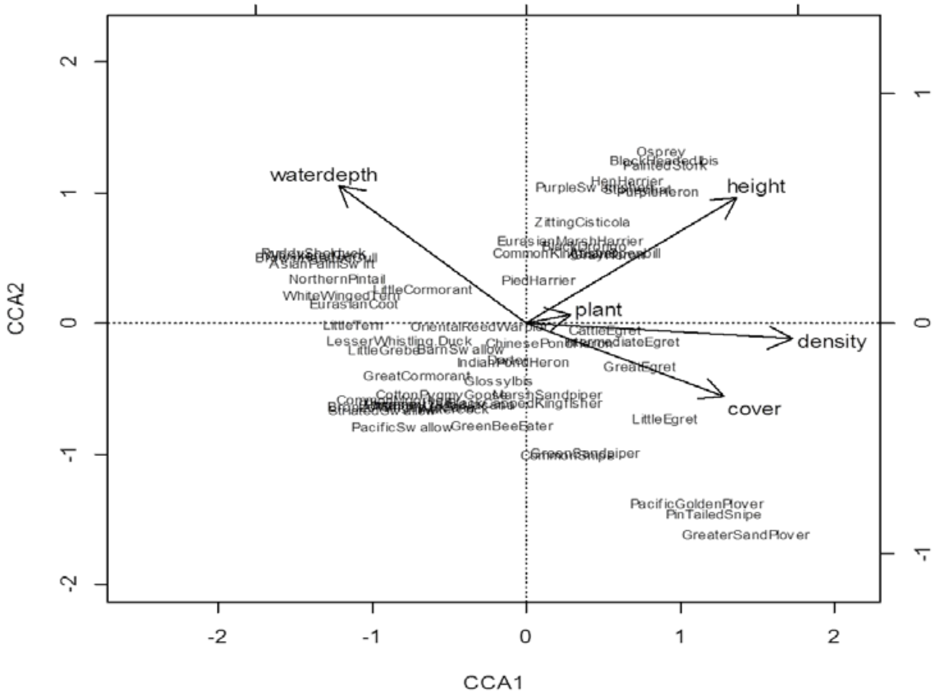

Figure 16**.** Canonical Correspondence Analysis ordination diagram with bird species and habitat variables measures (arrows). First axis is horizontal and second axis is vertical. Arrows indicate the direction of highest change of habitat variables measures. The location of a species score relative to arrows denote the habitat preferences of the species

4. Indicator species results

Among the 52 detected bird species during field survey, 35 species are recognized as indicator species (Table 10)**.** I found eight indicator species in short grassland, ten indicator species in tall grasslands, five indicator species in lotus field, eight indicator species in open water areas and four indicator species in rice field.

Indicator species of short grassland habitat were Marsh Sandpiper (*Tringa stagnatilis*), Oriental Darter (*Anhinga melanogaster*), Black-capped Kingfisher (*Halcyon pileata*), Indian Pond-heron (*Ardeola grayii*), Intermediate Egret (*Mesophoyx intermedia*), Glossy Ibis (*Plegadis falcinellus*), Chinese Pond-heron (*Ardeola bacchus*) and Green Sandpiper (*Tringa ochropus*).

Indicator species of tall grassland habitat were Purple Heron (*Ardea purpurea*), Purple Swamphen (*Porphyrio porphyrio*), Asian Openbill (*Anastomus oscitans*), Hen Harrier (*Circus cyaneus*), Blacked-headed Ibis (*Threskiornis melanocephalus*), Grey Heron (*Ardea cinerea*), Cattle Egret (*Bubulcus ibis*), Painted Stork (*Mycteria leucocephala*), Pied Harrier (*Circus melanoleucos*) and Common Kingfisher (*Alcedo atthis*).

Indicator species of lotus field habitat were Bronze-winged Jacana (*Metopidius indicus*), Garganey (*Anas querquedula*), Pheasant-tailed Jacana (*Hydrophasianus chirurgus*), Common Moorhen (*Gallinula chloropus*) and Cotton Pigmy-goose (*Nettapus coromandelianus*).

Indicator species in open water areas were Little Tern (*Sternula albifrons*), White-winged Tern (*Chlidonias leucopterus*), Ruddy Shelduck (*Tadorna ferruginea*), Brown-headed Gull (*Chroicocephalus brunnicephalus*), Eurasian Coot (*Fulica atra*), Little Cormorant (*Phalacrocorax niger*), Whiskered Tern (*Chlidonias hybrid*) and Little Grebe (*Tachybaptus ruficollis*).

Lastly, Pacific Golden Plover (*Pluvialis fulva*), Pin-tailed Snipe (*Gallinago stenura*), Little Egret (*Egretta garzetta*) and Great Egret (*Egretta alba*) were indicator species of rice field habitat.

Table 10. Indicator species in five habitat types of Moeyungyi Wetland in Myanmar (Dufrene and Legendre’s method)

Habitat Type	Species Name	Indval Value	p-value
Short Grassland	Marsh Sandpiper	0.663	0.001
	Oriental Darter	0.605	0.001
	Black-capped Kingfisher	0.600	0.011
	Indian Pond-heron	0.545	0.001
	Intermediate Egret	0.371	0.002
	Glossy Ibis	0.366	0.012
	Chinese Pond-heron	0.353	0.004
	Green Sandpiper	0.249	0.044
Tall Grassland	Purple Heron	0.801	0.001
	Purple Swamphen	0.744	0.001
	Asian Openbill	0.730	0.001
	Hen Harrier	0.641	0.002
	Black-headed Ibis	0.523	0.002
	Grey Heron	0.500	0.001
	Cattle Egret	0.426	0.014
	Painted Stork	0.419	0.007
	Pied Harrier	0.379	0.002
	Common Kingfisher	0.376	0.011

Habitat Type	Species Name	Indval Value	p-value
Lotus Field	Bronze-winged Jacana	0.978	0.001
	Garganey	0.900	0.001
	Pheasant-tailed Jacana	0.604	0.001
	Common Moorhen	0.600	0.001
	Cotton Pigmy-goose	0.475	0.003
Open Water	Little Tern	0.667	0.001
	White-winged Tern	0.566	0.001
	Ruddy Shelduck	0.561	0.001
	Brown-headed Gull	0.551	0.001
	Eurasian Coot	0.523	0.001
	Little Cormorant	0.522	0.001
	Whiskered Tern	0.479	0.005
	Little Grebe	0.407	0.008
Rice Field	Pacific Golden Plover	0.679	0.001
	Pin-tailed Snipe	0.672	0.001
	Little Egret	0.523	0.001
	Great Egret	0.343	0.024

V. Discussion

1. Species richness, abundances and diversity of bird among different habitats

The results of bird survey indicated that short grassland habitat had highest bird diversity, high bird species richness and high bird abundances. Tall grassland habitat hosted high bird diversity, high bird species richness and high bird abundances. High bird diversity, highest species richness and low bird abundance were found in lotus field. The open water areas showed high bird diversity, high species richness and abundances. On the other hand, rice field habitat showed the lowest bird diversity, lowest species richness and lowest bird abundances. Consequently, these results can be summarized into two major findings that the composition of bird communities was different among five habitats and, more importantly, that rice field may have lower indices for bird communities than any other habitat types in my study area. The latter suggests that natural marshes are more beneficial for maintaining of high species richness, abundances and diversity of birds than rice field habitat during wintering seasons in my study area.

This study supports multiple previous studies about rice fields as a worse habitat than natural marshes due to the disturbance. Especially in Asia and in some parts of Europe, the rice fields could not fully replace natural wetlands in the context of bird conservation and management, since the most bird species were strongly depended on natural marshes for foraging, roosting and nesting sites (Elphick 2000, Czech and Parsons 2002, Elphick and Oring 2003, Elphick 2004, Gopi Sundar 2006). The importance of grasslands have long been recognized for waterfowl (Gilmer et al. 1982) and shorebirds (Hunter et al. 1991; Shuford et al 1993, 1994). The presence of globally threatened avian species Black-headed Ibis (*Threskiornis melanocephalus*), Painted Stork (*Mycteria leucocephala*) and Oriental Darter (*Anhinga melanogaster*), in natural marshes, emphasize the significance marshy grassland habitat for the conservation of these threatened species and other waterbid communities

However, there are some exceptions, for instance, in Neotropic, and Mediterranean Europe, where the use of rice fields by waterbirds is higher than natural habitats in other regions as the natural wetlands of the Mediterranean regions have been reduced to some extent due to human populations and land use changes and rice field habitat can replace the loss of habitats for waterbirds (Falosa 1986, Falosa and Ruiz 1996, Blanco et al. 2006). Other studies also stated that rice fields may provide suitable habitat for waterbirds during wintering and migration (e.g. Treca 1994, Elphick and Oring 1998) and rice fields are also important foraging habitat for several bird species of Camargue, France (Tourenq et al. 2001).

At Moeyungyi wetland, rice fields were greatly used by only egrets, snipes and plovers. However, the numbers of observation were not too much. Generally, in terms of vegetation species, rice field supported only one dominant vegetation species of rice while grasslands and lotus fields supported more vegetation species. The least species richness, abundances and diversity of birds in rice fields may be due to the components of vegetation species in a rice field. The high species richness, abundances and diversity of birds in grasslands and lotus fields may be due to high vegetation species's components. Not only that, Wild Rice (*Oryza minuta*) bears many fruits in grassland habitats during the winter and it is one of the reasons that natural marshes can attract more birds during the winter. The Indian Lotus, *Nelumbium speciosum* grows in thick groups and these lotus fields are good habitats for some waterbirds such as Bronze-winged Jacana (*Metopidius indicus*), Pheasant-tailed Jacana (*Hydrophasianus chirurgus*) and so on. Species richness and abundances of some bird individuals were probably influenced by the aspects of vegetation species compositions, diversity, density and vegetation heights. Bryan and Best (1991) also mentioned this finding that the vegetation height and vegetation species composition are a major structural habitat, which is widely accepted to interpret the habitat selection of grassland birds.

The effects of human disturbances may encourage birds to move to other sites. Human activities disturb birds and individual bird species respond to human disturbances in some ways (Nisbet 2000, Pease et al 2005). Unfortunately, the early period of winter is busy season for farmers to plant and manage rice. Thus, higher disturbance and habitat change (ploughing) may influence on low number of birds at rice field habitats. Some researchers have mentioned that flooded rice fields are quite important habitats for waterbirds and can substitute for the losses of natural wetland habitats (Remsen et al.1991, Treca 1994, Tourenq et al. 2001). However, rice fields of my study site are irrigated seasonal rice fields and the water level is the lowest in rice fields when compared with other natural wetland areas (see water depth result).

Therefore, rice fields of my study site may not be good habitats for waterbirds in winter. The use of chemical fertilizers and pesticides in rice fields may also affect the habitat use of waterbird communities. Chemical fertilizers should be replaced with organic fertilizers to reduce side effects. However, rice fields are valuable as the control site of Moeyungyi Wetland. The water source of Moeyungyi Wetland depend on monsoon rain, so the wetland area is flooded in the rainy season and then, the water level is falling down in the dry season. When the water level is falling down, rice fields are more expanding into the wetland areas by the local people. Rice field areas should not be expanded more and more into the wetland areas to conserve the value of natural marshes of Moeyungyi Wetland and its bird communities.

2. Relationships between bird species and their habitat variables and indicator species

A significant correlation was found between bird species and habitat variables. CCA results (Figure 15-16) showed that the highest vegetation height, the most dense vegetation and the least plant species diversity were recorded in tall grasslands. The vegetation cover was the highest in rice field habitat, and the water depth was the deepest in open water areas. All habitat variables such as vegetation density, vegetation coverage, vegetation height, plant species diversity and water depth were associated with the occurrence of bird communities.

CCA results (Figure 16) show that the water depth is related to some diving birds such as cormorants, ducks, terns, etc. The water depth of open water areas is the deepest of all other habitats (see water depth result). So, I can suppose that diving birds prefer deep open water areas (Figure 15-16). The maintenance of open water areas with deep water depth is important for diving birds at the Moeyungyi Wetland.

The Moeyungyi wetland is flooded during the rainy season. Every year in February, water is withdrawn by the Irrigation Department through the sluice-gates to irrigate rice fields. The wetland area becomes progressively dry during the dry season. Every season, the effects of water level changes may negatively impact the waterbird populations that are present at the site during that time of the year. The proper water level should be maintained for the habitats of waterbirds. Therefore, water level management is urgently needed at Moeyungyi Wetland in all seasons.

The results of many studies also indicated that the water level is probably the major factor that influence habitat use of individual waterbirds species (Elphick and Oring 1998). Waterbirds that forage in the water without diving (except diving birds) depends on the length of theirs necks and leg in selecting the maximum water depth of feeding sites and usually feed in water depth deeper than 25 cm (Ntiamoa-Baidu et al. 1998, Colwell and Taft 2000, Hattori and Mae 2001; Traill and Brook 2011). In India, Black-necked Stork (*Ephippiorhynchus asiaticus*) avoided high water levels (> 60 cm) even though the patch had high prey density (Maheswaran and Rahmani 2001). In China, Siberian Cranes (*Grus leucogeranus*) move to other places when water levels are > 50 cm due to difficulties in accessing tubers and for Wattled Crane, water level > 35 cm would be difficult to wade and dig tubers (ICF 2012). Colwell and Oring 1988, Isola et al. 2000, Colwell and Taft 2000 also found that variation in the use of water depth at the foraging location increased with the size of species for example, small shorebirds use the water depth of (<5cm), large shorebirds use the water depth between (5-11 cm), teal use the water depth between (10-15 cm) and large dabbling ducks use the water depth of (>20 cm). Maintaining appropriate patterns of water fluctuations were essential for the management of wetlands and bird communities (Kushlan 1986).

CCA results in this study showed the habitat preferences of individual bird species (Figure 16). According to CCA results, different bird assemblages had distinct habitat preferences for habitats. Habitat suitability is one of the important factors affecting bird communities (Hattori and Mae 2001). The result of CCA was also concordant with indicator species results. For example, CCA results revealed that Little Cormorant, Little Grebe, Eurasian Coot, Little Tern, White-winged Tern, Ruddy Shelduck preferred deep water and non vegetated areas. The indicator species analysis also showed that these waterbird species are indicator species of open water areas.

In the same way, CCA results showed that waterbirds such as Asian Openbill, Purple Swamphen, Black-headed Ibis, Painted Stork, Hen Harrier prefer to tall grassland habitat with high vegetation height and much vegetation density. Indicator species results showed that these waterbird species are indicator species of tall grassland habitat. Therefore, the results of CCA was concordant with indicator species results. Relationships between vegetation height selection and bird species had been shown by other studies. Birds prefer to select lower vegetation height to allow more visual cues to discover prey items (Eiserer 1980, Berchard 1982). For instance, Shoebills and Wattled Cranes selected short sparse vegetation for foraging but tall and emergent macrophytes neighboring foraging sites could be important for roosting and nesting of both species (John et al. 2012).

CCA (Figure 15-16) results also confirmed that waterbird species such as Pacific Golden Plover, Pin-tailed Snipe and Greater Sand Plover prefer to use rice field habitat with very shallow water depth, thick vegetation cover, much vegetation density but with the shortest vegetation height. Indicator species results also confirmed that Pacific Golden Plover and Pin Tailed Snipe are indicator species of rice field. My CCA results showed the ecological preferences of these waterbird species.

Bryan and Best (1991) also mentioned that the vegetation height and vegetation species composition were a major structural habitat, which was widely used to explain habitat selection of grassland birds. These observations suggest that bird communities were significantly associated with plant species diversity, confirming the finding of Winternitz (1976) and James and Wamer (1982). However, the relationships differed at the spatial and temporal scales, which made interpretation to be difficult, but the variations were possibly due to seasonality in migrants and phenological events of plant species (Raman 2001).

The habitat use of waterbird species differs from one species to another species. Species richness and density of waterbirds that feed in water depended largely on the water depth but individual species usually had a preferred water depth for feeding (Colwell and Taft 2000). In the grassland of the USA, shallow wetlands with average depths of 10-20 cm support high waterbird richness because of the diverse feeding sites available, which vary from exposed mud to deeper water with submerged aquatic plants (Colwell and Taft 2000). For waterfowl and shorebirds, water depth at foraging sites varies with species morphologies; birds were limited by size to forage in habitats where food is available to them (Poysa 1983), for example, large-bodied, long-necked waterfowl forage in deeper water than small species (Poysa 1983). Among shorebirds, foraging depths were correlated with culmen and tarsus lengths (Baker 1979). No study on the foraging habitat selection of waterbird species as well as land birds found a Moeyungyi Wetland areas is available, therefore further studies are needed.

Since the study was only conducted during wintering period, therefore, seasonal and year-round survey are required. Long term studies and monitoring to understand the temporal and spatial dynamics of waterbird communities are required for effective management of wetlands and their bird communities.

VI. Conclusions and Management Implications

There was significant differences in the waterbird community structure and composition between five habitat types. Natural marshes held greater number and diversity of birds than the rice field. Therefore, natural marshes should be managed for the conservation of Moeyungyi Wetland Wildlife Sanctuary, according to its higher biodiversity and the conservation of threatened waterbird species. Rice field at Moeyungyi Wetland demonstrated lower ecological indices of the avian community. Currently, the encroachment of rice fields and increased grazing activities , such as duck farming and ranching of domestic water buffalos. The monitoring and management of these activities should be considered to maintain sufficient natural marsh area for healthy wetland ecosystem . Especially, three globally theatend species found during this study were all dependent on grass wetland habitat types. Thus, conservation and management of short grasslands and tall grasslands should be critical to conserve these endangered bird's habitat. From correlation analysis, we found that the vegetation height, cover and density, and weter depth, are important habitat characteristics for wintering waterbird community and these variables can be managed by anthropogenic influences greatly.

Indicator species found in this study can be a useful measure for the management of Moeyungyi Wetland, and even can be applied to broader geographic region including tropical South and Southeast Asia which holds similar wetland habitats and waterbird communities during winter.

During the winter, local people grow rice within and around wetlands. Rice fields around the wetland areas are useful as the control site of this areas. Rice fields of the Moeyungyi area are irrigated seasonal rice fields. Some farmers start growing rice in the middle or at the end of January. Rice fields are usually harvested during April and May. Growing rice within wetland areas is an encroachment by the local people. These are a cause of conflict between the Forest Department and the local people. Chemical fertilizers and pesticides are used in rice fields in order to improve the agricultural products. The livelihoods of local people heavily depend on the growing of rice and fishing activities. It might cause severe effects to our wetland ecosystem.

There are additional anthropogenic effects on wetland habitats at Moeyungyi. Reed plants are used as fuel by local people. The effects of grazing by domestic ducks and buffaloes at Moeyungyi Wetland have not studied yet.

The previous study in other countries showed that most waterbird species use rice fields as breeding sites rather than foraging sites. My study was conducted only during the winter season (but not the whole winter season) and could not reflect all farming practices and seasonal changes at the rice fields as well as at the natural marshes. Further surveys are needed in Moeyungyi areas seasonally to understand the habitat condition changes for bird communities.

Moreover, further studies would be needed to understand the influence of using rice fields by bird communities at different stages of rice cultivation (for example the earlier stage of growing rice, middle stage or green and mature stage of rice and post-harvest stage). Research is needed for detailed analysis of food resources for bird communities.

In the same way, grassland habitats would also need to be included when conducting surveys at the same time with rice cultivated stages in order to get more information on bird diversity and species richness among different habitats. We can use this information to help wildlife managers and agriculturalists to understand the importance of habitat types for the effective management of bird conservation in the Moeyungyi area. Wildlife managers need to know when and how to implement habitat manipulation such as water level manipulation, plant species diversity, vegetation coverages, vegetation density and vegetation height.

So long as these wetlands and their environments are kept in good condition, the birds will repeatedly visit and spend a comfortable time in Myanmar. Long term studies and monitoring are needed to understand the temporal and spatial dynamics of water bird communities. This will be very helpful in the design and implementation of effective management of wetlands and their bird communities. This information can then be used to draw management planning for future actions.

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Abstract in Korean

조류 서식지의 보전과 관리에 있어 서식지 유형에 따른 조류 군집의 특성에 대한 이해는 필수적으로 선행되어야 한다. 특히 다양한 서식지로 이뤄진 열대 동남아시아 지역의 습지는 중앙아시아, 동아시아 철새 이동경로내의 월동지로서, 물새 보전에 있어 매우 중요한 지역이다. 그러나 아직까지 열대 동남아시아 지역에서 서식지와 물새 군집의 관계에 대한 연구는 거의 이뤄지지 않은 상황이다. 본 연구는 미얀마의 모엔지 습지에서 서식지 유형별 조류군집의 특성을 비교하고, 각 서식지의 환경적 특징과 조류 군집 구조간의 관계를 파악하며, 지표종 분석(indicator anlaysis)을 통하여 각 서식지를 대표하는 지표종을 선정하는 것을 목적으로 하였다. 2014년 1월에서 2015년 2월 까지 서식지 유형별 월동기 조류 군집 특성과 와 환경 요인 조사를 실시하였다. 이를 위해 모엔지 습지를 대표하는 5개 서식지 유형(짧은 초습지 (short grassland), 키가 큰 초습지(tall grassland), 연밭(lotus field), 개방수역(open water area), 논(rice field)) 에서 각각 조사구를 선정하였다. 각 49개의 조사구에서 7분씩 6번의 정점 조사를 실시한 결과, 국제적 멸종위기종인 Black-headed Ibis (*Threskiornis melanocephalus*), Painted Stork (*Mycteria leucocephala*), Oriental Dater (*Anhinga melanogaster*)를 포함하여, 총 52종 11971개체가 확인되었다. 서식지 간 조류군집지표(종풍부도(species richness), 수도(species abundance), 종다양도(species diversity))를 비교한 결과, 논의 종풍부도, 수도, 종다양도 모두 다른 자연습지에 비해 매우 낮은 것으로 나타났다. 이는 본 연구의 조사 시기가 논 농사가 시작하는 시기라는 점에서 자연습지에 비해 논에서 사람에 의한 교란이 높았기 때문으로 예상되며, 이 외에 다른 서식지에 비해 낮은 식생다양도와 수위 등의 환경요인도 영향을 미쳤을 것으로 판단된다. 환경 요인과 종간의 관계를

파악하기 위해 정준상관분석(Canonical correspondence analysis)을 실시한 결과, 식생면적, 밀도, 높이 및 수위가 중요한 환경 요인으로 나타났으며, Marsh Sandpiper (*Tringa stagna*)와 Oriental Dater는 짧은 초습지, Puple Herons (*Ardea purpurea*)과 Puple Swamphen (*Ardea purpurea*)은 키가 큰 초습지, Bronze-winged Jacana (*Metopidius indicus*)와 Garganey (*Anas querquedula*) 는 연밭을 선호하는 것으로 나타났다. Little Tern (*Sternula albifrons*)과 White-winged Tern (*Chlidonias leucopterus*) 과 같은 잠수성 조류의 경우 식생이 없고 수심이 깊은 개방수역을 선호하는 것으로 나타났으며, Pacific Golden Plover(*Pluvialis fulva*)과 Pintail snipe (*Gallinago stenura*)는 수위가 낮고 식생 면적과 밀도가 높은 논을 선호하는 것으로 나타났다. 지표종 분석결과 5개의 서식지 유형에 대해 총 35종이 지표종으로 선정되었으며, 정준상관분석결과 또한 각 지표종과 서식지유형과의 관계를 지지하였다. 종합적으로, 모엔지 습지에서 월동하는 조류군집은 각 서식지 별로 다른 구조를 가지며, 특히 자연 습지가 조류군집에게 더 중요한 역할을 하는 것으로 판단된다. 따라서 향후 모엔지 습지에서 월동하는 조류군집의 보전을 위해서는 자연 습지의 보호와 관리가 매우 중요하며, 특히 멸종위기종인 Black-headed Ibis, Painted Stork, Oriental Dater가 지표종으로 선정된 짧은 초습지와 키가 큰 초습지에 대한 보전 및 관리가 중요하다고 생각된다. 향후 본 연구를 통해 선정된 지표종은 모엔지 습지의 서식지 관리에서 유용한 지표로 사용될 수 있으며, 더 나아가 본 연구 대상지와 유사한 습지 환경이 나타나는 남아시아 및 동남아시아 열대지역에서의 월동기 물새 서식지 관리에 확대 적용할 수 있을 것으로 판단된다.

주요어: 논, 물새 군집, 열대 동남아시아, 지표종분석, 자연 습지,

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