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Identifying Farm Pond Habitat Suitability for the Common Moorhen (*Gallinula chloropus*): A Conservation-Perspective Approach

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Abstract: The purpose of this study was to establish a habitat-suitability assessment model for *Gallinula chloropus*, or the Common Moorhen, to be applied to the selection of the most suitable farm pond for habitat conservation in Chiayi County, Taiwan. First, the fuzzy Delphi method was employed to evaluate habitat selection factors and calculate the weights of these factors. The results showed that the eight crucial factors, by importance, in descending order, were (1) area ratio of farmlands within 200 m of the farm pond; (2) pond area; (3) pond perimeter; (4) aquatic plant coverage of the pond surface; (5) drought period; (6) coverage of high and low shrubs around the pond bank; (7) bank type; and (8) water-surface-to-bank distance. Subsequently, field evaluations of 75 farm ponds in Chiayi County were performed. The results indicated that 15 farm ponds had highly-suitable habitats and were inhabited by unusually high numbers of Common Moorhens; these habitats were most in need of conservation. A total of two farm ponds were found to require habitat-environment improvements, and Common Moorhens with typical reproductive capacity could be appropriately introduced into 22 farm ponds to restore the ecosystem of the species. Additionally, the habitat suitability and number of Common Moorhens in 36 farm ponds were lower than average; these ponds could be used for agricultural irrigation, detention basins, or for recreational use by community residents. Finally, the total habitat suitability scores and occurrence of Common Moorhens in each farm pond were used to verify the accuracy of the habitat-suitability assessment model for the Common Moorhen. The overall accuracy was 0.8, and the Kappa value was 0.60, which indicates that the model established in this study exhibited high credibility. To sum up, this is an applicable framework not only to assess the habitat suitability of farm ponds for Common Moorhens, but also to determine whether a particular location may require the implementation of conservation practices. Furthermore, the findings in this research can provide useful information to all relevant stakeholders involved in the implementation of wildlife-habitat conservation and restoration at farm ponds.

Keywords: fuzzy Delphi method; Kappa; matrix analysis; Taiwan; conservation practice

1. Introduction

Taiwan is located in a subtropical region and features an island climate and large topographic differences. Topographic restrictions and short, fast rivers in combination with large differences in annual rainfall have resulted in considerable limitations regarding the river water sources available for agricultural irrigation. Thus, farm ponds are conserved as key sources of irrigation water. When Taiwan was under Qing rule (1874), large-scale construction of irrigation ditches and ponds was performed in the southwest region of Taiwan, resulting in a total of 219 farm ponds. When Taiwan was under Japanese rule, water resource construction was carried out actively. For example, the Chianan irrigation system and Wushantou Dam were completed in 1920, connecting the irrigation ditches and pond facilities across the entire Chianan Plain. After the Taiwan Retrocession, the country actively engaged in irrigation construction for farmlands. By 1995, the number of farm ponds in Southwestern Taiwan had reached 10,518 [1,2]. However, as industrial and urban development in Taiwan has reduced the demand for agriculture, the importance of farm ponds for irrigation use has decreased drastically [3–5]. As a result, the common occurrence of domestic wastewater discharge and waste disposal into farm ponds, as well as the filling of farm ponds, has led to excessive algae growth, eutrophication of water quality, and reduction of aquatic animals and plants, resulting in damage to biological habitats [6].

Numerous articles in the literature have indicated that the wetland environments of farm ponds are key habitats for organisms, such as plants, insects, fish, amphibians, reptiles, birds, and mammals, and can form complete ecosystems [2,7–11]. In an ecosystem, birds are higher vertebrates, and often play tertiary roles in the ecological pyramid. They provide functions for promoting the flow of energy and nutrient recycling of species and maintaining ecological balance between primary producers and consumers [12–17]. However, birds are quite sensitive in regard to habitat selection to environmental conditions. Thus, when the habitat is damaged or altered, the birds' clustering characteristics will change correspondingly [14,18,19]. Since birds are numerous, and easy to observe, record, and quantify, it is useful and more accessible to study the functioning and structure of wildlife species in terms of ecological theory and habitat conservation practices [17,20–23]. Also, several previous studies [10,19,24] have chosen water birds as indicators to investigate the characteristics and planning of biological environments around artificial/semi-artificial ponds. In a survey of 106 farm ponds conducted by the Chiayi County Government [25], a total of 17 species of birds were recorded, indicating that the farm pond is a crucial habitat for water bird species. Among them, *Gallinula chloropus* (Common Moorhen) is considered as one of the indicator species for researching the ecosystems of farm ponds [26].

G. chloropus is of the genus Gallinula and the family Rallidae [27]. In Taiwan, the species is a resident or common bird and generally resides in the fresh water of low plain areas. The habitat selection of birds is primarily affected by landscape composition, landscape structure, habitat heterogeneity, food resources, nesting sites, safety, climate, and mortality rate [27–30]. Most waterfowl forage in environments such as paddy fields, grasslands, agricultural lands, silvergrass fields, river mouth wetlands, and stream waters. Birds are more demanding in their selection of habitats during the breeding season; for instance, birds consider whether a potential habitat contains suitable nesting sites that might help them to evade natural enemies. During periods outside of the breeding season, however, food resources are the primary consideration; for example, birds might nest in an area that can provide abundant food resources. Water birds in the family Rallidae generally prefer to nest and roost in low bushes around water environments, whereas for foraging, they favor the areas surrounding waters or paddy field environments, bamboo groves, and thickets. Because of safety considerations during the breeding season, they will choose breeding sites in the bushes surrounding water environments and select water weeds as a nesting material [31–39]. Therefore, in addition to the use of the water in the farm pond itself for foraging, nesting, and breeding of birds, the vegetation cover around the bank is also a source of food and a hiding place for birds [31,33,40]. Several scholars have also indicated that both the diversity and the coverage of vegetation in the areas surrounding farm ponds affect the ecology of birds. A high degree of vegetation coverage indicates a high degree of shelter around the farm pond, which can provide birds with a habitat that is secure from outside interference [7,10,17,41].

A farm pond is a semi-natural habitat in a farmland landscape and provides a space for organisms to live, forage, and reproduce in [26,42]. A farm pond is also a habitat for birds. Thus, the creation of a farm pond environment that is suitable for habitation by birds is crucial for enhancing the eco-efficiency of the environment surrounding the farm pond [4,26,42–46]. In Taiwan, the function of farm ponds has gradually changed from agricultural irrigation to ecological conservation, through their role as habitats for birds (particularly the Common Moorhen) in agricultural landscapes. The purpose of this study was to establish a habitat-suitability assessment model for the Common Moorhen, which was applied to the assessment of farm ponds in Chiayi County to evaluate the suitability of farm ponds for habitat conservation. First, a literature review was performed to compile factors related to the use of farm ponds as habitats for the Common Moorhen. Second, the fuzzy Delphi method was employed to screen crucial relevant factors and calculate the weight coefficient of each factor. Third, a field survey of farm ponds and a field evaluation of each factor was used to calculate the habitat suitability of each farm pond. A survey of occurrences of the Common Moorhen were performed. Subsequently, the Kappa statistic was used to measure the proportion of agreement between the predictive high habitat suitability and the focal species present. Finally, a comparison matrix analysis was applied to classify farm ponds into four groups based on the occurrence count of Common Moorhens and the habitat suitability scores for each pond. The results of this research provide specific information about habitat conditions for the study area, which can be used to propose recommendations for proper conservation or management strategies for farm ponds.

2. Material and Methods

2.1. Study Area

The terrain on the west side of Chiayi County is flat and serves as a crucial area for rice production. However, because uneven monthly rainfall and distinct dry and wet seasons are not conducive to rice cultivation, farm ponds are used as water storage facilities [1,2,5]. From 1995 to 2007, approximately 30% of farm ponds in Chiayi County disappeared (i.e., a decrease from 1535 to 978). The main cause of this was a shift in land-use purpose to residential areas, construction sites, or fish farm ponds. A key concern in the study area is the protection of farm ponds as they are an important wildlife habitat in functioning agricultural systems. However, there are 978 remaining farm ponds in Chiayi County. Substantial amounts of time and money would be required to survey all of them. *Gallinula chloropus* likes various areas with water and aquatic plants, such as reed thickets and shrubs near bodies of water, such as lakes, ponds, swamps, paddy fields, riversides, and river mouths [31,32]. For this reason, we restricted our study to 180 farm ponds that are located in farmlands with a nearby irrigation network (e.g., river or other ponds) using 1:5000 aerial images. Then, we requested assistance from local stakeholders. Ponds identified as dry by local authorities were excluded from further analyses. A total of 75 farm ponds were selected, and their spatial distribution is shown as Figure 1.

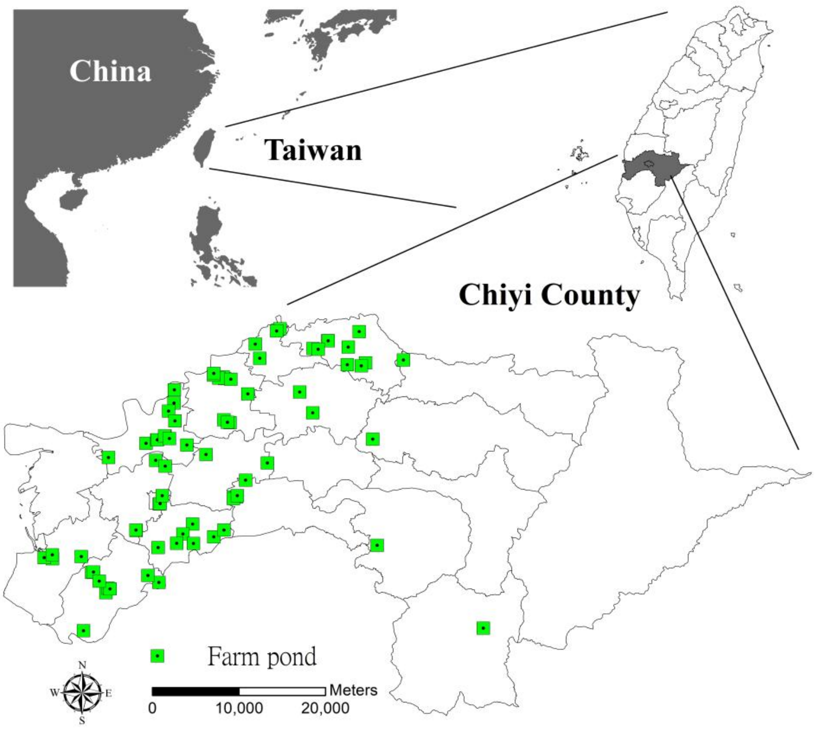


Figure 1. Locations of the 75 farm ponds that were selected to identify habitat suitability for common moorhen (*Gallinula chloropus*).

2.2. Fuzzy Delphi Analysis

Originally, the Delphi method was developed as a systematic, interactive forecasting, and organized communication technique which relied on a group of experts [4,5]. Later, an improved and more elaborated version, the fuzzy Delphi method, was developed. In this method, triangulation statistics are used to measure the distances between consensus levels within the expert group. Several previous studies have demonstrated how the fuzzy Delphi method can produce better results for real-life usage. For example, Ishikawa et al. [44] applied the dual triangular fuzzy number when carrying out a fuzzy integration of expert opinions and obtained more accurate results. Also, Jeng showed how the performance of the traditional fuzzy Delphi method could be improved noticeably [45]. The algorithm of the fuzzy Delphi method was modified by using double triangular fuzzy numbers to integrate expert judgments and then testing for consistency among the judgments using the gray zone test more effectively—in particular, avoiding the need to ask experts repeatedly [46].

We introduced the systematic approach with six steps, proposed by Chou et al. and Juang et al., to test experts' consensus [4,5]. An expert questionnaire was used to interview the experts. Experts with backgrounds involving birds, habitat conservation, biodiversity, and wetlands were invited. Each expert had at least 10 years of research experience and had published related research papers or had executed research projects in related fields. In addition, the experts possessed a favorable understanding of the ecology of the Common Moorhen and the status of farm ponds in Chiayi County. The expert survey was conducted from 1 May to 15 June 2015. The survey sheet detailed the purpose of the interview and gave the evaluation criteria. In order to gain more accurate answers, we called all experts, restated our research objectives, and addressed the contents of our evaluating framework by phone. Then, we collected their opinions via a survey instrument. A total of 15 experts completed the survey. All expert surveys were valid.

The survey sheet had two major sections. It began with a description of the hierarchical evaluation framework, which was applied to estimate the habitat suitability of farm ponds for Common Moorhens in Chiayi County, as well as the contents of all the indicators. Experts could suggest that the authors delete unimportant or redundant indicators to avoid interactions of factors. The second part was the questions section, which was designed for the experts to rank the importance levels of the indicators. The values of the Likert scale ranged from 0 to 10, with 0 representing the least important indicator and 10 indicating the most important indicator.

When the panel of experts formed a consensus and the indicators reached convergence, the triangular fuzzy number was greater than 0 [4,5]. When the experts' opinions were consistent, and the evaluation criteria achieved convergence in the fuzzy Delphi relationship, there was no standard threshold. The reason for this is that the threshold is generally determined by research objectives and subjective opinions [4,5]. For instance, more factors could be kept with lower threshold limits while additional factors could be deleted at higher thresholds. The threshold is the mean of all cognition values for first-layer and second-layer criteria [4,5,47], which was 6.934 in this study. Hence, any indicator with a cognition value less than 6.934 was deleted. Three second-layer indicators—area ratio of road area within 200 m of the farm pond, building coverage within 200 m of the farm pond, and water depth—were eliminated. After applying the fuzzy Delphi analysis to the screen criteria, two categories—external environments and internal environments—were defined as the first-layer criteria, while the second-layer criteria had seven remaining indicators (Table 1).

2.3. Environment Investigation of Pond Habitats

The results of the fuzzy Delphi analysis (Table 1) showed that there were eight factors to consider regarding the habitat suitability of the Common Moorhen: (1) area ratio of farmland area within 200 m; (2) pond area; (3) pond perimeter; (4) bank type; (5) shrub coverage of the pond bank; (6) aquatic plant coverage; (7) drought period; and (8) water-surface-to-bank distance. Based on the evaluation factors, this study conducted field surveys in 75 farm ponds in Chiayi County. The survey area of the surrounding environment of the farm ponds was based on the maximum activity range of the Common Moorhen of 200 m [32]. Land cover/land use (LCLU) maps were drawn using aerial photographs of land utilization; these status maps were used to calculate area and perimeter of each pond, as well as the area ratio of farmland area within a 200 m radius of each farm pond. A field survey was performed to categorize pond banks as earth ramp, grass strip, pebble work revetment, rubble (masonry) revetment, rubble (row) revetment, hollow block revetment, hexagonal porous brick revetment, gritstone slope, or reinforced concrete. To identify the drought period that affected each farm pond, a field survey of water volume across all four seasons was conducted; each pond was categorized as having year-round water, drought for 1–3 months, or drought for longer than 3 months. After the bank shrub coverage had been photographed with a camera, the ratio of plant coverage on the bank was calculated. Where all sides of a farm pond were fully overgrown with plants, that pond had coverage of 100%; where a pond had no plant growth on its bank, that pond had coverage of 0%. To determine the proportion aquatic plant coverage of farm ponds, we first delineated the area and distribution of floating plants from aerial photographs when performing field work. Then, we took panoramic photos from a human height perspective (i.e., 150 cm). Afterwards, we determined the proportions of aquatic plant coverage on the farm ponds based on collected information from the field investigations. Coverage was 100% when the bank was fully overgrown with plants, and coverage was 0% when the bank had no plants. The distance from the water surface to the bank was measured using measuring tape on-site at the farm ponds.

2.4. Population Census of Common Moorhen

Hsu (2001) proposed five methods for conducting a bird census: point count (also known as the circle method), transect count, counting flocks, time-species count, and area search [48]. Of these methods, the highest number of bird species can be observed using the transect count method, and thus, it is frequently applied to bird surveys [49]. During the survey of each farm pond, a circular survey area was defined, with a 100 m radius, and the farm pond was used as the center of that circular survey area [48]. Therefore, this study used the transect count method to conduct a survey by walking slowly along the perimeter of each farm pond. The number of birds witnessed or heard within the circular survey area was recorded. A total of four seasons were surveyed in 2014: 16–25 January was the winter survey period, 28 March–6 April was the spring survey period, 30 June–1 August was the summer survey period, and 31 October–14 December was the autumn survey period. Visual encounter surveys were conducted from 6:00 a.m. to 9:30 a.m. using Nikon binoculars, with each farm pond surveyed for 30–60 min.

2.5. Habitat Suitability Assessment and Statistical Analysis

In this study, we performed field investigations on 75 farm ponds and collected data for all indicators, in accordance with the evaluating framework of habitat suitability for the Common Moorhen. Specifically, the first-layer criteria were the external and internal environments of the farm ponds. Seven specific indicators (i.e., second-layer criteria) were ranked on five Likert scales, while the drought period was divided into three levels (Table 2). Scores were assigned based on the field investigation of farm ponds, with a higher score representing more preferable habitats for Common Moorhen. The actual suitability value of a farm pond was derived by summing up all weighted scores for each evaluation indicator. By comparing the final scores with each other, we defined which farm pond had the most suitable condition for our focal species.

Moreover, the Kappa statistic was used to measure the proportion of agreement between the predictive high habitat suitability and the focal species present, to determine the proportion of the ponds where Common Moorhens were observed (p_0) and the proportion presenting high habitat suitability for the Common Moorhen (p_e). The Kappa statistics were calculated with the following equation [5,32]:

$$\mathrm{k} = \frac{p_0 - p_e}{1 - p_e} = \frac{\sum_{i=1}^{c} p_{ii} - \sum_{i=1}^{c} p_{iT} p_{Ti}}{1 - \sum_{i=1}^{c} p_{iT} p_{Ti}}, \quad (1)$$

where $p_0 - p_e$ is the difference between the proportion of the pond where Common Moorhens were observed and that with high habitat suitability for Common Moorhens, while $1 - p_e$ is interpreted as the maximum possible correct number beyond that expected from the habitat suitability assessment for the Common Moorhen; c is the number of categories; p_{iT} shows the proportion of ponds in category i with observed Common Moorhens, taken from the marginal total of the last column of the contingency matrix; p_{Ti} shows the proportion of ponds in category i for the high habitat suitability for Common Moorhen, taken from the marginal totals of the last row of the contingency matrix and p_{ii} shows the proportion of ponds in the same category, i, for both the presence of Common Moorhen and high habitat suitability for Common Moorhen, taken from the diagonal elements of the contingency matrix [5].

3. Results

3.1. Population Census and Seasonal Variations of Common Moorhen in Farm Ponds

Surveys were conducted on 75 farm ponds in Chiayi County across four seasons. A total of 55 Common Moorhens appeared in 16 farm ponds during the spring season, with 10 Common Moorhens, the largest number, appearing in farm pond Number 3 in Datang Village, Dalin Township. In the summer season, a total of 27 Common Moorhens were observed in 11 farm ponds; the largest number, eight Common Moorhens, appeared in farm pond Number 3 in Machouhou Village, Lucao Township. In the autumn season, a total of 142 Common Moorhens were sighted in 14 farm ponds; the largest number, 50 Common Moorhens, appeared in the farm pond Number 1 in Pixiang Village, Taibao City. In the winter survey, a total of 221 Common Moorhens were found in 23 farm ponds, with the largest number, 50, observed in farm pond Number 3 in Machouhou Village, Lucao Township.

The number of Common Moorhens that appeared in farm ponds varied throughout the four seasons. The greatest number was observed in winter (221 Common Moorhens), followed by autumn

(142 Common Moorhens), and the fewest number of birds were observed in summer, only 27 Common Moorhens (Figure 2). This is primarily because the Common Moorhen exhibits the characteristic of familial aggregation in winter [16,33]. During the fallow period of rice farming (approximately October to February), the Common Moorhen gathers at farm ponds and then leaves the area between March and April to search for suitable breeding sites. From May to June, they engage in reproductive behavior in these fixed, pre-determined areas [34]. When harvesting begins in the paddies from July to August, parent birds can be found with juveniles. Subsequently, during the tilling of soil in September, Common Moorhens begin aggregating at farm ponds due to the end of the breeding season. Winter aggregation begins in October and continues until February of the next year.

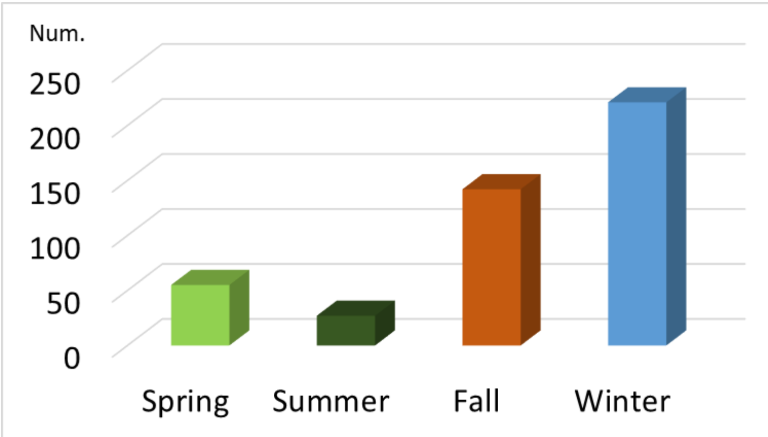


Figure 2. Total number of Common Moorhens appearing across the four seasons.

3.2. Evaluation Framework of Habitat Suitability

According to the analysis of expert opinions, a triangular fuzzy function was employed to calculate the mean of expert consensus scores as 6.934. The expert consensus score of the first-layer "external environment of farm ponds" (henceforth "external environment") was 6.986, and that of the "internal environment of farm ponds" (henceforth, "internal environment") was 8.167, indicating that the experts reached a consensus in the first layer of items. However, expert consensus scores were lower than the mean score in the second-layer external environment factors "area ratio of roads within 200 m of the farm pond" (5.652) and "area ratio of buildings within 200 m of the farm pond" (5.648), and also in the "water depth" (5.715) factor of the internal environment. This showed that experts did not reach a consensus; therefore, these three factors were excluded. The expert consensus scores of the remaining eight factors were all higher than the mean score and were thus included. These factors were "area ratio of farmlands within 200 m of the farm pond", "pond area", "pond perimeter", "bank type", "coverage of high and low shrubs around the pond bank", "aquatic plant coverage of farm pond surface", "drought period" and "water-surface-to-bank distance" (Table 1).

After each factor was confirmed using the fuzzy Delphi method, their relative weight coefficients were calculated (Table 1). The first layer included the external environment and internal environment. The weight coefficient of external environment was 0.457 and that of the internal environment was 0.543, indicating that for the habitat of the Common Moorhen, the suitability of the internal environment is more essential than that of the external environment.

Of the internal environment factors in the second layer, the weight coefficient of "aquatic plant coverage of farm pond surface" was the highest (0.215), indicating that aquatic plant coverage is the most essential factor in the internal environment of farm ponds. This was followed by "drought period" (0.210). The weight coefficient of "water-surface-to-bank distance" was the lowest (0.175); the importance of "water-surface-to-bank distance" was relatively low. Of the external environment factors, the weight coefficient of "pond area" was the highest (0.341), followed by "area ratio of farmlands within 200 m of the farm pond" (0.339), and then "pond perimeter" (0.319). All three are thus crucial factors.

The final weight coefficient was obtained by multiplying the indicator weight coefficient of the first layer by that of the second layer. The results showed that the most essential factors are "pond area" (0.156), "area ratio of farmlands within 200 m of the farm pond" (0.155), and "pond perimeter" (0.146), and that "water-surface-to-bank distance" (0.95) is the factor with the lowest importance (Table 1).

Table 1. Evaluation criteria and weight coefficients for the indicators of habitat suitability in farm ponds for Common Moorhen.

First-Layer Evaluation Criteria		Second-Layer Evaluation Criteria		Final Weight Coefficient (A × B)	Ref.
Main Category	**Relative Weight Coefficient (A)**	**Sub-Category: Specific Indicators**	**Relative Weight Coefficient (B)**		
External Environments	0.457	Pond area	0.341	0.156	[7,10,32,50–52]
		Area ratio of farmlands within 200m of the farm pond	0.339	0.155	[15,16,35,36,53]
		Pond perimeter	0.319	0.146	[32]
Internal Environments	0.543	Aquatic plant coverage of the pond surface (Winter)	0.215	0.117	[10,16,31,32,54]
		Drought period	0.210	0.114	[7,17,32]
		Shrub coverage of the pond bank (Winter)	0.206	0.112	[7,10,17,40,52,55,56]
		Bank type	0.193	0.105	[10,39,40]
		Water-surface-to-bank distance (Winter)	0.175	0.095	[32]

3.3. Evaluation Criteria of Habitat Suitability

3.3.1. Suitability of External Environments of Farm Ponds

The three factors used for the evaluation of the suitability of the external environment were the area ratio of farmlands within 200 m of the farm pond, the pond area, and the pond perimeter. According to the evaluation criteria in Table 2, the field survey revealed that 32% of the farmland area ratios within 200 m of farm ponds were $\geq$ 60% (Table 2), whereas the farmland area ratios of 32 farm ponds (43%) were between 40% and 60%. This indicated that the surroundings of farm ponds are still primarily agricultural landscapes and are suitable for the habitats of Common Moorhens. Surveying the factor "pond area" confirmed that most ponds (n = 35; 47%) were 1000–5000 m^2, followed by ponds that are 5000–50,000 m^2 (39%). Regarding "pond perimeter," half of the ponds (51%) are smaller than 300 m, and only 16% are greater than 1000 m, indicating that most farm ponds are of appropriate size to provide habitats for Common Moorhens.

The field evaluation scores for the three factors associated with the external environment were multiplied by their corresponding weight coefficients (Table 2) and then summed up to calculate the habitat suitability score of each pond, as depicted in Figure 3a. The analysis results indicated that the mean suitability score was 1.289, and that higher habitat suitability was observed for the external environments of farm ponds in Dalin, Singang, Shueishang, and Yijhu Townships.

3.3.2. Suitability of Internal Environments of Farm Ponds

Five factors were used to quantify the suitability of the internal environment, namely shrub coverage of the bank, aquatic plant coverage of the pond surface, water-surface-to-bank distance, drought period, and bank type. The shrub coverage for 28 farm ponds (37%) is $\geq$81%. However, 30 ponds (40%) have coverage of $\leq$20% (Table 2), indicating that the shrub coverage on the banks of Chiayi County farm ponds is highly polarized. The aquatic plant coverage of the pond surface is less than 20% for 58 ponds (77%), which is primarily attributable to the grass carp or black carp in farm ponds that consume aquatic plants, yielding a situation where only seven farm ponds (9%) have coverage percentages higher than 61%. The survey of the drought period of farm ponds found that 95% of farm ponds have year-round water (71 ponds), indicating that most ponds have water throughout the year for the survival of aquatic plants, aquatic insects, and frogs; these ponds facilitate nearby habitat formation for Common Moorhens. The water-surface-to-bank distance affects the movement paths of Common Moorhens. The results revealed that approximately 24% of the farm ponds have height differences of less than 60 cm, showing that in 18 farm ponds, the water level changes have only a small effect on the movement of Common Moorhens. In addition, 39% of farm ponds (29 ponds) have height differences of 181 cm and higher, indicating that the water level changes in these farm ponds cause severe barriers to the movement of Common Moorhens. The survey of the bank type verified that more than half (54%) of farm pond banks are composed of grass or soil slopes. The gentler slopes and common growth of shrubs and bushes could facilitate the hiding, migration, and foraging of Common Moorhens. At the same time, 35% (38 ponds) of pond banks were found to be composed of concrete, which is less functional for the foraging and hiding of Common Moorhens.

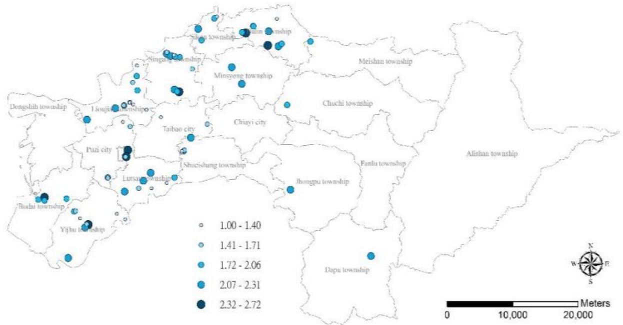
The field evaluation scores of the five factors associated with the internal environment were multiplied by their corresponding weight coefficients (Table 2) and then summed up to calculate the habitat suitability scores for each pond, as depicted in Figure 3b. The results of the analysis showed that the mean suitability score was 1.89. Higher habitat suitability was observed for the internal environments of farm ponds in Dalin and Lutsau townships, and Taibo city.

Table 2. Evaluation criteria for the habitat suitability assessment for Common Moorhen.

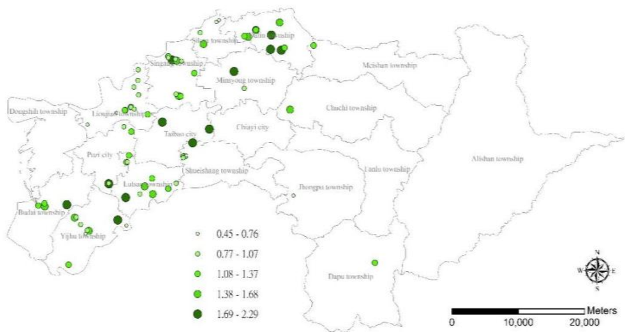
Evaluation Criteria		Score = 1		Score = 2		Score = 3		Score = 4		Score = 5	
First-Layer	**Second-Layer**	**Description**	***n* (%)**	**Description**	***n* (%)**	**Description**	***n* (%)**	**Description**	***n* (%)**	**Description**	***n* (%)**
External Environments	Area ratio of farmlands within 200 m of the farm pond	Less than 20%	6 (8%)	20–40%	13 (17%)	40–60%	32 (43%)	60–80%	17 (23%)	More than 80%	7 (9%)
	Pond area	500–1000 m^2	7 (9%)	1000–5000 m^2	35 (47%)	5000–10,000 m^2	11 (15%)	10,000–50,000 m^2	18 (24%)	50,000 m^2	4 (5%)
	Pond perimeter	Less than 200 m	18 (24%)	201–300 m	20 (27%)	301–600 m	15 (20%)	601–1000 m	10 (13%)	More than 1001 m	12 (16%)
Internal Environments	Bank type	Reinforced concrete	38 (35%)	Rubble (masonry)	12 (11%)	Pebblework	6 (5%)	Hollow block	1 (1%)	Grass slope, soil slope	54 (49%)
	Shrub coverage of the pond bank (winter)	Less than 20%	30 (40%)	21–40%	2 (3%)	41–60%	7 (9%)	61–80%	8 (11%)	More than 81%	28 (37%)
	Aquatic plant coverage of the pond surface (winter)	Less than 20%	58 (77%)	21–40%	7 (9%)	41–60%	3 (4%)	61–80%	3 (4%)	More than 81%	4 (5%)
	Drought period	Farm pond drought period of longer than 1–3 months	1 (1%)	-	-	Drought period within 1–3 months	3 (4%)	-	-	Pond has water year-round	71 (95%)
	Water-surface-to-bank distance (winter)	More than 181 cm	29 (39%)	131–180 cm	16 (21%)	101–130 cm	2 (3)	61–100 cm	10 (13%)	Less than 60 cm	18 (24%)

3.3.3. Overall Habitat Suitability of Farm Ponds

The habitat suitability scores associated with the external and internal environments of each pond were summed up to obtain the total habitat suitability score (Figure 3c). The mean of the total habitat suitability scores was 3.147, with farm ponds located in Dalin, Singang, Shueishang, and Yijhu Townships exhibiting higher scores.



(**a**)



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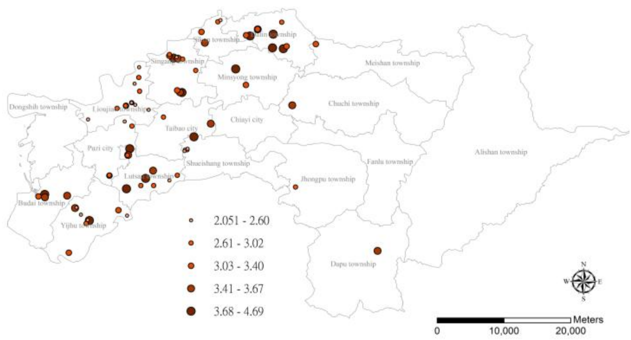

(**c**)

Figure 3. Habitat suitability assessment scores associated with the (**a**) internal and (**b**) external environments of farm ponds, as well as their (**c**) total habitat suitability scores.

3.4. Overall Accuracy of the Habitat-Suitability Assessment Model on Farm Ponds for the Common Moorhen

This study used the Kappa value to verify the credibility of the proposed model on the assessment of farm ponds as suitable habitats for the Common Moorhen. Based on a habitat suitability threshold score of 3.147 and the presence of Common Moorhens in 75 farm ponds, the overall accuracy was calculated to be 0.8 and the Kappa value was 0.60 (Table 3). This indicates that the habitat-suitability assessment method established by this study can effectively predict the presence of Common Moorhens.

Table 3. The overall accuracy analysis of the habitat suitability assessment and the presence of theCommon Moorhen.

Items		**Threshold Value: 3.147**		**Total (%)**
		Higher	**Lower**	
Presence of Common Moorhen	*Presence*	29	6	35
		(39%)	(8%)	(47%)
	Absence	9	31	40
		(12%)	(41%)	(53%)
Total		38	37	75
		(51%)	(49%)	(100%)

4. Discussion

4.1. Spatial Distribution of the Common Moorhen Population

The total number of Common Moorhens that appeared at farm ponds across the four seasons is shown in Figure 2. The results indicated 10 hot spots at which Common Moorhens appeared, and the farm ponds at which the most Common Moorhens appeared were in Dalin Township (Figure 4). Moreover, the total habitat suitability score including farm ponds exhibiting higher scores was also located in Dalin Township (Figure 3c). This was because the farm ponds in Dalin Township were simultaneously the primary habitat of *Rhacophorus arvalis*, a species endemic to Taiwan [5]. The Chiayi County government has conducted habitat conservation education for community residents in this area and has promoted related conservation programs; thus, local residents are highly aware of farm pond conservation and the conservation of organism habitats [4,5]. This has enabled the farm pond in Dalin Township to become a favorable habitat for both the Common Moorhen and *Rhacophorus arvalis.*

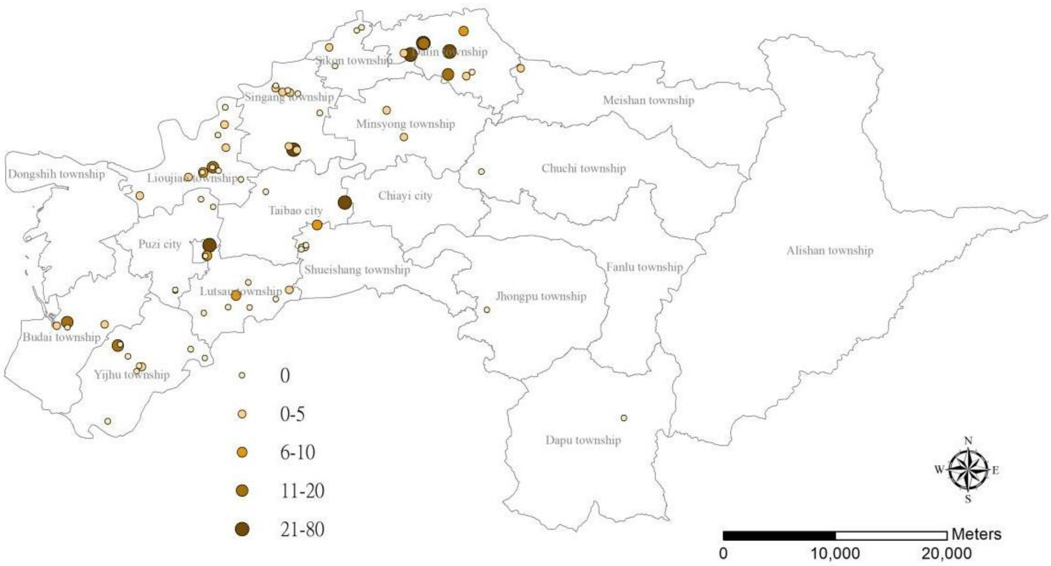

Figure 4. Spatial distribution of accumulated counts of Common Moorhens in 2014.

4.2. Comparisons of Habitat-Suitability Assessment Models

When developing a numerical model related to habitat assessment, correlations of statistical data are often expected to represent the relationship between species occurrence and environmental variables [57,58]. However, sometimes, mathematic outcomes cannot fully reflect complicated links between the species and habitat environments [59–61]. Here, we adapted the fuzzy Delphi method to integrate experts' opinions on habitat conditions of Common Moorhens, such as area ratio of farmlands within 200 m of the farm pond, pond area, pond perimeter, aquatic plant coverage, etc. This method is justified by experts and scholars who have in-depth knowledge and/or do long-term research on the particular species. Hence, the proposed factors exhibited a high degree of credibility and authenticity, which is difficult to achieve with a simple statistical model.

Juang et al. applied a similar method to evaluate frog habitat suitability and examined the model's accuracy by calculating the overall accuracy (0.8116) and Kappa test value (0.6061) [5]. The results not only verified the accuracy and credibility of the model but also indicated its effectiveness. Also, the adaptation of the fuzzy Delphi method for the development of a habitat assessment model is a fairly new application. Thus, to prove the method is reliable and repeatable, we used the same method to examine habitat suitability for Common Moorhens. The results still displayed an overall accuracy of 0.8 while the Kappa value was 0.60. This demonstrates not only the high credibility of the model established in this study but also the predictable performance of the framework. Additionally, like other numerical statistical models, the accuracy can be increased by collecting more samples (e.g., selecting more study sites) when applied in future research.

4.3. Implications of Habitat Management and Restoration for Common Moorhen Conservation

Habitat suitability assessment is one of the essential steps in habitat conservation and restoration [40]. Reasonable understanding of the results of assessment and their main criteria not only contributes to the conservation and restoration of habitats [62], but also helps to improve and maintain the existing habitat suitability grade [63]. In this study, a matrix analysis was conducted on habitat suitability scores (x-axis) and total numbers of Common Moorhens observed across four seasons (y-axis). The mean habitat suitability score was 3.147, and the mean of the total number of Common Moorhens was 5; the four quadrants were divided according to these two mean values (Figure 5).

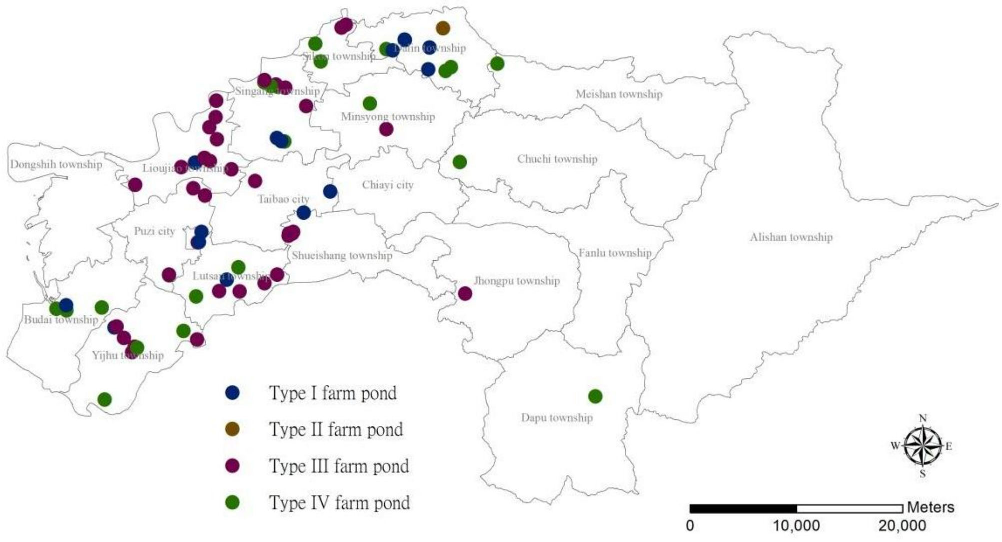

Figure 5. Geographic locations of four types of farm ponds.

The 15 farm ponds (20%) in the first quadrant exhibited habitat suitability scores and total Common Moorhen numbers greater than the mean values. These farm ponds featured a favorable habitat quality and biomass and should be designated as protected habitats for Common Moorhens. Considering Pond 1 in Shanglin Village, Dalin Township as an example, the environment of this farm pond is naturally favorable and features a spacious area. The water surface is covered with aquatic plants and the surrounding environment remains natural and diverse, including suitable environments such as paddy fields, bushes, forest, and bamboo groves. In addition to a high level of naturalness, it is located far away from human communities, residences, buildings, and roads, and therefore has a low level of anthropogenic interference. The habitat suitability score of this pond was 4.69. In addition, numerous Common Moorhens were observed across all four seasons. Accordingly, Pond 1 is a notable favorable habitat for the Common Moorhen; it should be preserved and could be used as an education site for farm pond ecology.

The habitat-suitability assessment scores for the two farm ponds in the second quadrant were less than the mean value, whereas the total number of Common Moorhens spotted across the four seasons was higher than the mean value (Figure 5). Taking Pond 1 in Tushih Village, Liujiao Township as an example, this small, strip-shaped farm pond is adjacent to a road on the left, and a portion of the bank is composed of cement. The shrub and aquatic plant coverage levels of the banks are moderately low, the drought period is conspicuous, and the water level varies greatly; thus, the habitat suitability score was only 2.94. However, after surveys across all four seasons, a total of 18 Common Moorhens appeared, primarily because the right side of the farm pond is near a large area of natural water, and there was a field of natural brush between the two. Thus, the two neighboring areas of water naturally form an environment for the habitat and foraging of Common Moorhens. Therefore, improving the left bank and aquatic plant coverage of the farm pond and increasing the stability of the water volume can substantially increase habitat suitability and contribute to the flourishing of the Common Moorhen.

In the farm ponds of the third quadrant, the habitat suitability assessment scores and total Common Moorhen numbers spotted across four seasons were lower than the mean values (Figure 5). The survey revealed 36 such ponds (48%). If this type of farm pond were to be restored as a habitat for Common Moorhens, the costs would be considerably high. Therefore, they should be used for other purposes, such as agricultural irrigation facilities, recreational environments for community residents, or detention basins for reducing the loss of crops and resident property due to floods. Taking Pond 1 in Youdong Village, Xikou Township as an example, it is located behind the Tiansong Temple, and is adjacent to County Highway 157. The pond is small and square-shaped, with the bank reinforced with concrete, and it exhibits no plant coverage on its banks or water surface. The overall environment has a considerably low level of naturalness and no Common Moorhens were found. Therefore, this farm pond should be used as a public space by the village community and for use by older individuals in the mornings and evenings who usually converse in front of the temple or for strolling.

A total of 22 farm ponds (29.3%) were in the fourth quadrant. Although their habitat suitability assessment scores were higher than the mean value, the total number of Common Moorhens observed were lower than the mean, indicating that these farm ponds have favorable habitat environments and are suitable for the reintroduction of the Common Moorhen and restoration of its ecosystem (Figure 5). Taking Pond 3 in Beiqian Village, Yijhu Township as an example, it is near farmland and there is a forest exit behind the pond. There are nearby water environments on both sides of the surrounding area, and the surrounding environment is natural and free of human interference; therefore, its habitat assessment score was high (3.89). Only one Common Moorhen was observed in the summer and one Common Moorhen was observed in the winter. The survey also revealed that several Ardeidae birds forage in and inhabit this area, indicating that this farm pond is a suitable habitat for birds such as Common Moorhens and Ardeidae. If the ecological network of Common Moorhens is to be restored, Common Moorhens with reproductive capacity can be suitably introduced to this pond.

It is known that the conservation of waterbird species and their habitats requires a comprehensive understanding of bird–environment relationships and management practices of not only breeding, but also foraging sites (e.g., [10,17]). Because of the degradation of natural habitats, farm ponds have become more important, acting as artificial/semi-artificial wetlands [10,17,53,64,65]. In our case, the Common Moorhen, a residential rail species, may heavily depend upon farm ponds as alternative habitats. Also, ponds linking to irrigation system can maintain water sources throughout the year because they receive water through transbasin diversion, which is able to provide alternative resources for waterbirds continuously. Moreover, farm ponds are often dug due to irrigation needs. Therefore, in order to enhance habitat conservation, it could be useful to develop some guidelines for the pond characteristics that have to be complied with in the construction process. As demonstrated herein and in previous studies [5,66,67], we can conclude that pond bank type (or construction material), vegetation presence, pond size and its location are important indicators regarding the value of these ponds as wildlife habitats. As the location and size of ponds depend on social or/and hydrological circumstances and may be difficult to manage, bank materials and vegetation cover should be considered as primary factors in control when implementing conservation practices.

5. Conclusions

This study employed an expert questionnaire survey and the fuzzy Delphi method to establish a model and assess the suitability of habitats for the Common Moorhen. The results indicated that the conditions of the internal environments of farm ponds are more essential than those of the external environments, and that the farm ponds located in Dalin Township have a higher overall habitat suitability and a greater number of Common Moorhens than farm ponds in other locations; the township is therefore a crucial conservation area for the Common Moorhen. The field survey results indicated that groups of Common Moorhens tend to aggregate near farm ponds during the winter; therefore, distinct differences exist between the numbers of Common Moorhens that appear at farm ponds throughout the four seasons.

Based on the final scores of the habitat suitability assessment, farm ponds were classified into four types of habitats through the quadrant matrix analysis. Each type has its requirements regarding Common Moorhen: habitat conservation, habitat restoration, species restoration or re-introducing, and only suitable as agricultural irrigation. The overall Kappa value proved the reliability of the evaluation framework. This work is a useful reference for stakeholders involved in the proposal of a practical habitat-conservation strategy that can achieve the dynamic equilibrium of coupled human–nature systems on agricultural landscapes.

Author Contributions: C.-H.L. established the framework and analysis methodology, performed the statistical analysis and spatial distribution analysis, created tables and graphs, and wrote the manuscript. S.-H.L. determined the research rationales and objectives, synthesized the results of the data analysis. C.-Y.T. performed the Common Moorhen field surveys and the multi-variance analysis. S.-H.C. determined the article structure and outline, wrote the manuscript, and acted as the corresponding author. All authors critically revised and approved the final manuscript.

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