Composition and Biomass of Aquatic Vegetation in the Poyang Lake, China

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The distribution of aquatic vegetation and associated community diversity and biomass in the Poyang Lake were investigated. The results showed that (1) 43 species of aquatic vascular plants were found in the Poyang Lake watershed which belonged to 22 families; (2) the vegetation of the Poyang Lake scattered in different areas which could be divided into 31 major plant communities and 5 plant zones including amphibian, emergent, floating-leaved, submerged, and floating input; (3) there were 67 aquatic plants in the lake area, and the standing stock (fresh weight) was 1519.41 t. The number of amphibians was the dominant plant species in the Poyang Lake, and the quantity and percentage of amphibians were predominant, which was far more than the other three life forms.

1. Introduction

Aquatic plants are an important component of lake ecosystems and are often regarded as indicators of lake environmental changes; they play an important role in maintaining the structure and function of lake ecosystems [1, 2]. Aquatic plants are the primary producers of aquatic ecosystems, being a kind of food source of many kinds of fish and other aquatic animals [3, 4]. They can regulate the lake water body, degrade various pollutants, and improve the transparency [5, 6]. In addition, aquatic plants can provide habitat to many organisms and increase the spatial niche of aquatic ecosystems [7, 8]. Therefore, it is important to know the distribution of aquatic plants and their communities to analyze the status of aquatic plants in the lake area.

Vegetation is an important component of wetland ecosystems, and biomass can quantify the contribution of wetland vegetation to carbon sinks and carbon sources [9]. Biomass estimation of wetlands plays an important role in understanding dynamic changes of the wetland ecosystem [10]. In previous studies, biomass estimation using indirect and direct methods has been conducted. For example, remote sensing technology and radar data have been widely used to estimate the biomass in recent years [2, 11]. Han et al. [11] investigated four decades of winter wetland changes in the Poyang Lake based on Landsat observations between 1973 and 2013. Luo et al. [2] revealed the distribution of aquatic vegetation types in Taihu Lake, China, by using a series of remotely sensed images with a resolution of 30 m (HJ-CCD and Landsat TM). Shen et al. [9] retrieved vegetation biomass in the Poyang Lake wetland by using polarimetric RADARSAT-2 data. These indirect methods offer the ability to continuously monitor growth and phenology on the same individuals over large areas but depend on the existence of strong relationships between the predictor variables and plant biomass [12–14]. Therefore, ground investigation of biomass is also very essential.

Poyang Lake, the largest freshwater lake in China, is well known for its ecological importance as a wetland system [9, 11]. The Poyang Lake region provides significant environmental benefits, such as supplying water resources and maintaining carbon storage and biodiversity [15, 16]. Guan et al. [17] pointed out that aquatic vegetation of Poyang Lake is very rich in number of species. The vegetation...
It distributes in about 2262 km² and accounts for 80.8% area of the lake. Jian et al. [18] studied the distribution area and biomass of Poyang Lake beach vegetation in the years of 1999 and 2000, and they found there were 28 families, 56 genera, 95 species, and 3 varieties. In April, 2000, they found that the total biomass of beach vegetation was $3.81 \times 10^6$ tons (fresh weight), with an average biomass of $3.736 \, \text{g m}^{-2}$ (fresh weight). Peng et al. [19] studied the association type diversity, community species diversity, community coverage, and biomass of aquatic plants in the fresh water lakes of the Poyang Plain District of China in 2001, and they found 42 associations of aquatic plants in the lakes, which include 11 amphibian, 6 emergent, 11 leaf-floating, and 14 submerged associations. Among all the associations, Carex cinerascens Ass. and Zizania latifolia Ass. possess the highest coverage and highest biomass, respectively. Although some survey of aquatic plants in the Poyang Lake has been conducted, ground investigation of aquatic plants in Poyang Lake was very rare in recent years.

In this paper, the species and biomass of aquatic plants in the Poyang Lake were investigated based on ground survey data in September, 2013. And the objective of this study is to investigate the composition of aquatic plants and community types and habitats of major aquatic plants in the Poyang Lake. This study will provide information for the monitoring and conservation of aquatic plant in the Poyang Lake.

2. Data and Methodology

2.1. Study Area and Data. Poyang Lake is located on the southern bank of the lower Yangtze reach (28° 22′ ~ 29° 45′ N and 11° 47′ ~ 116° 45′ E). It has five main tributary rivers: Ganjiang River, Fuhe River, Xinjiang River, Raohe River, and Xiushui River, and several smaller rivers. The basin area of the five rivers is 162,200 km², occupying 9% of Yangtze River basin. The climate is characterized as a subtropical, humid, monsoon climate with a 1620 mm mean annual precipitation and an annual average temperature of approximately 17°C [20].

The environmental conditions of the Poyang Lake are very suitable for the growth and reproduction of aquatic plants. Aquatic plants can provide habitat for many organisms, improve habitat diversity, and increase the spatial niche of aquatic ecosystem [21]. But the annual water level of the Poyang Lake changes greatly, especially in the flood season (April to November) and dry season (December to March). The characteristics of periodical variation of water level in the Poyang Lake might lead to the conversion of the lake beach and grassland.

2.2. Methodology. The species, community structure, coverage, and biomass of the Poyang Lake were investigated from September 7, 2013, to September 14, 2013. GPS and lake electronic map were used to set sampling points, and the samples of aquatic plants were collected at each sampling site. The category of aquatic plants in the Poyang Lake was defined according to the reference of Cook [22]. Division of “cluster” is based on the principle of dominant species, which is named as the name of the group. If a cluster is with two or more dominant species, different dominant species of the same layer were connected with “+”, and the dominant species of different layers were connected with “-”. At the sampling sites, amphibians, emergent plants, floating-leaved plants, and floating input plants were directly observed and recorded. Submerged plants were preliminarily identified with water sickle after collecting water and the characters of flowers, leaves, and fruits of each plant as well as field growth photos and accurate identification of aquatic plant species and genus [23]. For amphibian and emergent plant clusters, 6 samples of 2 m × 2 m were set randomly within 500 m² of each sampling point, and the total biomass (fresh quality) of the aerial parts of all the plants was measured and the biomass per unit area was calculated. For plants with large plant biomass, such as Phragmites communis Trin., we could estimate the number of plants in the quadrats. After selecting the representative fresh weight of the plants, we could calculate the standing amount of the plants. As the species with smaller biomass, such as Alternanthera philoxeroides (Mart.) Griseb., all the plants in the quadrats were collected and their fresh weight was calculated, and the mean values were calculated after several measurements of plant height. The floating-leaved plant cluster, the floating input plant cluster, and the submerged plant cluster were harvested 6 times randomly in the range of 500 m² for each sampling point with an underwater sickle with a cross-sectional area of 0.785 m², and the plant was uprooted and then washed, removing residual sticks and other impurities. The fresh weight of each plant was weighed and the frequency, coverage area, and coverage were recorded (visual method). All the plants, together with the roots, were dug and washed, and the plant depth was measured [24].

3. Results and Discussion

3.1. Characteristics of Aquatic Plants in the Poyang Lake. There were 43 species of aquatic plants in the lake area which belonged to 37 genera and 22 families according the survey in 2013 (see Figure 1 and Table 1). And it could be found that there were 16, 13, and 9 species, accounting for 37.21%, 30.23%, and 20.93% of the total species for the amphibians, emergent plants, and submerged plants, respectively. However, there were only 2 and 3 species for floating input plants and floating-leaved plants in the Poyang Lake, accounting for 4.65% and 6.98% of the total species.

It could be seen that the distribution of all kinds of plants was different; the most extensive degrees of various classes were Carex spp., Eleocharis tuberosa (Roxb.) Roem. et Schult., Polygonum L., and Nymphaoides peltatum (Gmel.) O. Kuntze. Most of the species were distributed in a large area or in a continuous distribution in the wetland or near shore of the lake, which were widely distributed and had strong adaptability to adversity. Most of the plants in the whole lake were in vegetative period.

The survey recorded 22 families, 37 genera, and 43 aquatic plant species; the number of species was significantly lower than the survey of aquatic plant species number in Poyang
Table 1: The composition of macrophytes in the Poyang Lake (September 7–14, 2013).

| Serial number | Plant community                | Phenological period                  | Lifestyle          |
|---------------|--------------------------------|--------------------------------------|--------------------|
| 1             | Sagittaria pygmaea Miq.        | Flowering fruit bearing stage         | Emerged plant      |
| 2             | Trapella sinensis Oliv.         | Fruit period (florescence)            | Floating-leaved plant |
| 3             | Carex rhyzochophyza C. A. Mey.  | Vegetative period                    | Amphibian          |
| 4             | Eichhornia crassipes (Mart.) Solms | Florescence                     | Amphibian          |
| 5             | Aeschynomene indica Linn.       | Flowering fruit bearing stage         | Emerged plant      |
| 6             | Samucus chinensis Lindl.        | Vegetative period                    | Amphibian          |
| 7             | Isachne globoasa (Thum.) Kuntze | Florescence                          | Amphibian          |
| 8             | Limnophila sessilifora (Vahl.) Bl. | Vegetative period                  | Amphibian          |
| 9             | Paspalum distichum L.           | Vegetative period                    | Amphibian          |
| 10            | Hydrocharis dubia (BL) Back.    | Flowering fruit bearing stage         | Submerged plant    |
| 11            | Ottelia alismoides (L.) Pers.   | Flowering fruit bearing stage         | Amphibian          |
| 12            | Ludwigia adscendens (L.) Hara   | Flowering fruit bearing stage         | Floating input plant |
| 13            | Juncellus serotinus             | Flowering fruit bearing stage         | Amphibian          |
| 14            | Blyxa japonica (Miq.) Maxim.    | —                                    | Submerged plant    |
| 15            | Marsilea quadrifolia L.         | Vegetative period                    | Amphibian          |
| 16            | Nephrolepis cordifolia (L.) Presl | Fruit period                        | Emerged plant      |
| 17            | Carex spp.                      | Florescence                          | Amphibian          |
| 18            | Microcarpaca minima (Koen.) Merr. | Vegetative period                 | Amphibian          |
| 19            | Oryza rufipogon Griff.          | Flowering fruit bearing stage         | Amphibian          |
| 20            | Myriophyllum spicatum L.        | Vegetative period                    | Submerged plant    |
| 21            | Typha angustifolia L.           | Fruit period                         | Emerged plant      |
| 22            | Monochoria vaginalis (Burm.f.) Presl | —                               | Emerged plant      |
| 23            | Rotala rotundifolia (Buch.-Ham) Koehne | —                               | Emerged plant      |
| 24            | Imperata cylindrica (Linn.) Beauv | Vegetative period                 | Amphibian          |
| 25            | Eleocharis tuberosa (Roxb.) Roem. et Schult. | Vegetative period             | Emerged plant      |
| 26            | Najas marina                    | Fruit period                         | Submerged plant    |
| 27            | Triarrherca sacchariflora       | Vegetative period                    | Emerged plant      |
| 28            | Cynodon dactylon (Linn.) Pers.  | Vegetative period                    | Amphibian          |
| 29            | Zizania caduciflora (Turcz. ex Trin.) H.-M. | Vegetative period       | Emerged plant      |
| 30            | Hydrilla verticillata (L.f.) Royle | Vegetative period               | Submerged plant    |
| 31            | Utricularia aurea Lour.         | Florescence                          | Submerged plant    |
| 32            | Ceratophyllum demersum L.       | Vegetative period                    | Submerged plant    |
| 33            | Vallisneria natans (Lour.) Hara | Flowering fruit bearing stage         | Submerged plant    |
| 34            | Utricularia vulgaris L.         | Flowering fruit bearing stage         | Submerged plant    |
| 35            | Polygonum L.                    | Vegetative period                    | Submerged plant    |
| 36            | Trapa bispinosa Roxb.           | Flowering fruit bearing stage         | Floating-leaved plant |
| 37            | Phragmites communis Trin.       | Vegetative period                    | Emerged plant      |
| 38            | Triarhena lutariopiraria        | Vegetative period                    | Amphibian          |
| 39            | Alternanthera Philoxeroides (Mart.) Griseb. | Florecence                      | Emerged plant      |
| 40            | Nymphoides peltatum (Gmel.) O. Kuntze | Florecence                        | Floating-leaved plant |
| 41            | Limnophila heterophylla (Roxb.) Benth. | Flowering fruit bearing stage       | Emerged plant      |
| 42            | Myriophyllum tuberculatum Roxburgh | Fruit period                     | Emerged plant      |
| 43            | Elymus dahuricus Turcz.         | Vegetative period                    | Amphibian          |

Lake [3], which may be because the latter sampling sites in the Poyang Lake were a bit too much. The results of this study were compared with the results of the survey of 28 families, 56 genera, 95 species, and 3 varieties of aquatic vegetation in the Poyang Lake [18]. The number of species was different and the reason may be the strength of this investigation was not enough, and the accuracy of traditional field survey research method was much lower than that of TM Landsat remote sensing technology. In view of this survey was only a single survey in autumn and was limited to water habitat, lake side vegetation was not a detailed investigation, and, therefore, the actual distribution of Poyang Lake aquatic plant species should be lower than the findings of Guan et al. [3] and Jian et al. [18].
3.2. Community Types and Habitats of Major Aquatic Plants in the Poyang Lake. The species of aquatic plants, the spatial structure, and ecological environment of the community were listed in Table 2 in the Poyang Lake. There were 31 main plant clusters in the Poyang Lake.

The amphibians mainly distributed in the water depth of 0.5–2.5 m meters of the beach in the flood season. The main species were amphibious plants that grew in both shallow and wetlands. There were 16 kinds of amphibians in the Poyang Lake, of which the most important and wide distribution was *Carex* spp., the least distribution was *Sambucus chinensis* Lindl., *Isachne globosa* (Thunb.) Kuntze, *Microcarpaea minima* (Koen.) Merr., and *Oryza rufipogon* Griff.

Emergent plants were located in the 12–15 m elevation of the shoal, and the water depth was generally 0.5–3.5 m in the flood season. The main species were plants that had only the base or lower part of the plant to be submerged in water, but the upper part of the plant was quite out of water. There were 13 kinds of emergent plants in the Poyang Lake, of which the most important and wide distribution was *Eleocharis tuberosa* (Roxb.) Roem. et Schult., and the least distribution was *Aeschynomene indica* Linn., *Typha angustifolia* L., *Monochoria vaginalis* (Burm.f.) Presl, *Rotala rotundifolia* (Buch.-Ham) Koehne, and *Myriophyllum spicatum* L.

Floating-leaved plants were located 11–13 meters above the lake bottom, where the lake water level was generally 2.5–4.5 meters in the flood season. The main species were some plants rooted in the lake, but the leaves were floating on the surface of the water. Moreover, a large number of submerged plants could also be found in this plant belt, such as *Vallisneria natans* (Lour.) Hara and *Hydrilla verticillata* (L.f.) Royle. There were 3 kinds of floating-leaved plants in the Poyang Lake, of which the most important and wide distribution was *Nymphoides peltatum* (Gmel.) O. Kuntze, and the least distribution was *Trapella sinensis* Oliv.

Submerged plants distributed in the 9–12 m elevation of the lake, and the lake water depth was generally 3.5–6.5 meters in the flood season. The main species were some of the plants immersed in water, such as *Hydrilla verticillata* (L.f.) Royle, *Ceratophyllum demersum* L. There were 9 kinds of submerged plants in the Poyang Lake, of which the most important and wide distribution was *Ceratophyllum demersum* L. and *Vallisneria natans* (Lour.) Hara, and the least distribution was *Blyxa japonica* (Miq.) Maxim., *Myriophyllum spicatum* L., and *Utricularia vulgaris* L.

The distribution area for floating input plant was very small, and the floating input plant was mainly located in small patches or sporadic distribution in the bay. There were 2 kinds of floating input plant in the Poyang Lake, of which the most important and wide distribution was *Eichhornia crassipes* (Mart.) Solms, and the least distribution was *Hydrocharis dubia* (BL) Back.

The main habitat types of aquatic macrophytes in the Poyang Lake were summarized in Table 3. Among the amphibians, the coverage of the typical *Carex* spp. cluster was generally 40–80%, and the plant height was about 25–100 cm. But in the lower edge of the distribution area, the growth of the *Carex* spp. cluster was delayed, and the plant coverage and
| Serial number | Plant community                                                                 |
|---------------|--------------------------------------------------------------------------------|
| 1             | Vallisneria natans (Lour.) Hara + Carex spp. + Limnophila sessiliflora (Vahl.) Bl. + Ceratophyllum demersum L. Carex spp. + Elymus dahuricus Turcz. + Vallisneria natans (Lour.) Hara + Myriophyllum tuberculatum Roxburgh + Nymphaeoides peltatum (Gmel.) O. Kuntze + Ceratophyllum demersum L. + Limnophila heterophylla (Roxb.) Benth. + Eleocharis tuberosa (Roxb.) Roem. et Schult. |
| 2             | Carex spp. Alteranthera philoxeroides (Mart.) Griseb. + Paspalum distichum L. + Paspalum distichum L.-Alteranthera philoxeroides (Mart.) Griseb. + Typha angustifolia L.-Alteranthera philoxeroides (Mart.) Griseb. |
| 3             | Aeschynomene indica Linn. + juncellus serotinus + Oryza rufipogon Griff. |
| 4             | Carex spp. + Polygonum L. |
| 5             | Marsilea quadrifolia L. |
| 6             | Paspalum distichum L. |
| 7             | Eichhornia crassipes (Mart.) Solms + Nymphaeoides peltatum (Gmel.) O. Kuntze |
| 8             | Trapa bispinosa Roxb. + Microcarpaea minima (Koen.) Merr. + Isachne globosa (Thunb.) Kuntze + Carex spp. Eleocharis tuberosa (Roxb.) Roem. et Schult. + Ludwigia adscendens (L.) Hara + Elymus dahuricus Turcz.-Carex spp. + Myriophyllum spicatum L.-Hydriella verticillata (L.f.) Royle + Hydrilla verticillata (L.f.) Royle-Vallisneria natans (Lour.) Hara. |
| 9             | Carex rhynchophypha C. A. Mey. Blyxa japonica (Miq.) Maxim. + juncellus serotinus + Sagittaria pygmaea Miq.-Hydriella verticillata (L.f.) Royle + Monochoria vaginalis (Burm.f.) Pres-Rotala rotundifolia (Buch.-Ham) Koehne. |
| 10            | Eichhornia crassipes (Mart.) Solms + Nymphaeoides peltatum (Gmel.) O. Kuntze + Marsilea quadrifolia L. + Alteranthera philoxeroides (Mart.) Griseb.-Eichhornia crassipes (Mart.) Solms. Hydrocharis dubia (Bl.) Back.-Triarrherca sacchariflora + Carex spp. + Hydriella verticillata (L.f.) Royle + Vallisneria natans (Lour.) Hara + Ceratophyllum demersum L. + Najas marina-Eleocharis tuberosa (Roxb.) Roem. et Schult. + Carex spp.-Triarrherca sacchariflora. |
| 11            | Vallisneria natans (Lour.) Hara + Nymphaeoides peltatum (Gmel.) O. Kuntze + Carex spp. + Limnophila heterophylla (Roxb.) Benth. + Ottelia alismoides (L.) Pers. + Trapa bispinosa Roxb.-Ottelia alismoides (L.) Pers. + Utricularia aurea Lour. + Hydrocharis dubia (Bl.) Back.-Trapa bispinosa Roxb. + Carex rhynchophypha C. A. Mey. + Trapa indica Oliv. + Sagittaria pygmaea Miq. + Eleocharis tuberosa (Roxb.) Roem. et Schult. Carex spp. + Nymphaeoides peltatum (Gmel.) O. Kuntze + Eleocharis tuberosa (Roxb.) Roem. et Schult. + Zizania caduciflora (Turch. ex Trin.) H.-M. + Elymus dahuricus Turcz. + Phragmites communis Trin. + Ceratophyllum demersum L. |
| 12            | Carex spp. Elymus dahuricus Turcz. |
| 13            | Carex spp. + Eleocharis tuberosa (Roxb.) Roem. et Schult. + Nymphaeoides peltatum (Gmel.) O. Kuntze + Eleocharis tuberosa (Roxb.) Roem. et Schult.-Polygonum L. |
| 14            | Carex spp. + Polygonum L. + Eleocharis tuberosa (Roxb.) Roem. et Schult.-Polygonum L. + Carex spp.-Eleocharis tuberosa (Roxb.) Roem. et Schult. |
| 15            | Carex spp. + Polygonum L. + Cynodon dactylon (Linn.) Pers. Carex spp. + Elymus dahuricus Turcz. + Phragmites communis Trin.-Cynodon dactylon (Linn.) Pers. Ceratophyllum demersum L. + Nymphaeoids peltatum (Gmel.) O. Kuntze + Imperata cylindrica (Linn.) Beauv + Carex spp. + Hydriella verticillata (L.f.) Royle + Vallisneria natans (Lour.) Hara + Eleocharis tuberosa (Roxb.) Roem. et Schult. |
| 16            | Carex spp. |
| 17            | Carex spp. + Eleocharis tuberosa (Roxb.) Roem. et Schult. + Imperata cylindrica (Linn.) Beauv. Carex spp. + Trapa bispinosa Roxb. + Ceratophyllum demersum L. + Utricularia aurea Lour. + Triarrhena lutioriparia + Triarrherca sacchariflora. Hydrocharis dubia (Bl.) Back.+ Triarrherca sacchariflora + Carex spp. + Hydriella verticillata (L.f.) Royle + Najas marina + Eleocharis tuberosa (Roxb.) Roem. et Schult. + Ceratophyllum demersum L. + Carex spp. + Nymphaeoids peltatum (Gmel.) O. Kuntze + Vallisneria natans (Lour.) Hara. Najas marina + Trapa bispinosa Roxb. + Carex spp. + Zizania caduciflora (Turch. ex Trin.) H.-M. + Triarrhena lutioriparia. Polygonum L. + Limnophila sessiliflora (Vahl.) Bl. + Utricularia vulgaris L. + Carex spp. + Eleocharis tuberosa (Roxb.) Roem. et Schult. + Elymus dahuricus Turcz. + Polygonum L. |
Table 3: The habitat profiles of main association types in macrophyte communities in the Poyang Lake.

| Serial number | Cluster type                                      | Sampling date    | Multiplicity-cluster degree | Height (cm) | Number of plants | Coverage (%) |
|---------------|---------------------------------------------------|------------------|-----------------------------|-------------|------------------|--------------|
| 1             | *Limnophila sessiliflora* (Vahl.) Bl.              | 2013/9/7         | 4, 3                        | 15–25       | 82               | 60           |
|               |                                                   | 2013/9/14        | 3, 3                        | 3–3         | 78               | 60           |
| 2             | *Limnophila heterophylla* (Roxb.) Benth.           | 2013/9/7         | 5, 4                        | 37–45       | 144              | 90           |
|               |                                                   | 2013/9/13        | 4, 4                        | 3–10        | 135              | 50           |
|               |                                                   | 2013/9/7         | 4, 5                        | 45–70       | 294              | 80           |
| 3             | *Carex* spp.                                      | 2013/9/7         | 3, 3                        | 30–80       | 170              | 40           |
|               |                                                   | 2013/9/8         | 5, 5                        | 50–100      | 3600             | 100          |
|               |                                                   | 2013/9/13        | 4, 5                        | 25–65       | 300              | 70           |
| 4             | *Vallisneria natans* (Lour.) Hara                 | 2013/9/7         | 5, 3                        | 45–70       | 26               | 90           |
|               |                                                   | 2013/9/12        | 5, 3                        | 15–30       | 20               | 90           |
|               |                                                   | 2013/9/7         | 3, 3                        | 20–50       | 850              | 30           |
| 5             | *Eleocharis tuberosa* (Roxb.) Roem. et Schult.    | 2013/9/11        | 5, 5                        | 30–85       | 1000             | 90           |
|               |                                                   | 2013/9/14        | 1, 4                        | 18–35       | 350              | 10           |
| 6             | *Phragmites communis* Trin.                       | 2013/9/7         | 2, 2                        | 60–250      | 80               | 15           |
|               |                                                   | 2013/9/14        | 1, 1                        | 56–70       | 36               | 10           |
| 7             | *Zizania caduciflora* (Turcz. ex Trin.) H.-M.     | 2013/9/7         | 4, 5                        | 60–120      | 260              | 60           |
| 8             | *Eleocharis tuberosa* (Roxb.) Roem.et Schult.-Polygonum L. | 2013/9/8 | 3, 3                        | 70–168      | 144              | 85           |
| 9             | *Alternanthera philoxeroides* (Mart.) Griseb.      | 2013/9/9         | 5, 5                        | 25–49       | 1000             | 95           |
|               |                                                   | 2013/9/9         | 5, 4                        | 10–50       | 900              | 100          |
|               |                                                   | 2013/9/9         | 5, 5                        | 42–70       | 672              | 95           |
| 10            | *Paspalum distichum* L.- *Alternanthera philoxeroides* (Mart.) Griseb. | 2013/9/9 | 4, 3                        | 10–25       | 1600             | 70           |
|               |                                                   | 2013/9/9         | 4, 3                        | 80–200      | 25               | 60           |
| 11            | *Typha angustifolia* L.- *Alternanthera philoxeroides* (Mart.) Griseb. | 2013/9/9 | 4, 3                        | 32–55       | 600              | 80           |
| 12            | *Paspalum distichum* L.                           | 2013/9/9         | 4, 5                        | 20–35       | 1000             | 100          |
| 13            | *Aeschynomene indica* Linn.                       | 2013/9/9         | 5, 3                        | 180–200     | 23               | 85           |
| 14            | *Oryza rufipogon* Griff.                          | 2013/9/9         | 5, 5                        | 70–120      | 160              | 100          |
| 15            | *Juncellus serotinus*                             | 2013/9/9         | 5, 3                        | 90–120      | 23               | 30           |
|               |                                                   | 2013/9/10        | 5, 3                        | 20–60       | 850              | 90           |
| 16            | *Carex* spp.- *Eleocharis tuberosa* (Roxb.) Roem. et Schult. | 2013/9/9 | 4, 3                        | 43–79       | 640              | 60           |
|               |                                                   | 2013/9/9         | 3, 4                        | 4–10        | 2000             | 40           |
| 17            | *Polygonum L.*                                    | 2013/9/10        | 5, 5                        | 20–45       | 1000             | 90           |
|               |                                                   | 2013/9/14        | 3, 3                        | 20–72       | 57               | 60           |
| 18            | *Cynodon dactylon* (Linn.) Pers.                  | 2013/9/10        | 5, 5                        | 6–10        | 420              | 90           |
| 19            | *Marsilea quadrifolia* L.                         | 2013/9/10        | 3, 2                        | 15–25       | 368              | 40           |
| 20            | *Eichhornia crassipes* (Mart.) Solms              | 2013/9/10        | 3, 2                        | 45–55       | 21               | 80           |
| 21            | *Isachne globosa* (Thunb.) Kuntze                 | 2013/9/10        | 5, 4                        | 12–25       | 170              | 95           |
| 22            | *Elymus dahuricus* Turcz.- *Carex* spp.           | 2013/9/10        | 5, 4                        | 20–35       | 700              | 80           |
| 23            | *Ludwigia adscendens* (L.) Hara                   | 2013/9/10        | 2, 5                        | 70–120      | 150              | 30           |
| 24            | *Carex rhynchocephya* C. A. Mey.                  | 2013/9/10        | 3, 3                        | 100–150     | 750              | 50           |
| 25            | *Sagittaria pygmaea* Miq.- *Hydilla verticillata* (L.f.) Royle | 2013/9/10 | 3, 3                        | 10–17       | 23               | 40           |
| 26            | *Phragmites communis* Trin.- *Cynodon dactylon* (Linn.) Pers. | 2013/9/11 | 3, 3                        | 30–90       | 95               | 40           |
| 27            | *Nymphoides peltatum* (Gmel.) O. Kuntze           | 2013/9/11        | 4, 3                        | 3–8         | 560              | 60           |
|               |                                                   | 2013/9/13        | 4, 3                        | 35–55       | 30               | 60           |
### Table 3: Continued.

| Serial number | Cluster type                          | Sampling date | Multiplicity-cluster degree | Height (cm) | Number of plants | Coverage (%) |
|---------------|---------------------------------------|---------------|------------------------------|-------------|------------------|--------------|
| 28            | *Imperata cylindrica* (Linn.) Beauv    | 2013/9/11     | 5, 5                         | 35–65       | 2560             | 90           |
|               |                                       | 2013/9/12     | 5, 4                         | 60–110      | 960              | 80           |
|               |                                       | 2013/9/12     | 5, 4                         | 60–110      | 960              | 80           |
| 29            | *Triarrhena lutarioriparia*           | 2013/9/12     | 5, 4                         | 70–165      | 650              | 85           |
| 30            | *Triarrherca sacchariflora*           | 2013/9/12     | 5, 5                         | 80–103      | 200              | 95           |
| 31            | *Hydrocharis dubia* (BL) Back.        | 2013/9/13     | 3, 3                         | 10–15       | 30               | 50           |
| 32            | *Ottelia alismoides* (L.) Pers.       | 2013/9/13     | 3, 4                         | 15          | 20               | 80           |
| 33            | *Hydrocharis dubia* (BL) Back.-*Trapa bispinosa* Roxb. | 2013/9/13    | 4, 4                         | 10–15       | 96               | 70           |
| 34            | *Carex rhyophypha* C. A. Mey.         | 2013/9/13     | 4, 4                         | 60–100      | 350              | 60           |
| 35            | *Sagittaria pygmaea* Miq.            | 2013/9/13     | 5, 3                         | 10–20       | 52               | 75           |
| 36            | *Neprolepis cordifolia* (L.) Presl    | 2013/9/14     | 5, 5                         | 13–25       | 500              | 95           |
| 37            | *Sambucus chinensis* Lindl.          | 2013/9/14     | 2, 2                         | 10–27       | 100              | 40           |
| 38            | *Elymus dahuricus* Turcz.             | 2013/9/11     | 3, 3                         | 20–70       | 40               | 50           |
|               |                                       | 2013/9/14     | 5, 4                         | 62–131      | 280              | 80           |

3.3. Quantitative Characteristics of Aquatic Plant Communities in the Poyang Lake. The number of aquatic plants in the lake area was 67, and the total of the aquatic plants’ fresh weight was 1519.41 t. Among them, the *Carex* spp., *Eleocharis tuberosa* (Roxb.) Roem. et Schult., and emergent plants were 919.66 t, while the submerged plants and floating-leaved plants were up to 599.75 t. The distribution of amphibians accounted for 58.21% of the total number of samples, and there were 14.93%, 16.42%, and 10.45% of the total plants number for the emergent plants, submerged plants, and floating-leaved plants in the Poyang Lake, respectively. It could be found that the number of amphibians was the dominant plant species in the Poyang Lake, and their quantity and percentage of the total biomass were predominant, which were far more than the other three life forms (Table 4).

Among the 16 typical cluster types, the total biomass was the highest in the *Carex* spp. cluster, followed by the *Polygonum* L. cluster, the *Zizania caduciflora* (Turcz. ex Trin.) H.-M. cluster, and the *Imperata cylindrica* (Linn.) Beauv cluster (Figure 2). This was in contrast to 1998 aquatic vegetation survey [25], the difference was large, and the proportion of *Vallisneria natans* (Lour.) Hara and *Hydriila verticillata* (L.f.) Royle was the largest, while the proportion of *Carex* spp. and *Polygonum* L. was very low. In the amphibians, *Carex* spp. cluster was the dominant species, and the distribution number was 34. In the emergent plants, *Zizania caduciflora* (Turcz. ex Trin.) H.-M. cluster, and *Phragmites communis*...
Table 4: Number of the association area and standing crop (fresh weight) in the total vegetation area and standing crop in the Poyang Lake.

| Serial number | Plant community                        | Quadrat number | Fresh weight | Existing quantity (t) | Dry weight | Dry weight range |
|---------------|----------------------------------------|----------------|--------------|-----------------------|------------|------------------|
| 1             | *Imperata cylindrica* (Linn.) Beauv     | 3              | 38.33        | 35–45                 | 10.26      | 9.18–10.8        |
| 2             | *Eleocharis tuberosa* (Roxb.) Roem. et Schult. | 6              | 94.08        | 11.5–380              | 6.285      | 4.62–11.34       |
| 3             | *Eleocharis tuberosa* (Roxb.) Roem. et Schult.-*Polygonum* L. | 2              | 137.5        | 75–200                | 21.345     | 20.65–22.04      |
| 4             | *Najas marina*                         | 1              | 35           | —                     | 25.53      | —                |
| 5             | *Triarrhena sacchariflora*             | 1              | 40           | —                     | 9.32       | —                |
| 6             | *Cynodon dactylon* (Linn.) Pers.       | 1              | 40           | —                     | 5.8        | —                |
| 7             | *Zizania caduciflora* (Turcz. ex Trin.) H.-M. | 2              | 99.76        | 9.52–190              | 104.08     | 6.46–201.7       |
| 8             | *Hydrilla verticillata* (L.f.) Royle   | 2              | 42.5         | 35–50                 | 6.195      | 3.61–8.78        |
| 9             | *Utricularia auricula* Lour.           | 1              | 50           | —                     | 15.28      | —                |
| 10            | *Elymus dahuricus* Turcz.              | 3              | 148.05       | 14.15–340             | 23.86333   | 5.99–55          |
| 11            | *Ceratophyllum demersum* L.            | 4              | 80           | 35–150                | 6.7775     | 3.07–10.08       |
| 12            | *Vallisneria natans* (Lour.) Hara      | 2              | 29.75        | 4.5–55                | 3.86       | 3.24–4.48        |
| 13            | *Utricularia vulgaris* L.              | 1              | 25           | —                     | 3.6        | —                |
| 14            | *Polygonum* L.                        | 6              | 34.11333     | 10.34–50              | 6.218333   | 4.6–9.71         |
| 15            | *Trapa bispinosa* Roxb.               | 2              | 57.5         | 55–60                 | 6.35       | 2.93–9.77        |
| 16            | *Phragmites communis* Trin.           | 1              | 120          | —                     | 15.43      | —                |
| 17            | *Phragmites communis* Trin.-*Cynodon dactylon* (Linn.) Pers. | 1              | 20           | —                     | 9.4        | —                |
| 18            | *Triarrhena lutariairiparia*           | 1              | 27.03        | —                     | 11.73      | —                |
| 19            | *Limnophila sessiliflora* (Vahl) Blume | 1              | 12.8         | —                     | 4.29       | —                |
| 20            | *Carex* spp.                          | 20             | 72.992       | 24.84–360             | 8.7425     | 4.22–16.96       |
| 21            | *Carex* spp.-*Eleocharis tuberosa* (Roxb.) Roem. et Schult. | 1              | 35           | —                     | 8.53       | —                |
| 22            | *Nymphoides peltatum* (Gmel.) O. Kuntze | 5              | 280          | 20–280                | 43.4       | 3.3–43.4         |

Trin. cluster distribution were in large quantities, each for 2. In the submerged plants, the distribution of *Ceratophyllum demersum* L. cluster was the largest, with 4 species. In the floating-leaved plants, the distribution of *Nymphoides peltatum* (Gmel.) O. Kuntze cluster was the largest, with 4 species. This pattern of distribution was associated with its reproductive strategies. The vast majority of grassland vegetation in the Poyang Lake interrupted their breeding during the summer season, which was suitable for plant growth during the flood season. Therefore, the plant with vigorous regenerative ability, for example, *Carex* spp., had become the most dominant species in the Poyang Lake grassland vegetation and *Carex* spp. were submerged by flood and became the carp and crucian carp spawning attachment. cluster in Poyang Lake was not only beneficial to grazing firewood and green manure, but also conducive to the reproduction of grass-lying fish sand the growth of herbivorous fish. The production of carp and crucian carp in the fishery of the Poyang Lake was about half of the total output, which was closely related to the seasonal succession of *Carex* spp. [26].

4. Conclusions

In this study, the distribution of aquatic vegetation and associated community diversity and biomass in the Poyang Lake were investigated with the aim of getting information for the monitoring and protection of aquatic plants in the Poyang Lake. Some interesting conclusions were obtained as follows:
(1) Nine species of aquatic plants were found in the Poyang Lake and Carex spp. dominated absolutely with multi grades 58 in the Poyang Lake. Most of the aquatic plant species were amphibians and a small number of the species were found on the beach floating plants or submerged plants or emergent plants.

(2) The vegetation of the Poyang Lake scattered in different areas which could be divided into 31 major plant communities and 5 plant zones including amphibian, emergent, floating-leaved, submerged, and floating input. The majority of aquatic vegetation distribution area in the Poyang Lake was Carex spp. cluster.

(3) There were 67 aquatic plants in the Poyang Lake, and the total of the aquatic plants' fresh weight was 1519.41 t. Moreover, it could be found that the amphibians were the dominant plant species in the Poyang Lake.

**Competing Interests**

The authors declare that they have no competing interests.

**Authors' Contributions**

Wei Du, Ziqi Li, and Zengxin Zhang analyzed the data, drew the figures, and finished the draft of the manuscript. Qiu Jin, Xi Chen, and Shanshan Jiang participated in the writing of this manuscript. All authors read and approved the final manuscript.

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