Ecological Stoichiometric Characteristics of Carbon, Nitrogen and Phosphorus in an Urban Wetland in Qinghai-Tibetan Plateau
—Taking Huoshaogou wetland in Xining City as an example

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Abstract—Ecological stoichiometry has been widely applied to ecosystem management around the world, mainly through analysis of carbon (C), nitrogen and phosphorus (P). Ecological stoichiometric characteristics have important implying meaning on key processes and mechanisms of protection, restoration and reconstruction of urban wetlands. This study selected the Huoshaogou urban wetland of Xining city as a case study. On the basis of experimental analysis data, we analyzed the characteristics of C, N and P contents and the inner coupling relationships among the C, N and P in sediments and plants of this wetland. Results indicated that: 1) The contents of the C in sediments are high and the C, N and P contents in the plants are relatively low. N and P in the sediments are, respectively, mainly at "level 1" and "level 4" in national soil nutrient classifications. 2) Limiting factors of plants growth: P may limit the plants growth in 1-5 cascades, N may limit the plants growth in 6-9 cascades; 3) There are statistically significant correlations between C and C/P in the sediments and N/P in the plants (P<0.05). The current results may provide theoretical support for the management of the Huoshaogou wetland.

Keywords—Ecological stoichiometric characteristics; sediments; plants; Urban wetlands

I. INTRODUCTION

As an important part of urban social-ecological systems [1, 2], urban wetlands provide significant ecological, environmental and social services [3]. With the acceleration of urbanization processes, unreasonable development and utilization have resulted in various problems in urban wetlands, such as area reducing, water pollution, biodiversity decreasing and functional degradation, etc. [4].

Ecological stoichiometry refers to research multiple chemical elements (C, N and P) in different ecosystems [5]. It is an effective method to learn the characteristics of C, N and P contents and coupling relationships among the different elements in plants and sediments [6]. Then we can understand the states of plants and the balance of whole ecosystems [7]. Thus, Ecological stoichiometry characteristics have direct indication significance on key processes and mechanisms of protection, restoration and reconstruction of urban wetlands [8-11]. There are a large number of studies on ecological stoichiometry in different spatio-temporal scales, for different ecosystem types [7] and vegetation types [12-13]. It is necessary to do more research on urban wetlands on the Qinghai-Tibetan Plateau for the two reasons: 1) The processes and technologies of protection, restoration and reconstruction on urban wetlands are obviously different from the natural wetlands and difficult to develop; 2) In the alpine region, ecological environment of urban wetlands is fragile and more sensitive to climate change, human impact and urbanization and need more attentions. Therefore, it is significant to take an urban wetland on the Qinghai-Tibetan Plateau as a research object. C, N and P are the necessary nutritional elements in plants growth and function exertion [13], cycles of them affect ecosystem productivity [14]. Ratios of C, N and P have important implications for plants [15]; C/N and C/P indicate the biological nutrient usage efficiency [16] and states of biological community structure, function and productivity [17]; N/P reflects if the N or P limits plants growth [18]. Thus, Ecological stoichiometry characteristics of C, N and P could indirectly tell us the interactive relationships between the plants and sediments and nutrient utilization strategies of plants [19]. It is also useful to understand inner balance mechanisms of ecosystems, and provides strong theoretical support for urban wetland management [20, 21].
II. STUDY AREA

The Huoshaogou River Wetland is located in eastern Xining city, Qinghai Province (N36°38'15"-36°39'01", E101°42'40"-101°43'55") (Fig. 1). The Huoshaogou River is a first tributary of the Huangshui River and the second tributary of the Yellow River. The area of the Huoshaogou River basin is 131 km² and its climate is continental plateau semi-arid, with thin air, long hours of sunshine and strong ultraviolet radiation.

For frequent human activities and sparse plants, soil erosion of the Huoshaogou wetland used to be very serious. In 2006, the river downstream restoration project had been carried out and 9 cascade wetlands were constructed. With the proceeding of restoration project, the ecological structure and function of the Huoshaogou wetland have been restored, making the wetland an important landscape in the Xining city.

III. MATERIAL METHOD

A. Samples Collection and Pretreatment

Sediment and plant samples were collected in September 2015. Plants samples and sediments were collected in each cascade. All the samples were baked at 105°C for 30 minutes, then put in a drying box (80°C) until the samples were dried completely. Finally, samples were weighed and sieved over mesh-sizes of 100 mm.

B. Indoor Determination

The contents of total organic carbon (TOC) in the sediments and plants were respectively determined by potassium permanganate oxidation external heating method and the Italian ouvert element analyzer (EA3000). The contents of total nitrogen (TN) and total phosphorus (TP) were determined, respectively, by the Alkaline potassium per sulfate digestion ultraviolet spectrophotometer and ammonium molybdate spectrophotometer method.

C. Data Processing

The average, maximum, minimum, range and coefficient of variation of C, N, P and C/N, C/P, N/P of the sediments and plants were processed by Excel 2003; The correlations of C, N, P, C/N, C/P and N/P between the sediments and the plants were processed by SPSS19.

IV. RESULTS

A. The General Characteristics of C, N, P of Sediments

<table>
<thead>
<tr>
<th>Elements</th>
<th>Average Value</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Coefficient of Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>23.66</td>
<td>18.29</td>
<td>30.19</td>
<td>0.16</td>
</tr>
<tr>
<td>N</td>
<td>2.34</td>
<td>1.72</td>
<td>3.23</td>
<td>0.21</td>
</tr>
<tr>
<td>P</td>
<td>0.66</td>
<td>0.45</td>
<td>1.09</td>
<td>0.33</td>
</tr>
</tbody>
</table>

The contents of C, N and P in sediments of the Huoshaogou wetland are shown in Table I, and the average contents of C, N and P are, respectively, 23.66mg/g, 2.34mg/g and 0.66mg/g. The spatial variations of C, N and P in sediments are significant (Fig. II): Basically, the contents of C and N changed with the decreasing cascades. C and N are closely linked and mutual influenced (r=0.74, P<0.05). A similar relationship between the contents of C and N was observed as follows: The highest value of C and N appeared in the 3rd cascades, the lowest value appeared in the 5th cascades. C and N contents have a sudden decline in the 6th and 7th cascade, respectively. The contents of P decreases markedly with the descending cascades, and the highest values and the lowest values are, respectively, in the 8th and 2st cascade.

Figure 1. The location and cascades of Huoshaogou river wetland.

Figure 2. The variation tendency of C, N and P in sediments of cascades.

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B. Characteristics of C, N, P Contents in Dominant Plants

As is shown in Table II, the mean values of C, N and P contents in emergent plants are significantly higher than that of Yangtze River [23](0.82mg/g) and Yellow River [23](0.23mg/g). Lower water velocity and higher vegetation may contribute to the above results [24,25]. According to standards in Table IV, most of sediments (N) are at "level 1" of national soil nutrient classifications. N in sediments is mainly derived from plants residues and biological nitrogen fixation [26] and a small amount of N comes from precipitation and flood transportation [27]. The contents of N are significantly lower than marsh wetlands of Jilin Province [28], and the contents of C, N and P in the river wetlands are significantly lower than the lakes and swamps [29]. Organic matter decomposes slowly under the anoxic condition, which lead peat accumulation is more significant and the greater amount of N accumulation. That also can explain why the contents of N in sediments are significantly higher than a river wetland in Ningxia Province [29]. The values of C/N in sediments are within the average range values in Chinese soil (10-12) [30]. The average value of C/P in sediments is lower than C/P average values in Chinese soil [31]. C/P indicate the ability of sediments bacteria to release and fixation of P [29] and C/P indicates low availability of P [19]. N/P in sediments are higher than the other study results [19, 32-33], indicating lower contents of P in the Huoshaoqou wetland.

The highest C and N in sediments appeared at the 3rd cascade. Reed and Typha minima have obvious effect on the recycles of C and N. The lowest contents of C and N appeared in the 5th cascade. The spatial variability of P contents is significant and they declined with the decreasing cascades. This is different from the results of grassland ecosystem in the hilly area of Loess plateau [34]. The highest contents of P(1.09mg/g) appeared in the 8th cascade and the lowest P contents (0.45mg/g) appeared in the 2nd cascade.

As depicted in Table III, C/N, C/P and N/P are fluctuated in different cascades. This is consistent with the theory of dynamic equilibrium [21]. Variation coefficient of plants is ranked as C/N>C/P>N/P>0.37mg/g and C/P in emergent plants and the submerged plants presented big difference, since different wetland plants have ability in carbon absorption. Average value of C/N(40.50) in emergent plants is higher than that of the submerged plants(15.79), indicating higher N utilization efficiency in emergent plants.

A. Effects of Plants on Sediments

The average C content in Huoshaoqou sediments is much higher than that of Yangtze River [23](0.82mg/g) and Yellow River [23](0.23mg/g). Lower water velocity and higher vegetation may contribute to the above results [24,25]. According to standards in Table IV, most of sediments (N) are at "level 1" of national soil nutrient classifications. N in sediments is mainly derived from plants residues and biological nitrogen fixation [26] and a small amount of N comes from precipitation and flood transportation [27]. The contents of N are significantly lower than marsh wetlands of Jilin Province [28], and the contents of C, N and P in the river wetlands are significantly lower than the lakes and swamps [29]. Organic matter decomposes slowly under the anoxic condition, which lead peat accumulation is more significant and the greater amount of N accumulation. That also can explain why the contents of N in sediments are significantly higher than a river wetland in Ningxia Province [29]. The values of C/N in sediments are within the average range values in Chinese soil (10-12) [30]. The average value of C/P in sediments is lower than C/P average values in Chinese soil [31]. C/P indicate the ability of sediments bacteria to release and fixation of P [29] and C/P indicates low availability of P [19]. N/P in sediments are higher than the other study results [19, 32-33], indicating lower contents of P in the Huoshaoqou wetland.

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B. Nutrient Utilization Strategies of Plants

The average content of C in dominant plants of Huoshaoqou wetland is lower than the forest ecosystem in the north and south transects in eastern China (480.1mg/g) [35]. N and P are lower than the average contents (13.54mg/g, 1.72mg/g) of China wetlands [18]. N and P in plants are significant mutual correlated (r=0.84, P<0.05). N is significant correlated with P in Emergent plants (r=0.91, P<0.05). There is no significant correlation among the C, N, and P in submerged plants, indicate that weak synergies in C, N and P [21]. The maximum C/P in plants is 1799.57, indicating the maximum use-effectiveness of P. The values of N/P are higher than the average values of terrestrial plants in China [35,36](14.4).
If N/P is less than 14, there is N limitation. Contrarily, there is P limitation [37]. These limitations would affect the nutrition absorb efficiency and photosynthetic capacity of plants [38]. Plants of 1-5 cascades are mainly limited by the P and plants in 6-9 cascades are mainly limited by the N. It is not reasonable to conclude that these nutrient supply deficiencies based on the low contents of certain elements in blades [39]. The indicating functions of N/P in different blades should be determined by specific region, ecosystem, and species [40].

### TABLE V. CORRELATIONS AMONG C, N, P CONTENTS AND C/N, C/P, N/P IN SEDIMENTS AND PLANTS

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>N</th>
<th>P</th>
<th>C/N</th>
<th>C/P</th>
<th>N/P</th>
</tr>
</thead>
<tbody>
<tr>
<td>sediments</td>
<td>&amp;dquo;level 1&amp;dquo;</td>
<td>&amp;dquo;level 4&amp;dquo;</td>
<td>&amp;dquo;level 1&amp;dquo;</td>
<td>&amp;dquo;level 4&amp;dquo;</td>
<td>&amp;dquo;level 1&amp;dquo;</td>
<td>&amp;dquo;level 4&amp;dquo;</td>
</tr>
<tr>
<td>C</td>
<td>0.55</td>
<td>0.09</td>
<td>0.40</td>
<td>0.46</td>
<td>0.04</td>
<td>-0.11</td>
</tr>
<tr>
<td>N</td>
<td>-0.12</td>
<td>-0.38</td>
<td>0.06</td>
<td>0.46</td>
<td>-0.12</td>
<td>-0.25</td>
</tr>
<tr>
<td>P</td>
<td>-0.41</td>
<td>-0.53</td>
<td>0.09</td>
<td>0.37</td>
<td>-0.31</td>
<td>-0.38</td>
</tr>
<tr>
<td>C/N</td>
<td>0.45</td>
<td>0.30</td>
<td>0.18</td>
<td>0.2</td>
<td>0.28</td>
<td>0.24</td>
</tr>
<tr>
<td>C/P</td>
<td>0.60</td>
<td>0.05</td>
<td>-0.2</td>
<td>-0.1</td>
<td>0.53</td>
<td>0.5</td>
</tr>
<tr>
<td>N/P</td>
<td>0.7*</td>
<td>0.57</td>
<td>-0.4</td>
<td>-0.12</td>
<td>0.73*</td>
<td>0.66</td>
</tr>
</tbody>
</table>

As is shown in Table V, there are no significant correlations between C, N, P, C/N, C/P, N/P in sediments and C, N, P in plants, which are different from the study results of Poyang Lake [30] and Minjiang Estuary [7]. These results may be related to different regions, sampling methods, etc. There is a significant correlation among C, C/N and N/P in plants (P <0.05), as the C and N in plants may indirectly affect the absorbing ability for N and P and then change the N/P.

### VI. CONCLUSIONS

We analyzed the ecological stoichiometric characteristics of C, N and P in the sediments and plants in the Huoshaozugou wetland, and discussed the effects of the plants on the C, N and P in the sediments and plants nutrient utilization strategies. The main conclusions are as follows:

1) The large input of plants litters and the strengthening of humification improve the contents of C and N in the sediments of the Huoshaozugou wetland. The contents of C are high, N and P in the sediments are, respectively, mainly at &quot;level 1&quot; and &quot;level 4&quot; of national soil nutrient classifications. The spatial variability of C, N and P in sediments is significant, maybe affected by the distribution of plants or the cascades.

2) The absorbing capacities of plants for C, N and P in Huoshaozugou wetland are not strong enough, and the productivity of plants in this wetland is low. The plants of 1-5 cascades and the 6-9 cascades are, respectively, mainly limited by P and N.

3) C, N, P, C/N, C/P and N/P in sediments are not significant correlated with C, N and P in plants, and contents of C and C/N of sediments are correlated with N/P of plants (P<0.05). The relationships between sediments and plants are not clear enough and still need further study.

### ACKNOWLEDGMENT

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### REFERENCES


