Households' willingness to reduce pollution threats in the Poyang Lake region, southern China

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A B S T R A C T

Environmental threats to wetland ecosystems are increasing, and these ecosystems are becoming increasingly sensitive to human impacts, leading to deterioration of these already fragile ecosystems. Poyang Lake is the largest freshwater lake in China and one of the most important wetlands in the world. However, water pollution and related environmental changes have increasingly drawn the scientific community's attention. The goal of this paper is to provide insights into the environmental threats to the Poyang Lake region as perceived from the households' perspective, and to investigate their willingness to pay for conservation of the lake's environment. We collected both primary and secondary data through a questionnaire delivered to 270 households and analysis of existing water monitoring data. The major threat confronting the Poyang Lake region is water pollution; water quality, as represented by the total nitrogen (TN) and total phosphorus (TP) concentrations and by chemical oxygen demand (COD), suggests a moderate to severe degree of eutrophication. The situation has worsened in recent years, particularly due to high TN and TP in agricultural drainage water caused by increasingly intensive use of chemical fertilizers by local farmers. Most households were willing to pay to mitigate these threats, but the magnitude of the payment was related to a farmer's dependence on the lake for their production and daily life. The results of our analysis will help managers develop more effective environmental management policies.

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1. Introduction

Human societies depend on ecosystems and their delivery of environmental services, but through the actions of broader biogeochemical cycles, human activities at one place can influence environmental conditions and people elsewhere (Vatn, 2010). This problem becomes severe in wetland ecosystems, where people and the environment are interconnected through the water resources provided by the ecosystem and used by local residents. This is particularly true in China's Poyang Lake region. Poyang Lake is the largest freshwater lake in China and one of the most important wetlands in the world. It is situated in northern Jiangxi province (Fig. 1), near the southern bank of the middle and lower reaches of the Yangtze River, which accounts for 9% of the Yangtze River basin. The lake exhibits marked seasonal changes in both area and volume (Wang et al., 2004). Poyang Lake is an overflow lake; instead of being supplied by streams or rivers that flow directly into the lake, it increases in size when the Yangtze River overflows its banks or during heavy rainfalls that produce large volumes of surface flow, and decreases in size due to less water inflow from the Yangtze River, reduced precipitation, deep drainage, and evaporation, and both receives and releases water in response to seasonal variations. The shape and water level in the lake vary seasonally, with a 13-m difference in the water height between the summer rainy season and the winter dry season. In the study area, mean temperatures range from a low of 4.4 °C in winter to a high of 30.0 °C in summer. Annual precipitation averages 1387–1795 mm, with 48.2% of this total falling from a low of 4.4 °C in winter to a high of 30.0 °C in summer. Annual precipitation averages 1387–1795 mm, with 48.2% of this total falling during the summer growing season (Wang et al., 2004). Because of the fertile surrounding land and rich bio-resources, Poyang Lake is an important habitat for a number of wild animals, including 159 water bird species (53% of the total number in China). It is one of the most important overwintering areas for migratory water birds in Asia, and is home to 98% of the global population of Siberian cranes (Grus leucogeranus), 50% of white-naped cranes (Grus vipio), 50% of swan geese (Anser cygnoides), and tens of thousands of egrets, spoonbills, storks, swans, geese, ducks, and shorebirds. Based on the existing research (e.g., Li et al., 2009), it is known that the Poyang Lake serves all the main functions of an ecosystem, including provisioning,
supporting, and regulating environmental functions, as well as serving cultural and recreational functions for local residents.

Poyang Lake and its surrounding regions comprise two cities and ten counties: Nanchang and Jiujiang cities, and Nanchang, Xinjiang, Jinxian, Yongxiu, Dean, Xingzi, Hukou, Yugan, and Poyang counties. These cover a total land area of 202.89 ha and sustain a population of 8.86 million. The rural population totals 5.99 million (68% of the total). Farmers practice small-scale farming activities, and cultivate more than ten types of crops in small farm fields, including rice (double or triple cropping), cotton, sweet potato, beans, peanuts, oil plants, vegetables, and fruits. To ensure a high yield, farmers usually use high inputs of fertilizers and pesticides.

Arable land and water area surrounding the lake are the two main types of land use (Fig. 2), and there is usually competition between the two types of land use in areas at risk of flooding. The area of arable land per capita totals 0.045 ha, which is only 42.4% of China's average value and less than the FAO's minimum recommendation (=0.053 ha) to sustain a human life. The most significant land use changes in recent years have been a decreasing farmland area and an increasing water area. The farmland area decreased by 19 416 ha between 1997 and 2005 (a 4.7% decrease compared with the area of cultivated land in 1997), and the total area of bodies of water increased by 14 661 ha (by 3.9% of the area in 1997) as a result of a land use policy designed to convert cultivated land into natural water areas to assist in wetland conservation (Wang et al., 2004). During this period, the forest area decreased by 1066 ha (0.2% of the 1997 value) and the grassland area decreased by 7.5% of the 1997 value. The built-up land increased from 59 148 ha in 1997 to 62 957 ha in 2005, a 6.4% increase, due to increasing urbanization, and the area of unused land increased slightly (by 0.42%) during the same time period.

Due to population growth (a 19.3% increase from 1997 to 2007) and increasingly intensive economic activities, environmental degradation has begun to occur. Pollution (including eutrophication) has intensified due to the discharge of waste water from industrial and domestic sources (Yang et al., 2011), as well as due to agricultural chemical inputs (Lv, 1996; Wang et al., 2008). The total nitrogen (TN) and total phosphorus (TP) concentrations averaged 1.06 mg/L and 0.067 mg/L, respectively, in the lake water, indicating severe eutrophication (Wang et al., 2008). The region's biodiversity has also decreased due to water pollution (Yu and Sun, 2006).

Local households are the users and managers of the region's resources, and Wunder et al. (2008) noted that, at least in theory, systems based on the needs of these households are “much more likely to be efficient” because these people have better knowledge of the resource and their needs than is possible for a central management agency. Therefore, it is imperative for decision-makers to understand the perspectives of the local people on environmental changes and their willingness to pay (WTP) for conservation of the resources that sustain them; this knowledge can guide them to improve management of the resources. In the present study, we attempted to provide insights into the environmental challenges in the Poyang Lake region from the households’ perspective. To do so, we investigated their willingness to pay for conservation of the lake’s environment. We used environmental

![Fig. 1. Location of Poyang Lake in China and in Jiangxi Province.](image1)

![Fig. 2. Land use patterns in the Poyang Lake region in 2008.](image2)
and socioeconomic research methods based on both primary and secondary data sources for the entire area.

2. Research methodology

The secondary data included a 1:100,000 scale land use map produced from Landsat TM satellite images produced by the Resource and Environmental Data Center of the Chinese Academy of Sciences (Liu et al., 2002). Other environmental data and documents were collected from the Lake Management Committee of Jiangxi Province, the Environmental Protection Department of Jiangxi Province, the Management Committee of the Poyang Lake Nature Reserve, the County Bureau for Science and Technology, and the Township Committees of administrative regions surrounding the lake. The primary data were derived through household questionnaires, group discussions and staff members of the local institutions.

2.1. Household questionnaire

In this study, we defined a household as a basic family unit in which two or more generations live together to share expenditures and incomes. We developed a structured household questionnaire to identify the perceptions of farmers about major environmental changes and their willingness to pay to protect their environment. We surveyed the participants using a structured interview process based on a questionnaire that we had previously tested to ensure the validity of the results. Based on our discussions with the abovementioned institutions, we selected representative communities in which to conduct the survey. The first selection criterion was that the community must be near the lake (Fig. 3); the average distance to the main body of the lake was 1.2 km, with a range of 0.5 to 2.0 km; in addition, the economic activities and daily life of the survey participants must depend heavily on the lake's water resources. Our study included a total of nine villages in six counties, and we surveyed their residents from 25 March to 11 April 2008. We used simple random sampling to select the households, and included a total of 270 householders in the final survey. These families represented more than 40% of the households in the selected villages.

2.2. Group discussions

We used group discussions to clarify any questions raised by the results of our questionnaire-based survey. In the group discussions, we identified the desires of the participants for actions that would resolve the problems they identified. In each group discussion, we attempted to identify shared topics of interest related to resource management and the participants' expectations and willingness to pay for environmental conservation.

2.3. Willingness to pay for environmental conservation

We used the contingent valuation method (CVM) to quantify each household’s willingness to pay (WTP) for environmental conservation. CVM is a kind of stated-preference approach that employs a hypothetical market system to extract WTP or willingness to accept for environmental goods (Carson, 2000; Hadker et al., 1997). CVM has become one of the most widely used valuation techniques due to its flexibility and its ability to estimate total values. In this study, we followed a specific design that has been developed over several years and studies (e.g., Liu and Zhen, 2007; Spash and Hanley, 1995; Spash et al., 2009). The survey was based on four sections: describing the purpose of the survey to participants and gathering of basic demographic data; the participant’s awareness of environmental changes in Poyang Lake and the surrounding regions; the participant’s WTP to reduce pollution threats in the lake; and identification of preferred solutions to the perceived problems.

In principle, the WTP represented the amount a respondent was willing to pay in exchange for an improvement in environmental quality (e.g., conservation of water, soil, and waterbirds; reduced dumping of wastes in the lake). The specific WTP was the maximum amount they would be willing to pay (from their annual income) to restore the environment of Poyang Lake and its surrounding area.

Existing methods for estimating WTP include Continuous CVM (represented by open-ended questions) and Discrete CVM (represented by Dichotomous Choice questions). In Continuous CVM, the interviewees are free to answer the open-ended questions by filling up the maximum amount they are willing to pay; also, it is easy for data analysis. The disadvantage is that it is sometimes difficult for the interviewees to give the appropriate answer when they don't have enough background information about the research object, or when they are actually not sure the maximum amount they are able to offer when they have to do so (Loomis and Walsh, 1997). While in Discrete CV, the interviewees are required to show their willingness by choosing either “Yes” or “No”, they don’t need to indicate the specific amount they are able to pay, which can avoid the problem of inconsistency between the stated WTP and actual amount being able to pay (Hoehn and Randall, 1987).

To gain necessary data for both WTP and associated specific amount to pay, we used single bound Dichotomous CVM method. In the questionnaire, the interviewees were asked “Are you willing to pay for environmental conservation of Poyang lake?”; the answer part include “Yes, I do” and “No, I don't pay” (refers to Table 2), the bid values were given to those who have agreed to pay to choose, which are 75, 188, 375, 750, 1125, 1875, and 3750 CNY per ha (1 CNY = USD 0.1465). Those bid values were determined based on preliminary survey data on income levels and pre-interviews with local people and officials.

For the specific analysis of WTP, Probit/Logit mode (Haneman, 1984) was applied; the standard form of the model is as following:

$$\text{Prob} = 1 - \frac{1}{1 + \exp(B_0 - B_1 X)}$$

(1)

Where,

- $\text{Prob}$ is probability to pay,
- $B_0, B_1$ are regression coefficients,
- $X$ is the bid value.
The relationship between the bid values and the consensus rate (i.e., the proportion of the households who are willing to pay the corresponding bid value) is shown in the following function:

\[ P = \frac{1}{1 + b_0 \times b_1^i} \]  

(2)

Where,

- \( P \) is the consensus rate,
- \( x \) is the bid value, and
- \( b_0 \) and \( b_1 \) are regression coefficients, where \( b_0 = e^{-B_0}, b_1 = e^{B_1}. \)

This is the cumulative probability function, and through differentiation of \( x (dx) \), we can get probability density function; when \( t \) tends to be infinite, the integral probability density function tends to be one.

Expected WTP of households is calculated using the following formula, which is derived from the above formula (1) in the condition of WTP \( \geq 0 \). The data was from close-ended question by giving specific bid values (Park et al., 1991; Sheng et al., 2001).

\[ E(x) = \int_{0}^{+\infty} xpdx \]  

(3)

Where,

- \( \rho \) is probability density of the households’ willingness to pay, and is expressed as:

\[ \rho = -P'(x) \]  

(4)

Where,

- \( P \) is the consensus rate from above formula (2),
- \( P'(x) \) represents the probability of a WTP value less than \( x \).

Continuous CVM including open-ended question was designed to collect information of individual household’s willingness to pay for conservation of water resources in Poyang Lake region. The interviewees were asked “how much are you willing to pay for environmental conservation of Poyang Lake?” To answer this question, each individual put his/her maximum affordable amount for payment. Data is analyzed using the following formula (5) to get their expected amount of WTP:

\[ E(WTP) = \sum_{i=1}^{4} p_i b_i \]  

(5)

Where,

- \( p_i \) is the proportion of households by income groups,
- \( i \) is number of income groups, which is 4 in this study with respective income of (CNY) \( \leq 10 000 \), 10 001 to 20 000, 20 001 to 50 000, \( \geq 50 001 \)
- \( b_i \) is the amount of WTP of each income group (CNY/ha/year).

This individual household based WTP is complementary of the results derived from single bound Dichotomous CVM (i.e., above formula (3)), combination of those two estimation methods is very helpful for analyzing WTP of the household.

We used version 16.0 of the SPSS software for Windows (SPSS, Chicago, IL) to analyze the data wherever needed, and Analyze-Regression—Linear Regression was used to analyze relationships between WTP and householders’ characteristics.

<table>
<thead>
<tr>
<th>Table 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic information on the surveyed households (n = 270).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Basic information</th>
<th>Group</th>
<th>Population</th>
<th>Proportion of total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Male</td>
<td>197</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>73</td>
<td>27</td>
</tr>
<tr>
<td>Age (years)</td>
<td>( \leq 30 )</td>
<td>12</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>31 to 50</td>
<td>104</td>
<td>38.5</td>
</tr>
<tr>
<td></td>
<td>( \geq 51 )</td>
<td>154</td>
<td>57.0</td>
</tr>
<tr>
<td>Education</td>
<td>None</td>
<td>50</td>
<td>18.4</td>
</tr>
<tr>
<td></td>
<td>Primary school</td>
<td>106</td>
<td>39.3</td>
</tr>
<tr>
<td></td>
<td>Middle school</td>
<td>79</td>
<td>29.3</td>
</tr>
<tr>
<td></td>
<td>High school or better</td>
<td>35</td>
<td>13.0</td>
</tr>
<tr>
<td>Primary crop</td>
<td>Rice</td>
<td>188</td>
<td>69.8</td>
</tr>
<tr>
<td></td>
<td>Oil plants</td>
<td>42</td>
<td>15.5</td>
</tr>
<tr>
<td></td>
<td>Cotton</td>
<td>26</td>
<td>9.6</td>
</tr>
<tr>
<td></td>
<td>Sweet potato</td>
<td>6</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>Peanuts and sesame</td>
<td>5</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>Vegetables</td>
<td>2</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>1</td>
<td>0.3</td>
</tr>
<tr>
<td>Income (CNY/year)</td>
<td>( \leq 10 000 )</td>
<td>94</td>
<td>34.8</td>
</tr>
<tr>
<td></td>
<td>10 001 to 20 000</td>
<td>81</td>
<td>30.0</td>
</tr>
<tr>
<td></td>
<td>20 001 to 50 000</td>
<td>69</td>
<td>25.6</td>
</tr>
<tr>
<td></td>
<td>( \geq 50 001 )</td>
<td>26</td>
<td>9.6</td>
</tr>
</tbody>
</table>

3. Results and discussions

3.1. Basic information on the households and their perceptions

The households averaged 4.8 people, of which most (73%) were male (Table 1). The per capita farmland area was 0.057 ha. The respondents ranged from 20 to 67 years old, but most (57%) were 51 years old or older. The respondents 30 years old or younger only accounted for 4.5% of the total. Most (81.6%) had at least a primary school education. Most (69.8%) cultivated at least one rice crop as their primary vegetable, followed by cultivation of oil plants (15.5%, primarily rapeseed) and cotton (9.6%). The annual income of the households averaged about 11 027 CNY, with the main income sources being off-farm work (37% of total income), farming (27%), remittance from the relatives or friends working in the cities (13%), government loans (8%), fishing (8%), animal rearing (5%), and government subsidies to pay for conservation of wetland areas (2%), such as payments to stop farming under land conversion program.

3.2. Household awareness of the causes and impacts of environmental change

Our surveys revealed five major perceived environmental problems in the Poyang Lake area (Table 2): water pollution (65% of the respondents), solid waste pollution (58%), soil loss by water erosion (40%), sedimentation (26%), and flood risks (20%). The factors that were perceived to contribute most to these adverse changes were rapid population growth (65% of the respondents), inputs of chemical fertilizers (64%), disposal of solid domestic wastes (31%), intensive fishing (31), and sand mining from the lake and surrounding areas (20%).

Water quality analyses (Table 3) show that since 2002, pollution levels have generally worsened. Chemical oxygen demand (COD) increased by an average of 16.7%, versus 129.4% for NH\(_3\)-N. The lake’s water quality degraded from level III in 2002 to level V in 2007, the worst level since 2002. The survey respondents believed that population growth and the associated increases in inputs of agricultural chemicals were the major causes of this water pollution. To increase crop production, farmers have applied increasing amounts of agricultural chemicals; for example, fertilizer use increased by 18.3% and pesticide use increased by 66.7% (Table 3). All of the sampled households have applied chemical fertilizers for rice, sweet potato, cotton, oil crops, and vegetables. The main fertilizers were urea, diammonium phosphate (DAP), and potassium sulfate (PS).
These are the most commonly used fertilizers in China due to their high nutrient concentration, low price, and high availability. The fertilizer combination differed between crops; urea + DAP was used by 84% of rice farmers, and the remaining rice farmers applied a more balanced combination (urea + DAP + PS). Vegetable farmers normally used urea + DAP + PS; this is because the higher economic benefits derived from vegetable cultivation and sales led farmers to devote special care to vegetable production.

Application of fertilizers (estimated based solely on the nitrogen content) increased from 1.06 t N/ha annually in 2002 to 1.22 t N/ha annually in 2007, and both amounts are much higher than the maximum amount (0.250 t N/ha) recommended by the Ministry of Environmental Protection (under decree number [2007]195). Pesticide is also intensively used, with the amount increasing from 0.04 t/ha annually in 2002 to 0.07 t/ha annually in 2007 (Table 3).

Increasingly intensive use of chemical fertilizers and pesticides has increased crop yield very significantly over the past years, however, it has also brought severe environmental concerns. Of the 130 large lakes in China, more than 60 are seriously polluted, mainly due to the input of N and P from different sources, and increased application of N and P fertilizer is believed to be a primary cause of pollution of lake water by these nutrients (Zhang et al., 1995). A recent investigation of Poyang Lake (Wang et al., 2008) showed that nitrate pollution of the lake's water due to excessive N fertilization has become a serious problem. The maximum TN and TP concentrations increased from 0.076 mg/L and 0.684 mg/L in 1988, respectively, to 0.148 and 0.479 mg/L in 2006 (Wang et al., 2008), which are both classified as severe eutrophication. The COD level has also increased in recent years, reaching a maximum of 1.6 mg/L in 2006 (Table 3), which represents a 33.3% increase from the 2002 level. Based on the criteria in Table 5, this represents a moderate eutrophication level, implying a high risk of severe eutrophication in the future, if current chemical use is not to be reduced.

### 3.3. Household perceptions of environmental conservation

To protect water quality, most of the respondents (60%) were willing to convert their lakeside farm fields into natural wetlands; this was followed by a willingness to reduce chemical use (43%) and to safely dispose of domestic solid wastes (38%). The conversion of farmland into wetland is one of the central government's major strategies to protect the Poyang wetland areas (Tang, 2006). Since 1998, China has conducted a series of flood-prevention projects, including this type of land conversion. About 221 000 households with a total population of 908 200 moved away from lakeshore areas, and most of the remaining households who still live near the lake have converted some of their farmland into natural wetland. The government has invested 341.35 billion CNY in this project, leading to the conversion of 860 000 ha. In December 2005, the State Council issued a decree entitled "Operationalizing Scientific Development Concepts and Strengthening Environmental Protection", in which it...
recommended that ecological projects such as farmland conversion should continue.

Under this policy, each household has converted some of their farmland into wetland (an average of 0.14 ha per household, equivalent to 0.03 ha per person), accounting for one-third of the total land area according to our survey. Our previous research revealed a negative correlation between the area of land conversion under this policy and household income ($r = -0.475, p < 0.01$) in the Poyang Lake region (CCICED, 2007). To compensate farmers for the economic loss resulting from their loss of farmland, the government has been providing compensation both in cash and in kind. For each unit area (ha) of converted farmland, farmers receive a payment of 177 CN¥/year and 35.5 kg of grain (rice). Farmers are eager to convert their remaining farmland into wetland because of the government compensation scheme, but workers released from farming activities must have a chance to find off-farm jobs that will let them earn income to replace the farm income they have lost. For the households we surveyed, we found that 37% of household income was derived from working away from the farm (e.g., in cities as migrant workers), the main reasons are insufficient land areas for farming and low income from farming.

### 3.4. Willingness to pay for the conservation of Poyang Lake

Most farmers (84%) were willing to pay for environmental conservation (Table 2); most wanted their payment to be used for cleaning the lake’s water (81%) and hiring inspectors to protect the water against future pollution (78%), but many also wanted it to be used for developing an eco-tourism industry (41%) and safely disposing of domestic solid waste through establishing disposing plants (34%). The bid amount was negatively correlated with the proportion of respondents who were willing to pay that amount (Table 6); the greater the required payment, the fewer respondents were willing to pay. Most farmers were willing to pay between 75 and 375 CN¥/ha (year) (15% of the respondents). The relationship between the bid amount and the proportion of the households willing to pay was expressed as follows:

$$P = \frac{1}{1 + 0.444 \times 10^{0.908}} \quad (F = 23.469, P = 0.005, R^2 = 0.824)$$

The regression was both close and significant. The relationship between the bid amount and the probability density of the households’ willingness to pay is expressed as follows:

$$\rho = -P(t) = \frac{1.332 \times 10^{-3} \times 10^{0.908}}{(1 + 0.444 \times 10^{0.908})^2} \quad (F = 23.469, P = 0.005, R^2 = 0.908)$$

Fig. 4 shows that the consensus rate decreases steadily with increasing bid value. Most of the farmers were willing to pay between 750 and 1125 CN¥ per ha of farmland, and 58% were willing to pay at much as 375 CN¥/ha. However, only 11% were willing to pay as much as 3750 CN¥/ha.

Householders with the highest income were willing to pay the most (2486 CN¥/ha/annually) for environmental conservation (Table 7), but these householders only accounted for 6.3% of the households that were willing to pay; the group with an annual income of 10 001 to 20 000 CN¥ had the next highest WTP (1020 CN¥), and accounted for 40.6% of the households that were willing to pay (the highest proportion). This can be explained by the fact that in the Poyang Lake region, about one-third of the households rely wholly on farming activities for their livelihood, and this group has an annual income ranging between 10 001 and 20 000 CN¥. This group is most aware of the importance of the quality of the lake’s water and of the surrounding environment for their daily life, and they therefore show a relatively high willingness to pay for improvement. For those whose income was above 20 001 CN¥, they relied mainly on off-farm income source working as migrant workers in the cities, and their average off-farm income accounted for more than 65% of the total income, they relied less on farm land and therefore had less WTP for the Lake’s conservation.

To calculate the expected amount the households would be willing to pay for the environmental protection of Poyang Lake, we used logistic regression analysis. Based on the above data, we plotted the graph shown in Fig. 4, which shows the relationship between the bid amount and the proportion of households who were willing to pay that amount ($P$). Using the data from Table 6, we obtained the following regression equation:

$$P = \frac{1}{1 + 0.444 \times 10^{0.908}} \quad (F = 23.469, P = 0.005, R^2 = 0.824)$$

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Fig. 4 shows that the consensus rate decreases steadily with increasing bid value. Most of the farmers were willing to pay between 750 and 1125 CN¥/year (with a high probability density of nearly $8 \times 10^{-4}$ for this range of values). The expected amount to pay can be estimated using Eqs. (2)–(4), which predict an average annual per household payment of 956 CN¥/ha.

Meanwhile, by using formula (5), the average amount of WTP was calculated, and the amount is 802 CN¥/ha/household/year. This and the above results could be used as reference values to design a conservation payment scheme and determine the total funding required to promote conservation in the Poyang Lake region.

### Table 6

The relationship between the bid amount and the proportion of the households willing to pay that amount for the conservation of Poyang Lake.

<table>
<thead>
<tr>
<th>Annual bid amount (CN¥/ha)</th>
<th>75</th>
<th>188</th>
<th>375</th>
<th>750</th>
<th>1125</th>
<th>1875</th>
<th>3750</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion of households willing to pay (%)</td>
<td>84</td>
<td>69</td>
<td>58</td>
<td>41</td>
<td>33</td>
<td>30</td>
<td>11</td>
</tr>
</tbody>
</table>

### Table 7

Relationship between household income and WTP.

<table>
<thead>
<tr>
<th>Income group (CN¥/year)</th>
<th>≤10 000</th>
<th>10 001 to 20 000</th>
<th>20 001 to 50 000</th>
<th>≥50 001</th>
</tr>
</thead>
<tbody>
<tr>
<td>WTP (CN¥/ha/year)</td>
<td>424</td>
<td>1020</td>
<td>454</td>
<td>2486</td>
</tr>
<tr>
<td>Proportion of those who are willingness to pay (%)</td>
<td>35.4</td>
<td>40.6</td>
<td>17.7</td>
<td>6.3</td>
</tr>
<tr>
<td>Proportion of total respondents (%)</td>
<td>12.6</td>
<td>14.4</td>
<td>6.3</td>
<td>2.2</td>
</tr>
</tbody>
</table>

Note: Using formula (5), the average amount of WTP is calculated, and the amount is 802 CN¥/ha/household/year.

* Is ratio of Number of households who have shown their WTP in each income group to Total number of households who have shown their WTP.
Analysis of relationship between WTP and households' characteristics indicates (Table 8) that the coefficient of production income is statistically significant with WTP (Sig = 0.06), this is because the higher the income from farm land production, the higher reliance on the land and water for farming, therefore, the more concern about wetland and the lake's water quality. While other coefficients such as age, average annual income, area converted from arable land to lake, perception of water quality, and awareness of the lake's function are not statistically significant with WTP, therefore, these characteristics have not affected WTP significantly.

4. Conclusion

Our research used government statistics, household surveys, and focused discussion groups to identify resident perceptions of the environmental threats in the Poyang Lake region of southern China, and household awareness of the causes and impacts of these threats. We also estimated their willingness to pay for conservation of the Poyang Lake region. We obtained the following main conclusions from our analysis:

• Water pollution is the major environmental threat in the Poyang Lake region, with TN, TP, COD, NO<sub>3</sub>–N, and NH<sub>4</sub>–N concentrations increasing from 2002 to 2007 and current water quality classified in the moderate to severe eutrophication levels.

• Increasing overuse of fertilizers and pesticides by local farmers, and particularly of nitrogen fertilizers, is the main cause of the pollution. Rapid population growth has led to more intense economic activities and produced more solid wastes and pollutants that are discharged into the lake and the surrounding environment.

• Most households are willing to pay to conserve the lake through various means, including reduced use of agricultural chemicals and conversion of lakeshore rice fields into natural wetlands. Most would also be willing to pay for environmental conservation of the lake region; the average annual payment per household was estimated to be 956 CNY per ha based on CVM (Haneman, 1984). To cross-check the result, we have designed open-ended questions to get individual household based WTP, which was 802 CNY per ha. Therefore, we could conclude that average annual amount of WTP per household is 802–956 CNY/ha, which is nearly 1/10 of the households' annual income derived from arable land production. This result is of significance for real policy making because firstly, it indicates a high investment is needed for conservation of Poyang Lake's environment. Currently, the household receives 177 CNY/ha from the government for conservation of the lake's water, which is far from meeting the demand as mentioned by the local people during the survey. The estimated result is helpful for the government to design a conservation payment scheme and make budget plan to promote conservation. Secondly, a higher WTP of the local people implies their high sense and awareness of environmental protection.

• According to descriptive analysis on the numerical data of questionnaire, a significant positive correlation was observed between income from agricultural production and WTP, implying a strong relation between households' dependence on wetland's land and water resources and their concerns to the Lake's conservation. The result would provide important information for the management of the lake by taking into consideration of perceptions and willingness of the householders who are involved heavily in farming activities, because they are the real users and managers of wetland ecosystem.

• To meet the growing pressure on the region's water resources, our results suggest that managers should focus on encouraging more efficient and balanced use of chemical and organic fertilizers. Developing appropriate payment systems to encourage more efficient and sustainable use of the region's resources would also encourage conservation.

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References


