Cold-humid effect of Baiyangdian wetland

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Abstract: Data support for wetland protection function evaluation can be provided by quantitatively analyzing the ability of regulating the regional climate of the wetland ecosystem. In this study, the cold-humid effect of the Baiyangdian wetland was analyzed by comparing the meteorological conditions of the Baiyangdian wetland and its surrounding areas. Meanwhile, the regulatory functions of the Baiyangdian wetland for the processes and magnitudes of temperature and relative humidity from August to October 2008 were evaluated. The results show that daily mean temperatures in the Baiyangdian wetland were lower than in the surrounding areas, and that temperature differences mainly occurred in the daytime but were not obvious at night. Diurnal temperature ranges in the Baiyangdian wetland were lower than in the surrounding areas, and the higher the diurnal temperature range in the surrounding areas was, the stronger the regulation ability of the Baiyangdian wetland. Compared with the surrounding areas, the decline of the daily minimum temperature in the Baiyangdian wetland was gentler, and the mean relative humidity there was higher. The present findings indicate that effects of the Baiyangdian wetland on climate and humidity regulation are significant.

Key words: Baiyangdian wetland; local climate; cold-humid effect; temperature regulation; relative humidity

1 Introduction

Wetlands, the kidneys of the earth, with a total global area of more than 1.28 billion hm$^2$, are considered the largest ecosystem in the world, together with forest and ocean (An 2004). They have the most biodiversity and ecological functions in nature, including supply functions, regulatory functions, supporting functions, and cultural functions (MEAB 2005). Climate regulation is one of the most important functions of wetlands. Local and regional temperatures, humidity, and other climate processes can be influenced by wetlands. Wetlands play a key role in regulating local climate as well as in reducing impacts caused by climate change.

There were several arguments in early studies concentrating on the cold-humid effect of wetlands as an accumulated environmental effect. Lu (1981) studied the climate characteristics of Fuxian Lake in Yunnan Province and concluded that the temperature in the lake area was...
higher than in the surrounding areas. Rong (1989) analyzed the climate effects in the area of Bositeng Lake in Xinjiang and concluded that the lake could adjust the temperature variation, increase precipitation, and reduce evaporation significantly. Jauregui (1990-1991) found that the Chapultepec Park in Mexico City was colder than its built-up surroundings only at night. Wang (1994) disputed Rong’s research using meteorological data from Chaiwobao Lake, also in Xinjiang, considering that the conclusion of lakes causing the increase of precipitation needs further discussion. Yang and Sha (1997) observed the local climate of the Lixia River in Jiangsu Province and pointed out that the temperature in the lake area was higher than in the upwind land surface in the daytime and lower than in the downwind land surface at night. Gao et al. (2002) found that temperatures measured from wetlands, both in the daytime and nighttime, were always higher than those from the surrounding farmland according to their research on cold-humid effects of wetlands in the Sanjiang Plain in the Northeast of China. Saaroni and Ziv (2003) carried out some observations of air and surface temperatures, relative humidity, solar radiation, and wind regime in a Mediterranean urban park and found lower temperatures, higher relative humidity, and lower heat stress indexes on the downwind side of the pond, compared with those from stations located upwind of the pond. Li et al. (2007) used a numerical simulation method to estimate the temperature decrease and humidity conditioning effects of wetlands on the surrounding areas, and developed an air flow and diffusion model combined with the moisture dynamic characteristics.

With the aims of wetland function assessment, we took the Baiyangdian wetland, located in Hebei Province in China, as our research focus in this study. This paper is organized as follows: (1) meteorological conditions of the internal wetland and its surrounding areas are compared, (2) the cold-humid effect of the Baiyangdian wetland is analyzed, and (3) local climate regulation abilities of the wetland are assessed.

2 Study area and data collection

2.1 Wetland description

The Baiyangdian wetland, located in the middle reach of the Daqing River, is the largest fresh water wetland in North China. When the water level of the wetland reaches 10.5 m, the corresponding water surface area is 366 km². The Baiyangdian wetland consists of 143 lakes and 3,700 trenches. The longitude of the wetland varies from 115°38' E to 116°07'E, and the latitude varies from 38°43'N to 39°02'N. The Baiyangdian wetland lies in a warm semi-humid continental monsoon climate zone with an annual mean temperature of 12.1°C, annual mean precipitation of 524.9 mm, and annual mean evaporation of 1,369.0 mm. There are distinct seasons, with a dry and cold winter and the high-temperature summer.

2.2 Data collection and processing

In order to analyze the cold-humid effect of the Baiyangdian wetland, a temporary weather
station was established in the central area of the wetland for measuring the meteorological factors including air temperature, relative humidity, and net radiation. In this study, the air temperature and relative humidity in the Baiyangdian wetland were measured with two probes (model: HMP45D, VAIASLA, Finland), and signals from all sensors were recorded by a data logger (model: SQ2020, GRANT, UK) every hour. In addition, the same types of meteorological data were collected from the surrounding areas (Anxin County, Gaoyang County, and Rongcheng County). Fig. 1 and Table 1 provide details of the four stations.

![Fig. 1 Geographic location of Baiyangdian wetland](image)

**Table 1 Details of weather stations**

<table>
<thead>
<tr>
<th>Station</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Distance* (km)</th>
<th>Station</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Distance* (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baiyangdian</td>
<td>38°53'N</td>
<td>116°01'E</td>
<td>0.0</td>
<td>Rongcheng</td>
<td>39°03'N</td>
<td>115°51'E</td>
<td>23.5</td>
</tr>
<tr>
<td>Anxin</td>
<td>38°56'N</td>
<td>115°56'E</td>
<td>9.0</td>
<td>Gaoyang</td>
<td>38°43'N</td>
<td>115°46'E</td>
<td>28.5</td>
</tr>
</tbody>
</table>

Note: * means distance from Baiyangdian weather station to every other station.

We collected the meteorological data at 2:00 am, 8:00 am, 2:00 pm, and 8:00 pm every day in the Baiyangdian wetland and the surrounding areas (Anxin County, Gaoyang County, and Rongcheng County). The abilities of the Baiyangdian wetland for temperature and relative humidity regulation were analyzed. The daily mean temperature and relative humidity used in this paper were the average values at the four times noted above.

The positive linear correlations for daily temperature and relative humidity between the Baiyangdian wetland and the surrounding areas from August to October 2008 are clearly shown in Figs. 2 and 3. The coefficients of determination ($R^2$) for daily temperature were 0.988 (Baiyangdian-Anxin), 0.988 (Baiyangdian-Gaoyang), and 0.990 (Baiyangdian-Rongcheng), and for relative humidity they were 0.921 (Baiyangdian-Anxin), 0.902 (Baiyangdian-Gaoyang), and 0.888 (Baiyangdian-Rongcheng). An index of agreement ($d$) was also considered and calculated as follows:
\[ d = 1 - \frac{\sum_{i=1}^{n} (R_i - B_i)^2}{\sum_{i=1}^{n} (|R_i - \bar{B}| + |B_i - \bar{B}|)^2} \]  

where \( B_i \) and \( R_i \) are the measured data of daily temperature or relative humidity in the Baiyangdian wetland and the surrounding areas at the different time of measurement, respectively; \( \bar{B} \) is the average of the measured data in the Baiyangdian wetland; and \( n \) is the number of measurement. Indexes of agreement for daily temperature were 0.988 (Baiyangdian-Anxin), 0.988 (Baiyangdian-Gaoyang), and 0.978 (Baiyangdian-Rongcheng), and for relative humidity they were 0.973 (Baiyangdian-Anxin), 0.962 (Baiyangdian-Gaoyang), and 0.914 (Baiyangdian-Rongcheng). The positive linear relationships and values of the index of agreement close to one indicated that the meteorological data we used in this study have significant agreement.

3 Results and discussion

3.1 Basic conditions of cold-humid effect

Generally, a wetland with a broad water area can not only influence the value of temperature but also regulate its daily change process because water has a larger heat capacity and can also store and release more heat than the land surface. The air humidity in the wetland can be significantly influenced by vegetation evapotranspiration and water evaporation, and differences in humidity between the wetland and the surrounding areas can be found.
Temperatures in the wetland can also be regulated through heat absorption in transpiration and evaporation processes. The cold-humid effect mainly depends on the differences in natural conditions between the wetland and surrounding areas. The more different the natural conditions, the more obvious the regulatory function for climate. In general, regulatory functions of wetlands for climate are much stronger in dry areas.

The Baiyangdian wetland, a typical wetland in the Haihe Basin, has satisfying conditions for climate regulation. According to statistical data, the total water supply volume of the Haihe Basin is 40.2 billion m$^3$, and the water resources utilization ratio is 98%. Until June 2008, the water surface area of the wetland increased to 140 km$^2$ after the implementation of a water diversion from the Yellow River to the Baiyangdian wetland. Reeds and lotus roots are widely distributed in the Baiyangdian wetland, with areas of approximately of 8000 hm$^2$ and 6600 hm$^2$, respectively. As the most typical aquatic vegetation in the Baiyangdian wetland, reeds mature in August and September every year, leading to the most dramatic evapotranspiration process and the strongest ability of climate regulation in a year.

### 3.2 Temperature regulation

#### 3.2.1 Daily mean temperature regulation

In general, the regulatory function of the Baiyangdian wetland for daily mean temperature can be represented by the differences in temperatures between the wetland and the surrounding areas. Fig. 4 shows the comparison of daily mean temperatures between the Baiyangdian wetland and Anxin County as well as the Baiyangdian wetland and Rongcheng County from August to October 2008. The daily mean temperatures in the Baiyangdian wetland were always lower than in Anxin and Rongcheng counties during this period except for individual days. This was because the temperatures in the wetland were effectively reduced by water evaporation and plant evapotranspiration in the wetland.

![Fig. 4 Regulatory effects on daily mean temperature from August to October 2008](image)

Furthermore, it can be found that daily mean temperatures in Anxin County were lower than in Rongcheng County on most of the days from August to September, while daily mean temperature in these two counties were consistent in October. We can draw a conclusion that the low temperature in the Baiyangdian wetland could effectively affect Anxin County from August to September. However, Rongcheng County, which is relatively far from the wetland,
could not be significantly influenced in the same period. Meanwhile, in October, because of the exhaustion of plant evapotranspiration, regulatory functions of the Baiyangdian wetland for Anxin County were not obvious anymore, and there was less of a difference between the two curves. At this time, the differences in underlying surfaces between the Baiyangdian wetland and the two counties had significant influences on the ability of the wetland to regulate temperature.

Moreover, with the falling of temperatures in this period, there was a decreasing trend of temperature differences between the wetland and the surrounding areas. According to the observed data, daily mean temperatures in the Baiyangdian wetland were 1.32°C, 1.01°C, and 0.61°C lower than in Anxin County, respectively, in August, September, and October, and 2.08°C, 1.72°C, and 0.65°C lower than in Rongcheng County, respectively, over the same period. Therefore, low-temperature effects of the Baiyangdian wetland were obvious in August and September and weak in October. As a result, the temperate and climate in the Baiyangdian wetland can provide advantageous conditions for local agriculture and tourism.

### 3.2.2 Daily temperature process regulation

Table 2 presents the temperature difference between the Baiyangdian wetland and the surrounding areas at 2:00 am, 8:00 am, 2:00 pm, and 8:00 pm in different months, demonstrating the regulatory function of the wetland for temperature.

<table>
<thead>
<tr>
<th>Period</th>
<th>$\Delta T_1$ (°C)</th>
<th>$\Delta T_2$ (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2:00 am</td>
<td>8:00 am</td>
</tr>
<tr>
<td>Aug.</td>
<td>–0.61</td>
<td>–1.22</td>
</tr>
<tr>
<td>Sep.</td>
<td>–0.32</td>
<td>–1.04</td>
</tr>
<tr>
<td>Oct.</td>
<td>0.11</td>
<td>0.22</td>
</tr>
<tr>
<td>Mean</td>
<td>–0.27</td>
<td>–0.68</td>
</tr>
</tbody>
</table>

Note: $\Delta T_1$ is the temperature difference between Baiyangdian and Anxin County, and $\Delta T_2$ is the temperature difference between Baiyangdian and Gaoyang County.

As seen in Table 2, the minimum temperature differences between the Baiyangdian wetland and the two counties occurred at 2:00 am and the maximum temperature difference occurred at 2:00 pm. In the lower temperature period (October), temperatures in the Baiyangdian wetland were higher than in the surrounding areas at 2:00 am and 8:00 am.

Anxin County and Gaoyang County had the daily minimum temperature at 2:00 am and the maximum daily temperature at 2:00 pm (Table 3). The Baiyangdian wetland had a short-time effect of constant temperature which could regulate the process of temperature increase and decrease. The reason is that the heat capacity of water is much larger than that of soil. In the daytime, temperatures in the wetland would not increase quickly because water could absorb so much solar radiation heat. At night, temperatures in the wetland would not decrease quickly because water could release heat. Consequently, the Baiyangdian wetland
could enhance the low temperature and reduce high temperature. As a result, daily temperature change processes of the Baiyangdian wetland were fairly stable.

**Table 3** Mean temperatures at different times in Anxin and Gaoyang counties

<table>
<thead>
<tr>
<th>Site</th>
<th>Period</th>
<th>2:00 am</th>
<th>8:00 am</th>
<th>2:00 pm</th>
<th>8:00 pm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anxin County</td>
<td>Aug.</td>
<td>22.6</td>
<td>23.6</td>
<td>29.1</td>
<td>25.1</td>
</tr>
<tr>
<td></td>
<td>Sep.</td>
<td>17.5</td>
<td>17.9</td>
<td>24.9</td>
<td>19.8</td>
</tr>
<tr>
<td></td>
<td>Oct.</td>
<td>10.8</td>
<td>10.7</td>
<td>20.0</td>
<td>13.5</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>17.0</td>
<td>17.4</td>
<td>24.7</td>
<td>19.5</td>
</tr>
<tr>
<td>Gaoyang County</td>
<td>Aug.</td>
<td>22.7</td>
<td>23.6</td>
<td>28.7</td>
<td>25.1</td>
</tr>
<tr>
<td></td>
<td>Sep.</td>
<td>17.4</td>
<td>18.1</td>
<td>24.8</td>
<td>20.3</td>
</tr>
<tr>
<td></td>
<td>Oct.</td>
<td>10.7</td>
<td>10.7</td>
<td>20.1</td>
<td>13.6</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>16.9</td>
<td>17.5</td>
<td>24.5</td>
<td>19.7</td>
</tr>
</tbody>
</table>

3.2.3 Diurnal temperature range regulation

Fig. 5 presents the diurnal temperature ranges in the Baiyangdian wetland, which were lower than in Anxin and Gaoyang counties. From August to October, the mean value of the diurnal temperature range was 8.3°C in the Baiyangdian wetland, and 10.9°C and 10.8°C in Anxin and Gaoyang counties, respectively. During this research period, the maximum value of the diurnal temperature range was 15.1°C (October 14) in the Baiyangdian wetland, 19.6°C (October 19) in Anxin County, and 19.9°C (October 12) in Gaoyang County.

Meanwhile, it can be concluded that the larger the diurnal temperature range in surrounding areas is, the more obvious the regulatory function of the Baiyangdian wetland for the diurnal temperature range. Fig. 6 shows the regulatory function of the Baiyangdian wetland for the diurnal temperature range through comparison of the Baiyangdian wetland and Anxin County. We find that the change trend of the regulatory function of the Baiyangdian wetland for the diurnal temperature range was similar to the change trend of the diurnal temperature range of Anxin County. This illustrates that the Baiyangdian wetland could moderate the changes of temperature. In other words, the changes of the diurnal temperature range could be relatively gentle because of the wetland.
3.2.4 Daily minimum temperature regulation

Fig. 7 presents the comparison of daily minimum temperatures of the Baiyangdian wetland and Anxin and Gaoyang counties. It is obvious that the falling process of daily minimum temperatures in the Baiyangdian wetland was gentler from August to October. During this period, the minimum value of daily minimum temperature was 5.2°C in the Baiyangdian wetland. However, it was 1.1°C in Anxin County and 0.1°C in Gaoyang County. This result was consistent with the conclusion of Lu and Wei (1990), in which the extreme minimum temperature at the lake surface was 3-5°C higher than in the surrounding areas. Because of the regulatory function of the wetland for the daily minimum temperature, the range of daily minimum temperature variation in the Baiyangdian wetland could be effectively reduced while the daily minimum temperature in the surrounding areas significantly fell. Therefore, the Baiyangdian wetland can effectively avoid the extreme low temperature, supporting local agricultural production and human life.

![Fig. 7 Comparison of daily minimum temperatures from August to October 2008](image)

3.3 Daily mean relative humidity regulation

The air humidity in the Baiyangdian wetland was significantly increased through water evaporation from the large area of free water surface and the intense transpiration of widely distributed reeds. The mean relative humidity of the study period in the Baiyangdian wetland was 1.75% higher than in Anxin County, 2.60% higher than in Gaoyang County, and 5.82% higher than in Rongcheng County.

As mentioned above, the differences in daily mean relative humidity between the Baiyangdian wetland and the surrounding areas can be taken as the criteria to assess the regulatory function of the wetland for daily mean relative humidity. The regulatory function of the Baiyangdian wetland for the daily mean relative humidity from August to October 2008 is shown in Fig. 8. It indicates that the humidity condition in Anxin County could be significantly influenced by the Baiyangdian wetland because of a relatively short distance between the two places and a high relative humidity in the Baiyangdian wetland in August and September. The relative humidity in Anxin County was higher than in Rongcheng County. In October, the regulatory function of the wetland for the daily mean relative humidity of Anxin
County obviously decreased and the values of the relative humidity in Anxin and Rongcheng counties were approximately consistent.

![Figure 8](image)

**Fig. 8** Regulatory effects on daily mean relative humidity from August to October 2008

4 Conclusions

This study selected meteorological data from Baiyangdian wetland and the surrounding areas to analyze the regulatory functions of the wetland for the local climate. The conclusions are as follows:

(1) From August to October 2008, the mean value of the daily mean temperature in the Baiyangdian wetland was 0.98°C lower than in Anxin County, 0.98°C lower than in Gaoyang County, and 1.48°C lower than in Rongcheng County. The main reason for this phenomenon is the heat absorption by water evaporation and plant transpiration.

(2) The regulatory function of the Baiyangdian wetland for temperature was weakest at 2:00 am and strongest at 2:00 pm. This was because the heat capacity of water in the wetland was larger than in the surrounding lands. Much more solar radiation energy could be absorbed by the wetland in the daytime and released at night. Consequently, the daily temperature change process could be regulated effectively.

(3) The diurnal temperature range in the Baiyangdian wetland was lower than in surrounding areas. The higher the diurnal temperature range in the surrounding areas was, the stronger the ability of the Baiyangdian wetland for regulating the diurnal temperature range. It was found that the daily minimum temperature decline process was gentler in the Baiyangdian wetland than in surrounding areas. From August to October, the minimum value of the daily minimum temperature was 5.2°C in the Baiyangdian wetland, 1.1°C in Anxin County, and 0.1°C in Gaoyang County.

(4) The relative humidity in the Baiyangdian wetland was 1.75% higher than in Anxin County, 2.60% higher than in Gaoyang County, and 5.82% higher than in Rongcheng County. This was because of water evaporation and plant transpiration.

References


