How water transfer could promote the carbon sink in reed wetland

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Abstract. The hydrologic condition is the basic attribute of the wetland ecosystem, which affects the carbon exchange process between the wetland soil and the vegetation atmosphere, and then affects the change of carbon sink. Artificial water transfer or ecological replenishment is one of the most direct and effective measures used to control wetland saturation levels. The relationship was established, between water flux, water level fluctuation and the influence of artificial water transfer, to discuss the variation of carbon sink and when to implement water transfer and how to control water (water level) to achieve carbon sink in Baiyangdian reed (Phragmites australis) wetland under the influence of artificial water transfer. The research results show the amount of carbon sink is changed only -0.72 gC/m\textsuperscript{2} (-0.08\%) in spring, and the influence is minimal, which is changed -19.49 kgC/m\textsuperscript{2} (-2.10\%) in summer, and the adverse effect was great, which is changed 133.85 kgC/m\textsuperscript{2} (14.41\%) in autumn, but the carbon sink increases and decreases, and the carbon sequestration is unstable, which is changed 17.89 kgC/m\textsuperscript{2} (1.93\%) in winter, and the effect is favorable. Therefore, according to the effect of carbon sink in reed wetland, the time in the early spring of winter (February to March) is the best water transfer time in Baiyangdian. When the water level fluctuation is controlled at 0.3 m, the carbon sink change is 230.79 kgC/m\textsuperscript{2} (9.07\%), which is beneficial to the increase of carbon sink in reed wetland. The model established in this study can be helpful to understand the mechanism of carbon sink in reed wetland through artificial water transfer in Reed wetlands, also can be used in the optimal design of the ecological service function for the restoration of damaged wetland.

1. Introduction
Wetland is one of the most important terrestrial ecosystems, and it plays an important role in the global carbon cycle [1-4]. Wetland is considered a high carbon sink ecosystem, in which the carbon sink reaches 830 Tg/a [5]. The biomass of wetland vegetation and high decomposition rate is low in favor of wetland soil organic carbon accumulation [6-8]. The wetland is suitable for high biomass of herbaceous plant growth, especially the reed wetland ecosystem is the main river wetland and coastal wetland types [9,10], and is widely distributed in the world [11,12]. Therefore, it is one of the effective measures to alleviate the greenhouse gas emissions by using the high biomass of the wetland reed to absorb the atmospheric CO\textsubscript{2} and create a high carbon sink ecosystem.

Because the unique vegetation types, hydrological cycle changes and climate conditions, they have great diversity in carbon cycle and greenhouse gas emissions in different types of wetland [11,13,14]. Hydrological processes are considered to be the key factor in determining the formation and
maintenance of wetlands and their processes [15], having essential roles in controlling the structure and function of wetland ecosystems in both the short-term and long-term [14,16,17]. Additionally, wetland water level affect photosynthetic processes in local vegetation [2,18,19], as well as the rate of CO₂ and CH₄ emissions from soils [20-25], which both ultimately affect the level of organic carbon storage in soils. Therefore, the increase and decrease in water levels are opposing forces driving wetland carbon resource dynamics, resulting in variations in carbon sink/source in wetland ecosystems [1,26]. Consequently, the research on the impact mechanism of the carbon cycle process of wetland ecosystem under human disturbance becomes a hot spot [19,27-30].

The yield and quality of reed in Baiyangdian ranks the first of the four largest reeds in China. The aboveground biomass of reed accumulation can reach 43 t/hm² [31] in reed fields, higher than the domestic average value of 10 t/hm²; and the vegetation biomass of reed carbon reserves is 3.17 kg/m² [31,32]. It is clearly that, the reed wetland ecosystem (reed field) proper to Baiyangdian has great potential to promote carbon sink and alleviate the greenhouse gas emissions. Based on the study of Baiyangdian reed wetlands under the influence of artificial water transfer management, this paper establishes a model for the relationship between the reed field ecosystem carbon flux and the fluctuation of water levels, in order to discuss: 1) how does artificial water transfer affect the carbon sink of reed wetland ecosystem? 2) How to control the best water transfer time and water level/flow in order to achieve the increase of carbon sinks?

2. Description of the modeled ecosystem

Baiyangdian wetland is located centrally in Xiong An new district of China (founded in April 1, 2017), and is the largest freshwater lake wetland area in the North China Plains (38°43′~39°02′ N, 115°38′~116°07′ E), with a total area of 366 km² at the water elevation of 10.5 meter, the “Baiyangdian wetland geographical location” was described in figure 1. The average annual precipitation over the whole basin region is 510 mm, 80% of which occurring from July to September, while the average annual water evaporation is 1690 mm, notably larger than the level of precipitation [33,34]. There are more than 3,700 trenches and 143 small lakes in the wetland, with landscape connecting the lake, trenches, fields, terraces and surface water. Due to the complex characteristics of the topography and terrain in wetland regions, the spatial distribution of wetland water depths is generally highly variable. The average level of the flora is about 7.5~8.5 m, while the average water depth is between 1 and 2 m.
The Baiyangdian wetland ecosystem contains a reed community, the flora present in the region is dominated by reed. Artificial water transfer has a significant influence on the Baiyangdian wetland, maintaining the minimum ecological required water level at Baiyangdian wetland (7.3 m) and ensuring ecological system functioning [35]. An average annual 0.8 billion cubic meters were transferred from 2001 to 2011, allowing the Baiyangdian reed wetland to maintain water levels of between 6.6 and 8.6 m [34,36].

When the surface water level rises above 6.9 m, the reed area increases accordingly, conversely reducing in with lower water levels [37]. The increase in the volume of the water that occurs when surface water levels rise [38], results in flooding of reed communities grown at low altitudes. Studies have shown that when the water depth exceeds 30cm for an extended period it causes death of low altitude reed buds, while a decrease in surface water level leads to their rapid propagation [39]. Additionally, water level changes also affect soil CO$_2$ and CH$_4$ production and emissions, therefore artificial transfer affects the structure of wetlands, the growth of reed and the carbon sink, as well as the hydrological conditions of the Baiyangdian wetland. Therefore, it is essential to study artificial transfer design parameters such as water diversion time and water level fluctuation range, to restore and maintain effective carbon sink functions of the Baiyangdian wetland.

3. Materials and methods

3.1. Data collection

The sampling of reed biomass was performed between June-October 2009, with sampling sites (Yuanyang island, Beitianzhuang, Quantou) selected at the reed terraces in Baiyangdian wetland [32]. The subsurface biomass established using monitoring data from the sampling period was utilized as validation data, with the initial values of above-ground and subsurface biomass and litter biomass, obtained from the literature [40]. The relationship between above-ground biomass and average water depths in reed communities in the growing season, were verified using the findings reported by Zhao [34], during the April-October 2010 period.

The wetland CH$_4$ data sampling sites (Nanliuzhuang, Wangjiazhai) was in the Wangjiazhai area, close to the reed sampling sites. Sampling was performed using the closed static box method between July 2008 and June 2009 [41]. The CO$_2$ sampling site (Shihoudian) was in the Shihou station [31], Sampling was performed using the closed static box method between April and October in 2012.

Data on environmental temperatures, solar radiation and other parameters were supplied by the local Anxin County Annals, while Anxin County Meteorological Bureau data on hydrological conditions was combined with water transfer data supplied by the Baoding Water Authority. CO$_2$ concentrations in the air were assumed to be 400 ppm [42].

3.2. Model

3.2.1. Model description. Wetland carbon flux is the result of the combined actions of wetland soil and plant respiration and photosynthetic processes, which characterize the exchange status of CO$_2$ between soil and plant systems. The carbon cycle begins with the photosynthetic activity of plant leaves, which results in the absorption of CO$_2$ from the air, converting it into the fixed carbon within the plant, which is transferred from the aerial plant regions to underground rhizomes and vice versa as required. Plant and soil microbe respiration both contribute to the release of carbon into the atmosphere from soils [1,41]. Based on these carbon cycle processes, this study utilized STELLA software (version 9.1.3. STELLA is an advanced modeling software based on system dynamics. It has a powerful modeling environment and convenient operation methods. It is favored by researchers and scholars at home and abroad, especially in ecological research) to construct the biomass carbon cycle model of above-ground, under-ground and soils in the reed wetland sampling sites. The model sets three state variables, ground level biomass carbon (PaC); under-ground biomass carbon (PbC); and soil biomass carbon (PsC), with the model concept block diagram shown in figure 2. The unit of state
was gCm$^{-2}$, with the model generating gCm$^{-2}$d$^{-1}$ for the simulation time from January 1 to December 31 in 2012.

The model forced function provides the relationship between CO$_2$ concentration, ambient temperature, solar radiation, water depth and state variables, the “STELLA analysis concept diagram” was described in figure 2, while the “Symbolic meaning and unit in the model” was described in table 1.

**Figure 2.** STELLA concept diagram.

**Table 1.** Symbolic meaning and unit in the model.

| Description                        | unit               |
|------------------------------------|--------------------|
| Pac                                | Reed ground tissue biomass carbon gCm$^{-2}$ |
| Pbc                                | Reed underground tissue biomass gCm$^{-2}$ |
| PsC                                | Soil Reed biomass carbon gCm$^{-2}$ |
| photosynthesis                     | Photosynthesis gCm$^{-2}$ per day |
| decayPa                            | Reed ground tissue litter biomass gCm$^{-2}$ per day |
| mortalPa                           | Reed ground tissue death biomass carbon gCm$^{-2}$ per day |
| mortalPb                           | Reed underground tissue death biomass carbon gCm$^{-2}$ per day |
| respirePa                          | Reed tissue tissue respiration gCm$^{-2}$ per day |
| respirePb                          | Reed underground tissue respiration gCm$^{-2}$ per day |
| react                              | Underground part of the amount of activation gCm$^{-2}$ per day |
| tansfer                           | Part of the ground to the underground transmission gCm$^{-2}$ per day |
| Carbonemission                     | Carbon dioxide - carbon release in soil gCm$^{-2}$ per day |
| Methaneemission                    | Methane - carbon release in soil gCm$^{-2}$ per day |
| CO$_2$flux                         | System carbon dioxide flux gCO$_2$m$^{-2}$ per day |
| Air temperature                    | Daily average air temperature Degrees (°C) |
Concen CO₂ | Air carbon dioxide concentration | ppm per year
---|---|---
CarryaC | Reed maximum environmental capacity | gCm⁻²
Rad | Solar radiation intensity | MJ m⁻² per year
waterdepth | Suitable depth / average depth | M
waterdepthmax | Maximum depth of water | M
carbonrate | The rate of carbon dioxide release in soil | gg⁻¹ per day
decayratePa | The rate of litterfall on the aboveground tissue of reed | gg⁻¹ per day
mortalratePa | The death rate of reed tissue | gg⁻¹ per day
mortalratePb | Reed underground tissue death rate | gg⁻¹ per day
mathrate | Methane release rate in soil | gg⁻¹ per day
respirratioPa | Reshry tissue respiration rate | gg⁻¹ per day
respirratioPb | Reed tissue respiration rate | gg⁻¹ per day
Reratio | The activation rate of the underground part | gg⁻¹ per day
Transratio | The ground part to the underground transmission rate | gg⁻¹ per day

3.2.2. **Biomass model equation of reed.** The “Biomass model equation” was described in table 2.

| Description |
|---|
| **Pac** | $dP_C/dt = \text{Photosynthesis} + \text{react} - \text{transfer} - \text{respire}_{Pa} - \text{decay}_{Pa} - \text{mortal}_{Pa}$ |
| **Pbc** | $dP_{bc}/dt = \text{transfer} - \text{react} - \text{respire}_{Pb} - \text{mortal}_{Pb}$ |
| **PsC** | $dP_{sC}/dt = \text{decay}_{Pa} + \text{mortal}_{Pa} + \text{decay}_{Pb} - \text{Methaneemission} - \text{Carbonemission}$ |
| **photosynthesis** | Photosynthesis=$\frac{\text{Concen}_\text{CO}_2}{(\text{Concen}_\text{CO}_2+300)}*(\text{Rad}/(\text{Rad}+6))*\theta^\text{Air\_tempurature-20} *P_{C}^\text{(1-PaC/CarryaC)}$ |
| **decayPa** | decay_{Pa}=mortalrate_{Pa}*P_{aC}^\text{Air\_temperature-20} |
| **mortalPa** | mortal_{Pa}= mortalate_{Pa}*P_{aC}^\text{Air\_temperature-20} |
| **mortalPb** | mortal_{Pb}= mortalrate_{Pb}*P_{bC}^\text{Air\_temperature-20} |
| **respirePa** | respire_{Pa}= mrespiratio_{Pa}*P_{aC}^\text{Air\_temperature-20} |
| **respirePb** | respire_{Pb}= mrespiratio_{Pb}*P_{bC}^\text{Air\_temperature-20} |
| **react** | React=\text{reratio}*P_{bC}^\text{Air\_temperature-20} |
| **transfer** | Transfer=\text{tranratio}*P_{aC}^\text{Air\_temperature-20} |
| **Carbonemission** | Carbonemission=PsC*carbonrate^\theta^\text{Air\_temperature-20} |
| **Methaneemission** | Methaneemission=PsC*mathrate^\theta^\text{Air\_temperature-20} |
| **CO₂flux** | $\text{CO₂flux} = (\text{respire}_{Pa} + \text{respire}_{Pb} + \text{Carbonemission})*44/12 + \text{Methaneemission}*16/12*25 - \text{photosynthesis}*44/12$ |

3.3. **Verification**

This study of dynamics of both above-ground and under-ground *reed* biomass, provides a significant volume of data for calibration of the model, while model calibration data used for other parameters were taken from the literature [16,31-35,43,44]. Model calibration was repeated using the test method until parameters were in good agreement with the observed values, the “Basic model parameters post-
calibration” was described in table 3 and the “Basic model parameters” was described in figure 3.

**Table 3. Basic model parameters post-calibration.**

| Description                | unit       | source |
|----------------------------|------------|--------|
| INIT Pac=103               | 100~150 gCm$^{-2}$ | [32]   |
| INIT Pbc=1650              | 1500~2000 gCm$^{-2}$ | [32]   |
| INIT PsC=0                 | gCm$^{-2}$  | [32]   |
| INIT Concen CO$_2$=400280~404.83 ppm per year | http://www.carbonify.com |
| $\theta$=1.05~1.09         |            | Calibrate; |
| CarryaC=2450               | 1000~5000 gCm$^{-2}$ | [31-33,40] |
| waterdepthmax=1.8          | 0.0~2.0 m  | [33-35] |
| Rad=14.67                  | 14.67 MJ m$^{-2}$ per year [31] |
| decayratePa=0.005          | 0.0~0.18 gg$^{-1}$ per day | Calibrate |
| mortalratePa=0.001         | 0.0~0.15 gg$^{-1}$ per day | [16,43] |
| mortalratePb=0.001         | 0.0~1.0 gg$^{-1}$ per day |        |
| tranratio=0.20             | 0.0~0.35 gg$^{-1}$ per day | [44]   |
| carbratio=0.4              | 0.0~0.5 gg$^{-1}$ per day | Calibrate; |
| mathratio=0.006            | 0.0~0.3 gg$^{-1}$ per day | Calibrate; |

**Figure 3. Basic model parameters.**

**Figure 4. CO$_2$ flux test.**

On the basis of the above model verification, the CO$_2$ flux of reed field ecosystem under the suitable water level (7.3 m elevation) is simulated and analyzed. The results of the simulation is tested only because of less monitoring data, the “CO$_2$ flux test” was described in figure 4. The test results show that the CO$_2$ flux simulation value is in good agreement with the monitoring value ($R^2(L)=0.701$), and the simulation results can represent the CO$_2$ flux results of Baiyangdian reed field ecosystem.
3.4. Forecast
Based on the above model verification, the seasonal variations in water level with a fluctuation range of less than 0.8 meters [19,34,35], were set to simulate the water diversion situation in the Baiyangdian wetland, allowing the change of carbon sink in reed field ecosystem during the growth season to be predicted. Variations were observed in the carbon sink of reed field during different seasons (spring, summer, autumn and winter) and with varying water level (0.1 m, 0.3 m, 0.5 m, 0.8 m).

4. Result
4.1. The whole growth season
First, the CO$_2$-C daily exchange of reed field ecosystem under the suitable water level (7.3 m elevation) was simulated in this paper, the “Variation of CO$_2$-C daily exchange in reed field according to flood depth” was described in figure 5. At the beginning (4-5 months), the carbon absorption was greater than the release because of the reed growth quickly, and the carbon sink increased, and the peak value of CO$_2$-C daily exchange was -120.48 gC/m$^2$/d (the article defines that the value is negative when the system absorbs CO$_2$, and vice versa), which appeared in May. Then (6-7 months), the carbon sink began to weaken because of the growth of reeds entered the stable period, and the CO$_2$-C daily exchange began to decrease. From the late August to the end of the growing season, carbon sink kept on decreasing because of carbon releasing, the peak value of CO$_2$-C daily exchange was 41.22 gC/m$^2$/d, and it appeared at the end of the growing season in October. But in the whole growing season, the cumulative CO$_2$-C uptake of Baiyangdian reed field ecosystem was 928.5 kgC/m$^2$, which was slightly higher than the monitoring value 722 kgC/m$^2$. The reason may be that the monitoring value only statistics the data of 4-10 months, and neglects the month of 2-3, resulting in a slight difference in the simulation results. The results of the simulation and monitoring showed that the reed field ecosystem in Baiyangdian was the sink of CO$_2$ in the whole growing season.

![Figure 5. Variation of CO$_2$-C daily exchange in reed field according to flood depth.](image)

Then, the prediction of carbon sinks under the fluctuation of water level. The result shows that, the water level fluctuations caused by water transfer will affect the CO$_2$-C daily exchange processes, the “Variation of CO$_2$-C daily exchange in reed field according to flood depth” was described in figure 5.
A water level change of 0.1 meter, the peak value of CO$_2$-C daily exchange is decreased by 7.2% respectively, throughout the whole growth season, and the Carbon sink is decreased by 8.23% in the year. The water level changes 0.3 meter, the peak value of CO$_2$-C daily exchange increased by 26%, and the carbon sink increased by 9.07% in the year. The water level changes 0.5 meter, the peak value of CO$_2$-C daily exchange is increased by 23.7%, but the carbon sink in the whole year is reduced by 13.26% because of the increase of carbon release in the later period. The water level changes 0.8 meter, the peak value of CO$_2$-C daily exchange varies from 4.7% to -219.6%, and the carbon sink is reduced by 45.10% in the year. It can be seen that the control of water level fluctuation value of artificial water transfer should be in 0.3 meter, and the carbon sink of reed field ecosystem can be increased to a certain extent.

4.2. The seasonal variation
The findings of this study show that the growth of reed communities increased throughout the 4-5 month growth season and that the peak CO$_2$ flux value was -120.48 mgCO$_2$/m$^2$, which was observed in May. Following this, the flux of carbon monoxide began to decrease and the overall carbon flux began to decrease from late August to the end of the growth season. It is of note, that the peak value of CO$_2$ flux (41.22 mgCO$_2$/m$^2$) was observed in October, which is the end of the growing season, the “Seasonal variation of CO$_2$ flux in the reed terrace at a water level of 0.3 m” was described in figure 6.

![Figure 6. Seasonal variation of CO$_2$ flux in the reed terrace at a water level of 0.3 m.](image_url)

This study effectively predicts carbon flux fluctuation in Reed terrace, based on the fluctuation of water levels by 0.3m over different seasons and results show that fluctuation in water level has a significant influence on the carbon flux of Reed. During spring, (March-May), maximal carbon flux occurs in May and the peak time is similar to that of the suitable water level, and the peak of carbon flux. For the -119.63 mgCO$_2$/m$^2$, the more appropriate water level decreased by 0.8%, still the performance of carbon-based. From June to the end of the growth season, the CO$_2$ flux and water levels remained constant, showing that the spring water transfer had no long-term effect on the carbon flux of the Reed terrace.

During summer (June-August), the peak carbon flux was present in May, at -149.66 mgCO$_2$/m$^2$ with an increase in water level by 24.2%. However, a water diversion program in July induced carbon
emissions with a small carbon flux peak of 19.47 mgCO$_2$/m$^2$. From August to the end of the growing season the dominant phase of carbon release occurs, showing that the summer water transfer had a significant influence on the level of carbon flux in the Reed terrace, accelerating carbon release.

During autumn (September - November), the water level and peak value of carbon flux remained unchanged from May and the peak value of CO$_2$ flux remained at -120.48 mgCO$_2$/m$^2$. During early September carbon fixation processes play a dominant role, with a small peak value of CO$_2$ flux observed in August (-39.94 mgCO$_2$/m$^2$), which was 2-fold higher than the level of carbon flux observed at the optimal water level, showing strong carbon sequestration characteristics. From September to the end of the growing season, the peak value of CO$_2$ flux was 50.18 mgCO$_2$/m$^2$, resulting in a 21.7% increase in carbon flux as compared to under optimal water level conditions. Therefore, there were both benefits and drawbacks to the autumn water transfer.

In winter (December - February), the water level and peak value of carbon flux returned to the level observed in May with a peak value of CO$_2$ flux of -120.48 mgCO$_2$/m$^2$, while enhanced carbon release characteristics were observed. The peak value of CO$_2$ flux during November was 42.25 mgCO$_2$/m$^2$, which was only 2.5% higher than under optimal water level conditions, showing some carbon release despite the overall minor effect of the winter water transfer on carbon fixation.

These analyses show the distinct seasonality of the effect of artificial water transfer on carbon flux in the Baiyangdian Reed wetland, with significant adverse effects in summer; mixed effects during autumn; minimal effect in winter and the least impact in spring. Therefore, from the perspective of establishing optimal carbon fixation in the Reed wetland, spring (March - May) is the best period for water diversion programs in the Baiyangdian wetland, with fluctuation value of water levels controlled within 0.3 meters.

5. Discussion

Water level plays an important role in the growth of wetland plants [19,44-46], may affect vegetative fixation and release of CO$_2$ during photosynthesis and respiration [2,44,47]. Plant biomass reflects the level of ecosystem productivity and the fixed morphology of carbon. Literature shows that wetland plant biomass is significantly correlated with the phreatic water level relationship and that CH$_4$ or CO$_2$ processes in wetland soils are a function of water depth [18,19,44], with CH$_4$ release under saturated conditions and CO$_2$ release under dry conditions [48]. On this basis, the carbon flux model presented here was constructed for reed wetlands, with results showing that predicted values are in good agreement with monitored values for changes in biomass and respiration rates of wetland soils.

Seasonal (spring, summer, autumn and winter) water transfer significantly affects the reed station ecosystem carbon flux, with varying degrees of impact depending on the season, which was also observed at the Swan Chau Wetlands [49], Panjin Wetlands [28] and Chongming Wetlands. The present study found that the spring water transfer caused the phenomenon of peak carbon flux reduction (May), due to flooding inhibiting the growth of Reed at the beginning of the growth season, with this effect persisting for 4-5 months [3,50,51]. This results in reduced respiration in reed terraces, but while the carbon content of biomass was less, the overall impact was not found to be significant.

Summer water transfer resulted in the characteristics of early carbon release in July, possibly due to the flooded conditions and high ambient temperatures, providing an anaerobic environment for the production and release of methane [52,53]. Flooding inhibited the growth of Reed, resulting in a reduction in carbon sequestration. The growth of reed is naturally inhibited in autumn and winter and water transfer had little effect on the growth of reed, but provided an anaerobic environment and therefore increased the level of carbon release. These findings show that effective artificial replenishment focused on maintaining the optimal water level for growth of reed, will contribute to the stability of carbon flux in reed wetlands.

The effect of artificial water transfer on the carbon flux of reed wetlands, shows that water diversions can maintain an effective level of flux in wetlands under appropriate water level control conditions. The short-term increase in carbon flux during summer periods, resulted in July experiencing carbon release characteristics, while autumn and winter water transfer reduced carbon
flux overall. To maintain or increase the level of carbon flux in Baiyangdian reed wetlands, these findings suggest that the optimal water diversion time was during spring (March - May), ensuring the water level fluctuation range is controlled within 0.3 m.

Wetland plant growth and carbon cycle processes are extremely complex, depending on many factors. This study selects the most important hydrological conditions for analysis, although human control and regulation are also critical aspects that should be considered in the restoration of damaged wetland ecological functioning, with these findings showing the relevance of considering seasonality, spatial and environmental factors.

6. Conclusions
This paper analyzes the effect of seasonal water level fluctuation on carbon flux in the Baiyangdian Reed wetlands, managed by artificial water transfer. These findings establish the relationship between water level change and Reed biomass, as well as the relationship between water level change and wetland carbon flux. The carbon flux model of Reed wetlands was effectively verified according to seasonal variations in water level and the change in carbon flux in the Reed wetland was established.

These results show that spring water transfer has the least effect on wetland carbon flux and that carbon flux is increased during the early stages of the summer water transfer event, with increased carbon release characteristics in the later stages of summer and water transfer during autumn and winter increases overall carbon release. Artificial water transfer significantly affects carbon flux in wetlands and appropriate artificial water transfer must contribute to the growth and carbon flux of Reed in the Baiyangdian wetland. The optimal water diversion time in the Baiyangdian wetlands is in spring, ensuring that water level fluctuation is controlled within 0.3 m.

In this study, the carbon flux model of the Baiyangdian Reed wetland was established based on artificial water transfer, which helps understand the effect of artificial water transfer on the change in both biomass and the level of carbon flux observed in Reed wetland during the growth season. These findings can be used to implement artificial water transfer and ecological service function design, as well as being applied to other related wetland research areas.

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