Research on Poyang Lake Regional Protection and Management Countermeasures under the Change of River-lake Relationship

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Abstract. In recent years, with the construction and operation of the Three Gorges Project, a series of changes have taken place in the relationship between the Yangtze River and Poyang Lake. Changes in hydrological conditions have led to problems in the Poyang Lake area such as early dry season, extended dry duration, and lower dry water level. As the largest freshwater lake in my country, Poyang Lake is an important treasure house of water resources in the middle and lower reaches of the Yangtze River. It is of great significance to study the protection and management of Poyang Lake under the changing relationship between rivers and lakes. This article analyzes the impact of changes in the relationship between rivers and lakes on the hydrological situation of the Poyang Lake area, and sorts out the problems of the ecological environment under the changes of rivers and lakes. On this basis, combined with the ongoing Poyang Lake water conservancy project, the importance of the construction of the hub is analyzed, and relevant suggestions for the current problems facing Poyang Lake are put forward.

1 Introduction

The water volume of Poyang Lake during the dry season has shown a downward trend in recent years [1]. Studies have shown that the main reason for the low water changes of Poyang Lake is the corresponding changes in precipitation and the incoming water of the five rivers, followed by the changes in the upper and middle reaches of the Yangtze River [2-3]. After the completion of the Three Gorges Project, impounding water at the end of the flood season will change the amount of water inflow from the Yangtze River, and the supporting effect of the Yangtze River at the end of the flood season will affect the hydrological situation of Poyang Lake. The operation of the Three Gorges Project will have certain impacts on hydrology, sedimentation, water environment and wetland ecology [4]. In view of the abnormal changes in the climate of the Yangtze River Basin and the driving factors for the low water regime of Poyang Lake, many scholars have used mathematical models to quantitatively give the influence of different factors on the low water regime of Poyang Lake. Lai et al. [5] pointed out that the impoundment of the Three Gorges Project has changed the original hydraulic relationship between the rivers and lakes, causing the water level of the mainstream of the Yangtze River to drop rapidly, the hydraulic slope increases, and the outflow flow from the lake mouth increases, which accelerates the decline of the water level of Poyang Lake. On the basis of understanding and analyzing the changing laws of river and lake water regimes, carry out the identification of the factors affecting river and lake water regimes, and the research is convenient to reveal the driving mechanism of the interaction between rivers and lakes. In recent years, research on the evolution mechanism of the water cycle system affected by climate change and human activities has attracted widespread attention at home and abroad, especially after the Three Gorges Project, how it will affect the middle and lower reaches of the Yangtze River, especially the Dongting Lake, Poyang Lake and other lake systems, Is the focus of current research.

In the 21st century, the Chinese State Council have attached great importance to the protection and management of Poyang Lake, especially since the low water level in the lake area. The central leadership has made important instructions many times and put forward clear management requirements. In April 2007, the then Premier Wen Jiabao instructed "to maintain the clean water of Poyang Lake and one lake forever"; in September 2009, the then Vice Premier Li Keqiang made clear instructions when inspecting Poyang Lake: "The first is to build the Poyang Lake ecological water conservancy project. Put it in the overall structure of the Yangtze River system, and consider it at the national level; second, the entire construction project must highlight the ecological characteristics, make overall plans, and take the path of ecological development, so as to provide experience for the Poyang Lake area to

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achieve sound and rapid economic and social development; The third is to build the project into a symbol of the Poyang Lake Ecological Economic Zone, which can not only be used for sightseeing, but also generate comprehensive benefits, which is conducive to sustainable development." On March 6, 2015, General Secretary Xi Jinping emphasized when participating in the deliberations of the Jiangxi delegation at the Third Session of the Twelfth National People's Congress: "The extreme drought, reduced water volume, and sharp decline of fish in Poyang Lake should arouse great attention. If you wait until the ecological environment is destroyed, it will be too late. Don't go to that step. The price paid to go to that step is too heavy." The Jiangxi Provincial Party Committee and the Provincial Government earnestly implemented the central government. The spirit of instruction of the leading comrades, in the process of research and demonstration of the Poyang Lake Water Conservancy Project, always pay attention to listening to different voices, soliciting opinions widely, fully absorbing and tolerating various suggestions; carrying out a large number of basic research work in a targeted manner; gradually transforming the construction Concept and perfect construction plan. The Poyang Lake Water Conservancy Project follows the brand-new concept of "One lake with clean water", "Benefits for both rivers and lakes", and "Adjusting dryness but not flood control". The main goal is to improve the carrying capacity of water resources and water environment of Poyang Lake during the dry season, and give full play to the impact of water conservancy projects. The basic role of protecting the ecological environment and promoting economic and social development [6].

At present, the relationship between Poyang Lake and the Yangtze River has changed. The low water period of Poyang Lake area has advanced, the low water duration has been lengthened, and the low water level has decreased. Poyang Lake has presented a series of ecological and environmental problems. Considering the preliminary demonstration work of the Poyang Lake Water Conservancy Project, it is very necessary to put forward the protection and management countermeasures of Poyang Lake under the change of the relationship between the rivers and lakes.

2 Study Area

The Poyang Lake is the largest freshwater lake in China and a world-famous wetland. It is known as the "Kidney of the Yangtze River" and "Bird Paradise". It is an important ecological barrier for the Yangtze River. Poyang Lake receives water from the "Five Rivers (Ganjiang, Fuhe, Xinjiang, Raohe, Xiushui)" and enters the Yangtze River from Hukou, and it has an important regulation and storage function. The lake area is 3706 km^2 (corresponding to the flood control water level of the Hukou Station is 22.50 m), and the total length of the lake shore line is 1200 km. Poyang Lake is an over-water type, throughput-type and seasonal lake, with a unique form of "During the flood period, it was a lake with a surface of water, and during the dry period it was a linear river". The area is flat, with concentrated arable land, and two major agricultural products production areas in the Poyang Lake Plain and the Ganfu Plain. It is an important national granary; the area has a large population, industrial parks are distributed around the lake, and the economic development is full of vitality; the area is rich in ecological resources, and it undertakes the "Five Rivers", "Three screens (Northeast Jiangxi-Eastern Jiangxi mountain forest ecological screen, Northwest Jiangxi-West Jiangxi mountain forest ecological screen, and southern Jiangxi mountain forest ecological screen)", the ecological location is important.

3 Analysis of changes in the relationship of river-lake

Due to the dual effects of changes in natural factors and increasing human activities, especially the construction and operation of reservoirs on the trunk and tributaries of the Yangtze River, a series of changes have taken place in the runoff and sediment transport process of the Yangtze River, and the water-sediment conditions of the river-lake system in the middle and lower reaches of the Yangtze River have also changed. In particular, significant changes have taken place in the incoming sediment conditions, causing the river-lake system of the Yangtze River and Poyang Lake to present new characteristics in water-sediment transport, erosion and deposition evolution, and river-lake relationships.

3.1 Decreased water level in the lake area

Affected by the impoundment of the Three Gorges Reservoir and the upstream controlling reservoir after the flood and the erosion of the main stream, the main stream water level decreased from September to October at the end of the flood season, which caused the water of Poyang Lake to be quickly pulled out, and the water level of Poyang Lake decreased during the dry season. From 2003 to 2017, compared with 1980 to 2002, the average water level of Poyang Lake decreased by 0.56 to 2.31m, and the water level of Xingzi Station was below 10m, and the duration was extended by more than 20 days. In 2004, Xingzi, Kangshan, and Yongxiu stations appeared to have the lowest water level since actual data were available. The daily average water level process at Hukou Station before and after the construction of the Three Gorges Reservoir is shown in Figure 1.

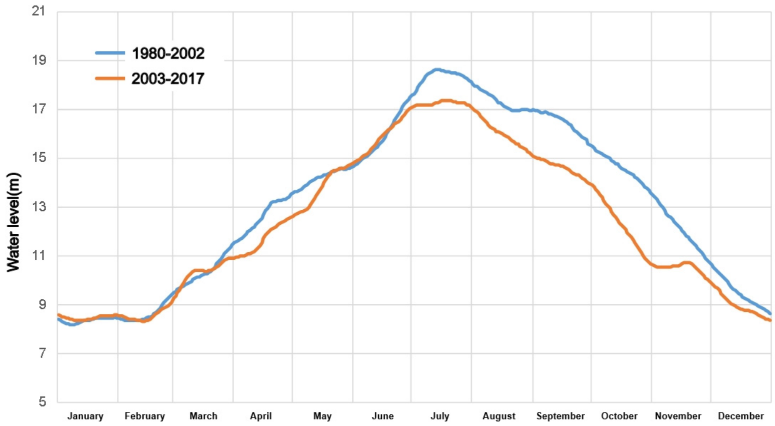

Figure 1 The daily average water level process at Hukou Station before and after the construction of the Three Gorges Reservoir

3.2 Changes in sediment discharge into and out of the lake

The amount of water into the lake of the five rivers of Poyang Lake has not changed much. The amount of sediment into the lake has been significantly reduced, but the amount of sediment out the lake has increased. From 1956 to 2017, the average annual runoff and sediment transport into Poyang Lake from the "Five Rivers" (excluding the incoming flow from the interval) were $1094\times10^8m^3$ and 1220×10^8t, respectively. There was no obvious trend change for the runoff. Since 1961, there has been a continuous decreasing trend, and the annual sediment discharge of Hokou Station has also shown a continuous decreasing trend from 1956 to 2002. From 2003 to 2017, the average annual amount of sediment into the lake from the "Five Rivers" decreased to 5.82 million tons, a decrease of 43.5% compared to 1991 to 2002. At the same time, the amount of sediment out the lake showed an increasing trend with an increase of 61.2%, compared with 1991~2002. The annual runoff and sediment process at Hukou Station is shown in Figure 2.

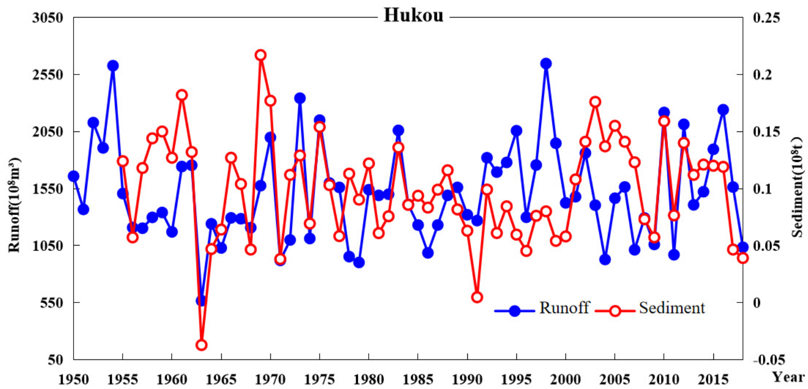

Figure 2 The annual runoff and sediment process at Hukou Station

3.3 Changes in sediment discharge into and out of the lake

The amount of water flowing back into Poyang Lake from the Yangtze River, the maximum backflow rate, and the average number of days of backflow in the year all showed a decreasing trend. From 1956 to 2017, there were 764 days in 54 years of backflow. The total amount of water poured into the lake was $1455\times10^8m^3$, and the average annual amount of water poured into the lake was 28.5×10^8t. The maximum backflow was 13,600m³/s on July 11, 1991. From 2003 to 2017, there were 129 days in 12 years of backflow. The total amount of water poured into the lake was $265\times10^8m^3$, and the average annual amount of water poured into the lake was $221\times10^8m^3$. The maximum backflow flow was 6160m³/s on September 9, 2003.

3.4 Changes in sediment discharge into and out of the lake

The water channel into the river in the Poyang Lake area was significantly lowered, and the water level at Xingzi Station was significantly reduced. According to the calculation and analysis of the amount of sediment into and out the lake in recent years and the comparison of the measured topography of the lake area in 1998 and 2010, the Poyang Lake area was slowly silting up before 2003. From 1998 to 2010, due to the erosion of the source and the impact of sand mining caused by the decrease in the water level of the main stream, the area of the water channel into the river was significantly undercut, the river bed elevation showed a downward trend during the dry season, and the area of the section below the water level of 15m increased significantly. The average daily water level drop between Xingzi Station and Hukou Station from 1956 to 2002 was 0.57m. When the water level at Hukou Station was below 12m, the average drop was 0.80m. Due to the undercutting of the watercourse section of the river, the average daily water level drop between Xingzi Station and Hukou Station from 2003 to 2012 was 0.28m. When the water level at Hukou Station was below 12m, the average drop was 0.35m; the water level drop is significantly reduced, indicating that the water level of Xingzi Station at the same water level of Hukou Station is significantly reduced.

3.5 Changes in dry season

The dry season of Poyang Lake is advanced and the dry duration is lengthened. Affected by the impoundment of the Three Gorges Reservoir and the upstream control reservoir and the erosion of the main stream, the water level of Poyang Lake dropped significantly from September to October. Compared with 1980-2002, the water level of the lake area dropped by 0.52-2.20m from 2003 to 2017, and the low water level appeared earlier about 31 days. Among them, the drop in the water level in late September was mainly due to the impact of the Three Gorges Reservoir's impoundment. The drop in October was the combined effect of the impoundment of the Three Gorges Reservoir, changes in natural runoff, and the impoundment of other projects. The drop in water level in November was mainly due to the erosion of mainstream rivers, changes in natural runoff, and other water storage projects. During the dry season, the Three Gorges Reservoir increased the discharge flow and slowed down the impact of river erosion on the low water level.

4 Ecological environmental impact under the changing relationship between rivers and lakes

4.1 More severe water utilization situation

July to September is the peak time for water consumption in the Poyang Lake region, accounting for about 50% of the total annual water consumption, while the inflow of water in the same period only accounts for about 20% of the annual inflow. Incoming water and water use do not match in time, which brings great difficulties to the utilization of water resources. At the same time, the flood and low water levels of Poyang Lake fluctuate greatly, and the water level usually fluctuates as high as 10m during the year, which also brings more adverse effects on water resources utilization. Especially in recent years, the low water level of Poyang Lake has been reduced and the dry season has advanced, which has further aggravated the difficulty of water diversion(pumping) in the lake area, and has a greater impact on lakeside agricultural irrigation and urban domestic water supply.

4.2 Increasingly prominent water environment problems

The water body decreases, the water pollution concentration increases, and the water quality decreases; the submerged vegetation is greatly reduced, from the original 20% to less than 5%, and the water purification capacity decreases. In the 1980s, the water quality of Poyang Lake was dominated by Grade I and II water quality, accounting for an average of 85%, and Grade III water accounting for 15%, showing a slow downward trend. In the 1990s, it was still dominated by Grade I and II water, accounting for an average of 70%. Grade III water accounts for 30%, and the downward trend is accelerating; in 21st century, especially after 2003, only 50% of Grade I and II water, 32% of III water, and 18% of water bodies inferior to Grade III water, the water quality is declining obviously. The water quality in the flood season is obviously better than that in the dry season, and the average percentage of Grade II water in the flood season is 15% higher than that in the non-flood season.

4.3 Declining water ecosystem quality

In recent years, the low water level of Poyang Lake appeared earlier and the low water period extended, which has a significant impact on vegetation growth. 1) The water level drops ahead of schedule, and the beaches are exposed 1-2 months ahead of schedule. The exposed area is greatly increased, and the soil moisture content is low, which cannot meet the ecological water demand of wetland plants. Reeds, Nandi and other watery plants have expanded in area, expanded to low-elevation areas, and sparsely planted. Wetland vegetation on beaches above 15m has gradually degraded into neutral meadows dominated by bermudagrass; 2) The emergence of low water level has exposed the area that could maintain 50-100cm in the dry season and turned into a mudflat. A large number of submerged plants died due to prolonged exposure, and the area of submerged vegetation such as prickly pear was increased. It accounted for 20% of the vegetation area of the whole lake in the past century, and it has dropped to less than 5% now; 3) Due to the drop in the water level, the area of the lake has shrunk, and human disturbance activities have increased, resulting in reduced habitat and shelter conditions for birds, affecting the virtuous cycle of the wetland ecosystem, and threatening the quality of the Poyang Lake ecosystem. With the degradation of the wetland ecosystem, its ecological service functions such as water conservation, climate regulation, pollution degradation, and provision of migratory bird habitats are gradually declining. In addition, changes in hydrological rhythms have affected the reproduction of many fishes. The area of spawning grounds and feeding grounds for resident fishes in the lake has shrunk, the water level of the wintering grounds has become shallower, and the feed intake of juvenile fish has been affected, and their survival and habitat range have been further threatened. The types and scale of fish floods in the lake area have been significantly reduced, and the amount of fish resources has been drastically reduced by more than 70% compared with before the 1980s. The structure of economic fish populations has shown a lower age and miniaturization. According to statistics, the total annual catch of Poyang Lake in 2000 was 35,900t, and by 2009 it had been reduced to 23,500 t, a reduction of 1/3. The rapid receding of water caused the mussels, snails and other benthic animals on the mudflats to be exposed to the beach, dehydration and death, and the types of benthic animals were greatly reduced compared with the 1980s.

5 Significance of Poyang Lake Water Conservancy Project Construction

The continuous stability of the water volume and quality of Poyang Lake is directly related to the water safety around Poyang Lake and even the middle and lower reaches of the Yangtze River. In order to cope with the impact of post-flood impoundment of reservoirs in the upper reaches of the Yangtze River and the reduction of inflow from the upper reaches of Poyang Lake, avoid the problem of low water periods in Poyang Lake, and maintain the "clear water" of Poyang Lake, Jiangxi Province proposed the construction of the Poyang Lake Water Control Project[7]. By scientifically dispatching the Poyang Lake Water Conservancy Project, giving full play to the role of Poyang Lake's regulation and storage, and strengthening the unified dispatch and management of water resources, it is an important means to optimize the water resources allocation pattern of the Yangtze River Basin [8-10].

5.1 Keeping floods and regulating dryness is the central task of Poyang Lake Water Conservancy Project

According to the current pivotal dispatch principle of “adjusting drought without controlling floods and benefiting both rivers and lakes”, the rivers and lakes will be connected from March to August during the flood season to maintain the flood discharge (storage) function of Poyang Lake; in early and mid-September, opportunistically store the end-flood flood before the impoundment of the Three Gorges Reservoir, and use the flood resources of Poyang Lake to improve the water replenishment capacity of Poyang Lake in the dry season; During the dry season, the water level of Poyang Lake is moderately adjusted. The water of Poyang Lake is quickly pulled into the Yangtze River (especially during the impoundment period of the upper reaches of the Yangtze River), to maintain the natural decline of the water level in the lake area, optimize the time-history distribution of water resources in the mainstream downstream of the Yangtze River, and improve the degree of water supply security. According to analysis and calculation, according to the operation scheduling method proposed at this stage, after the control and operation of the project, during the storage period of the Three Gorges Reservoir (September 16 to the end of October), the downstream supplementary water volume can be more than $2.04\times10^8 m^3$, and it will be available from November 1 to the end of December. The discharge volume was $3.11\times10^8 m^3$, with an increase of $2.85\times10^8 m^3$ from January to February, and an increase of $3.05\times10^8 m^3$ in the first ten days of March. During the whole dry season, the discharge flow of Poyang Lake has increased to varying degrees, which improves the water supply capacity of the Yangtze River and creates irreplaceable conditions for the rational allocation of water resources in the middle and lower reaches of the Yangtze River.

5.2 Improving the water quality of the lake area and increasing the carrying capacity of the water environment of the mainstream of the Yangtze River

According to the Research Report on *the Deepening Demonstration of the Poyang Lake Water Conservancy Project's Impact on Poyang Lake Water Quality* compiled by the Ministry of Ecology and Environment, the current water quality of Poyang Lake during the dry season is generally Grade IV to V, and the distribution area of Grade III water quality is about 16%. After the operation, the water environment capacity and wetland area in the dry season have been increased, and the pollution holding and purification capacity of the lake water body will be improved to a certain extent, and the water quality of the lake area in the dry season will be effectively improved. The water area of Grade III can reach $256km^2$, which accounts for an increase from 16% to 23% of the total lake area, and the wanter area of Grade IV~V is about $856km^2$, accounting for about 77%. Even with the increase of the pollution load into the lake, the water quality during the dry season after the operation of the project is significantly improved compared with that when the project is not built, so that a large amount of clean fresh water can be supplied to the lower reaches of the Yangtze River during the dry season, further improving the water quality of the mainstream of the Yangtze River during the dry season, and increasing the water environmental carrying capacity of the Yangtze River mainstream..

5.3 Maintaining suitable lake capacity and improving emergency response capacity of the Yangtze River mainstream

In response to emergent water pollution incidents in the lower reaches of the Yangtze River, although the Three Gorges Reservoir has a relatively large storage capacity, it is too far away to respond to emergencies with weak flexibility. After the Poyang Lake Water Control Project is put into operation, during the three months when the water level of the Yangtze River is the lowest from December to February of the following year, the lake area can maintain a certain water level and volume (10m water level corresponds to a lake capacity of $8.11\times10^8 m^3$), which can be provided for downstream high-quality water anytime, so as to play the emergency role of the hub. When special water environmental events (such as salt tides, water pollution events, etc.) occur in the mainstream of the Yangtze River, and the water level in the lake area drops from 10.0m to 6m (slightly higher than the measured minimum water level), the static volume is about $6.70\times10^8 m^3$. It can provide emergency supplementation of more than $2500 m^3/s$ in the lower reaches of the Yangtze River for three consecutive days, which can effectively slow down or eliminate the adverse effects caused by sudden water pollution incidents, and improve the safety assurance rate of comprehensive utilization of water resources in the mainstream of the Yangtze River and emergency response capabilities.

5.4 Strengthen river basin management and improve the unified dispatching capacity of water resources in the Yangtze River Basin

In order to further improve the ability of unified management and deployment of water resources in the Yangtze River Basin, without affecting the flood control and water resources development and utilization in the middle and lower reaches of the Yangtze River, promote the construction and operation of the Poyang Lake Water Conservancy Project and make it subject to the unified arrangements of the entire Yangtze River basin and adhere to the benefits of both rivers and lakes, Cooperating closely with the Three Gorges Project and the upper Yangtze River cascade reservoirs to carry out joint dispatch and optimized operation, implement water storage at staggered time, increase dispatch flexibility, and provide necessary engineering conditions for the reasonable allocation of water resources in the middle and lower reaches of the Yangtze River.

6 Conclusions

(1) In recent years, with the construction and operation of cascade reservoirs in the middle and upper reaches of the Yangtze River represented by the Three Gorges Reservoir, a series of changes have taken place in the relationship between the Yangtze River and Poyang Lake. Changes in hydrological conditions have induced problems in the Poyang Lake area, such as the advance of the dry season, the extension of the dry duration, and the drop in the water level during the dry season.

(2) The current changes in the hydrological situation in the Poyang Lake area have induced a series of ecological and environmental problems. For example, the situation of water resources utilization around the lake area is more severe, the water environment problems in the lake area are becoming increasingly prominent, and the quality of the lake area's water ecosystem is deteriorating. These are all urgently needed to be resolved. If the problem persists for a long time, it will seriously affect the health of Poyang Lake.

(3) According to the previous demonstration materials of the Poyang Lake Water Conservancy Project, the construction of the project will improve the hydrological situation of Poyang Lake, thereby improving the water quality of the lake area, strengthening the unified water resources dispatching capacity of the Yangtze River Basin, and improving the emergency response capacity of the Yangtze River mainstream.

(4) In addition, it is still necessary to strengthen the observation and study of the impact on the Poyang Lake area after the operation of the upper reaches of the Yangtze River reservoir group with the Three Gorges Reservoir group as the core. Strengthen the construction of comprehensive station networks such as hydrological station network, river and lake monitoring station network, and water environment monitoring station network, improve the monitoring and early warning system, realize information sharing, and carry out continuous dynamic monitoring and evaluation. In particular, it is necessary to strengthen the observation and basic research work of the superimposed impact on Poyang Lake after the upstream reservoir group is gradually put into use.

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