Study on the Influence and Countermeasures of the Canal Projects on Aquatic Ecological Environment of Rivers along the Line

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Abstract: Canal plays a prominent role in improving regional transportation conditions, regional economic development and cultural dissemination. However, the complexity of the canal project will inevitably cause disturbance to water bodies and develop a series of impacts. This paper summarizes the engineering contents involved in the canal projects, combines the experience of the waterway and water conservancy hub on the water ecological environment, analyzes the main environmental impacts on the aquatic ecology along the canal during the construction and operation periods. Then effective countermeasures were proposed at different levels, such as canal design, engineering construction and ecological restoration. This work can serve as a reference for the protection of the aquatic ecological environment in canal development.

1. Foreword

The development of the water transport plays a significant role in promoting inland water transportation, strengthening inter-regional links, and promoting economic development. By the end of 2021, the navigable mileage of inland waterways in China is 127600 kilometers. Among the navigable mileage of inland waterways, the Yangtze River system is 64668 km, the Pearl River system is 16789 km, the Yellow River system is 3533 km, the Heilongjiang River system is 8211 km, the Beijing-Hangzhou Grand Canal is 1423 km, the Minjiang River system is 1973 km, and the Huaihe River water system is 17500 km[1].

In order to promote the high-quality development of inland waterway shipping, give full play to comparative advantages, effectively promote the optimization of transportation structure, realize the modernization of inland waterway shipping, and better serve the construction of a strong transportation country and the implementation of major national strategies, the Ministry of Transport proposes to open up the north-south inter-basin water transport channel, build a new Grand Canal, promote the restoration of the north section of the Yellow River in the Beijing-Hangzhou Canal, as well as the Pinglu Canal and other canal communication projects, and form a longitudinal corridor of the Beijing-Hangzhou Canal, the Yangtze Huaihe Trunk Line, the Zhejiang Jiangxi Guandong Channel, and the Han Hunan Guangxi Channel[2], which indicates that China's water transport industry will usher in a new period of development.

2. Content analysis of the Canal Project

The canal project focuses on maximizing existing water systems utilization, and connecting multiple water systems through manual excavation to realize shipping development. Taking the three canals studied by the existing demonstration as an example, the Pinglu Canal starts at the mouth of the Pingtang River in Nanning and goes into the territory of Qinzhou, and finally merges into Qinjiang River and enters the sea via Qinzhou Port, with a total route of about 140 km[4]. The Xiangxi Canal runs from Chenglingji (Yueyang City) of Hunan Province in the north of the Yangtze River, south to the West River route in Wuzhou, Guangxi Province, with a total length of 1238 km[5]. The Ganyue Canal starts from Poyang Lake Estuary (Yangtze River) in Jiangxi Province and ends at Sanshui Estuary of Beijiang River in Foshan City, Guangdong Province, with a total length of about 1148
km[6].

<table>
<thead>
<tr>
<th>Project content</th>
<th>Pinglu Canal</th>
<th>Xianggui Canal*</th>
<th>Ganyue Canal*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of the total line (km)</td>
<td>140</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Water system connectivity</td>
<td>Watershed situation involved</td>
<td>Yujiang River System and Qinjiang River System</td>
<td>Yangtze River System and Xijiang River System</td>
</tr>
<tr>
<td>River conditions involved</td>
<td>5</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Length of natural River (km)</td>
<td>86</td>
<td>230</td>
<td>215</td>
</tr>
<tr>
<td>Length of cross-Mountains segment</td>
<td>29.5</td>
<td>28</td>
<td>30</td>
</tr>
<tr>
<td>Man-made canal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Navigation Junction</td>
<td>Number of new, renovated and expanded navigation buildings</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Number of new, renovated and expanded bridges</td>
<td>28</td>
<td>76</td>
<td>94</td>
</tr>
<tr>
<td>Waterway regulation</td>
<td>Cutoff of river</td>
<td>57</td>
<td>112</td>
</tr>
<tr>
<td>Channel dredging ratio (%)</td>
<td>98</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Quantity of reef blasting and excavation work (×10⁴m³)</td>
<td>8850</td>
<td>60744</td>
<td>24430</td>
</tr>
<tr>
<td>Water transfer project</td>
<td>Recent water regulation(m³/s)</td>
<td>24</td>
<td>17.94</td>
</tr>
<tr>
<td>Long term water regulation (m³/s)</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auxiliary project</td>
<td>Navigation Aids Engineering, Public Works, Anchorage Engineering</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data from the canal study phase measurement results, the specific data to engineering measurement shall prevail

*, Cross-Mountains segment of canal

It can be seen that the three canals all have relatively long mileage, and involve multiple rivers connection projects. In addition to cascade hub construction, and river crossing bridge renovation to achieve the corresponding level of the waterway, the Canal project also involves water system connection, excavation of crossing sections, cross basin water transfer, and supporting engineering content. Compared with traditional waterway construction projects, the canal project is complex, and with high development intensity. Therefore, development and navigation of the canals projects will have significant impacts on the ecological environment of the water area.

3. Aquatic ecological impact analysis of canal project

3.1 Aquatic ecological impacts during the construction period of the canal

Impact on aquatic habitats. Dredging and reef cleaning of the canal will generate a large amount of suspended sediment, resulting in an increase of the suspended solids content in river construction areas. It was found that the concentration of suspended solids in water quality indicators is negatively correlated with the density and diversity of zooplankton[10]. The cutting and straightening project has a cutting effect on the river channel, destroys the integrity of the original river channel, makes the river ecosystem landscape patchy, and also has impacts on the coastal ecosystem. The disappearance of the curved riverbank weakens the material exchange within the river. The reduction of deep pools and shoals can lead to the simplification of the ecological environment, and the weakened river self-purification capacity. At the same time, the erosion of the river bank is intensified, which makes the organisms in the river decrease or disappear[8,9].

The impact of the hub project on the habitat mainly comes from the bottom and slope of the approach channel during the lock construction, cofferdam construction and dredging, which will cause an increase in turbidity and suspended solids in the local waters, and will have a local impact on the habitats of phytoplankton, benthic organisms and fish. Wastewaters in the cofferdam discharged without treated will affect the water quality and the habitat environment of aquatic organisms.

Impact on aquatic organisms. The construction processes of channel dredging, reef clearing projects, hub construction, and bridge reconstruction disturb the water bodies, then the concentration of suspended solids in the water increases. The high concentration of suspended solids lead to the decrease of water clarity, directly or indirectly inhibiting the growth and reproduction of phytoplankton and zooplankton[10,11].

It was found that when the suspended sediment content exceeds 1000mg/L, the growth of phytoplankton would be significant inhibitory, and further aggravated the inhibitory effect on zooplankton[12]. High suspended solids concentration (>500 mg/L) can easily cause respiratory and digestive disorders in shellfish, affecting their reproduction and growth[11]. The lethal concentration of suspended solids for adult fish was 52000 mg/L, and the significantly affected concentration was 500 mg/L. For juveniles, the lethal concentration of suspended solids was 250 mg/L, and the significantly affected concentration was 125 mg/L. However, the suspended solids impacts were temporary and will gradually recover with the completion of construction[14].
In addition, the sediment disturbance from construction will also cause the loss of benthos, fish eggs and larvae. The loss can be estimated by referring to the corresponding prediction method of “Technical Regulations for Impact Assessment of Construction Projects on Marine Biological Resources” (SC/T9110-2007).

3.2 Aquatic ecological impacts during the operation period of the canal

Impact on aquatic habitats. The expansion and dredging of the river channel in the canal construction significantly increase in water flow and aquatic habitat space. Changed water flow conditions in the river caused the natural rhythm of water flow turn weak, the habitat conditions tend to be single. The operation of the canal hub will affect the flow velocity, transparency, dissolved oxygen, and nutrient salts of the river. The water system connectivity project of the canal can effectively improve the water system structure and pattern of the connected areas [15]. In addition, water diversion project in canal construction can alleviate the shortage of water resource scarcity in connected areas, and improve the regional water environmental conditions [16,17].

The water diversion project of the canal is a redistribution of water resources along the canal to respond to the needs of shipping. It can optimize the allocation pattern of water resource, increase the water volume of tributaries, and also improve the ecological environment of the river, which has a positive effect on the basin. However, due to the different hydrochemical and ecological environment conditions of water bodies in different basins, as well as the constraints of water cycle and biological cycle, water diversion project also has certain negative impacts on aquatic ecosystem. Studies have shown that water diversion has a significant impact on the salinity and SS of the Mississippi Delta estuary [18]. However, as the largest source of nitrate nitrogen and total nitrogen in the Mississippi River estuary delta, water diversion also effectively supplements nutrients in the estuarine area [19]. It has been suggested that water diversion can reduce the food available to shrimp in the affected area, which will eventually result in a decrease in the growth rate of different species of shrimp [20]. In addition, water diversion may bring some pollutants into downstream water bodies, causing an increase in pollution load and even deterioration of water quality.

Impact on aquatic organisms. After the operation of the canal hub, the water habitat will transform from river type to lake type, and the upstream flow rate of the hub will slow down to form a still water zone. Changes in flow, velocity, and water level upstream and downstream of the hub cause changes in the habitat of aquatic organisms, thus affecting the growth of aquatic organisms in the watershed [21]. Changes in hydrological conditions affect the self-purification capacity of water bodies, which can impact the water quality and the living environment of aquatic organisms [22]. A reservoir with stratified water temperatures may affect aquatic life in the reservoir area and downstream of the reservoir [23].

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**Fig1.** Phytoplankton changes in the reservoir area before and after the construction of Qiaogong Hydropower Station

**Fig2.** Zooplankton changes in the reservoir area before and after the construction of Qiaogong Hydropower Station
Figures 1 and 2 show the changes of phytoplankton-zooplankton in the reservoir area before and after the completion of the Qiaogong Hydropower Station. It can be seen that after the completion and operation of the canal hub, the number of macrophytoplankton species increase significantly, and the proportion of different species, density and biomass will also change to a certain extent. The decrease of Euglenophyta is the largest. The species of zooplankton suitable for hydrostatic open water will appear, while the species and quantity of cladocera and copepods will decrease.

The construction of the hub has gradually blocked the free connectivity between the original river bodies and the natural exchange between nutrients and organisms. It was noted that the diversity of phytoplankton, hygophytes, zoobenthos and fish in the water body was lower than that in the connected water, and the food web structure tends to be more simplified. The operation of the hub may block the migration pathways of the wild fish, which has a direct impact on the degradation of fish populations.

**Impact of alien biological invasion.** Alien biological invasion does affect the habitat of indigenous fishes, especially the carnivore ones, to a certain extent. Exotic fish species might cause several harmful effects, such as a significant decline in the species and population of those indigenous fish, and a cruel competitive environment for food resources and living space among all the aquatic lifes, which could destroy the replenishment of local fish populations and contaminated the germplasm resources of local fish. It is found that the phenomenon of alien fish invasion was widespread in the reservoir areas of many completed hydropower projects, and even some exotic fish have become dominant species in some reservoirs, which has contributed a significant negative impact on the original water ecosystem. In order to reduce the ecological harm caused by exotic fish, an early warning and monitoring mechanism should be strengthened, as well as the protection of indigenous fish.

4. Countermeasures for aquatic ecological impact of canal project

1. In order to achieve an aquatic ecological restoration, maintain biodiversity, and reduce the harmful impact of canal development on aquatic ecology, the concept of ecological waterway should be strengthened during the design, construction, and maintenance of the canal. Optimize the construction site, minimize the construction scale of waterway regulation as much as possible to reduce the damage to the original ecological environment.

2. Carry out a comprehensive local research on river ecology to build a basic data for ecological restoration affected by the canal construction. Based on ecological surveys, combined with the analysis of the impact of aquatic organisms, biological protection objects are divided into two categories: short-term attention and long-term considerations.

3. Based on the impact of canal construction and operation on water ecology, protection measures can be implemented from two dimensions: engineering and restoration. From the engineering point of view, research and design of hub fish facilities should be carried out, and ecological operation models and mechanisms should be studied; From the perspective of ecological restoration, the water ecological protection measures should be proposed from the aspects of aquatic habitat protection, biological habitat maintenance, proliferation and release, as well as fishery management.

5. Conclusion

This study summarized the main construction content of three cross-basin canals, analyzed the impacts of canal development on the natural rivers and the impacts of aquatic ecology along the line. The study concluded that the impact of the canal on the aquatic ecology of rivers mainly includes the changes of aquatic habitat conditions and aquatic species, as well as the invasion of alien organisms. Channel projects, such as dredging, reef blasting during the canal construction would inevitably cause a series of changes in the aquatic habitat environment, the mass losses of benthic organisms and fish eggs. The influences of the canal and dam operation on aquatic organisms were mainly contributed on the physical and biological isolation of aquatic organisms and ecological connectivity of water systems, which possibly cause various ecological risks of the water system and water environment. Finally, measures for protecting and restoring harmful impact of the canal on the aquatic ecological environment were proposed from three aspects: ecological canal design, engineering regulation, and ecological restoration.

References

9. Han B, Endreny T A. Detailed river stage mapping and head gradient analysis during meander cutoff in a laboratory river.