Research Status and Prospect of Fish Habitat

Ya Liu1,2, Sichen Tong1,2,*, Yongfeng Xiong1,2

1 School of River and Ocean Engineering, Chongqing Jiaotong University, Chongqing, 400074, China
2 National Engineering Research Center for Inland Waterway Regulation, Chongqing, 400074, China
* Corresponding author’s e-mail: tongsichen@ cqjtu. edu. cn

Abstract: The impact of habitat changes on fish has become increasingly prominent, leading to the decline of fish population in varying degrees. Therefore, the study of fish habitat is an important means to protect fish resources. This article introduces the current status of fish habitat research at home and abroad. Overseas fish habitats are more comprehensive. Domestic fish habitat research mainly focuses on fish reproduction hydrology research, fish reproduction hydrodynamics research, and fish habitat suitability. The purpose of this study is to provide a systematic scientific basis for the protection of fish key habitats, and to protect the sustainable utilization of fish germplasm resources and the sustainable development of fisheries.

1. Background
In view of the decline in the overall resources of freshwater fish and the obvious trend of species attenuation, how to supplement fish germplasm resources and improve fish habitat environment has become one of the major challenges under the current world situation that economic development has priority over environmental protection.

The ecological effects of human activities on fish can be roughly divided into two categories: one is the direct impact on fish. For example, overfishing directly reduces the amount of fish resources and causes the decline of fish resources. The other one is the change of fish habitat, which indirectly affects fish.

The impact of habitat changes on fish is increasingly prominent. Data show that at the beginning of this century, 5% of China's major rivers are no longer suitable for fish[1]. Due to its blocking effect and the huge changes to the hydrological situation of rivers, water conservancy projects have caused the compression of suitable habitat environment for fish, which in turn has a significant impact on the composition and quantity of fish[2].

2. Research on fish habitats abroad
Foreign scholars have carried out a lot of research work on fish spawning ground habitats. When human activities have increasingly affected fish habitats, some countries in Europe and the United States began to study and evaluate fish habitats in the 1960s. In the 1980s, as the concept of flow biotopes and functional habitats defined by ecology[3], many scholars use the establishment of habitat performance curves to study the relationship between the two.

2.1 Research on hydrodynamic characteristics
Hydrodynamic characteristics are an important part of fish habitat research, and flow velocity is the
most basic evaluation index in dynamic characteristics. Through investigations, it is found that the river trout spawning grounds located in the Suran River and Pollon River in France have similar flow rates, indicating that grayling has a preferred spawning flow rate. Biggs et al. [4] discussed the significance of flow rate gradients to attached organisms, and believed that it is helpful for the mixing of nutrients. Moir et al. [5] considered that velocity, water depth and Froude number are important hydraulic indexes to describe spawning grounds of Atlantic salmon. Among them, Froude number, as a dimensionless parameter, can be selected as an evaluation index between different habitats.

Crowder and Diplas believe that [6] the complex flow pattern of water flow caused by river topography, meandering, boulders and other factors, can be characterized by the kinetic energy gradient and the kinetic energy gradient increase rate. There is a positive correlation between the eigenvalues and the spatial flow regime. It is found that fish rest in places with a small kinetic energy gradient, and choose places with a large kinetic energy gradient to eat.

2.2 Habitat fitness model evaluation

Some methods suitable for the evaluation of habitat health began to appear in the 1980s. In 1982, the United States Fish and Wildlife Conservation Society proposed the Intra-River Flow Increasing Method Theory. Among the methods and theories, the habitat model is its core, using endangered species as indicator organisms to determine the quantitative relationship between the available habitat area suitable for survival and flow. The habitat fitness model was used to evaluate the habitat fitness of the Polyodon spathula and Acipenser brevirostrum [7]. Since then, researchers have used new tools, such as GIS-based platforms, to provide new ideas for the study of habitat fitness and other models, and conduct habitat evaluation more accurately and efficiently [8].

3. Domestic fish habitat research

3.1 Research on fish reproduction hydrological conditions

3.1.1 Temperature

Temperature is an extremely important hydrological factor in the process of fish growth and reproduction. Each fish has a specific spawning water temperature requirement. Spring spawning fish Species need the water temperature to reach the minimum temperature required for reproduction, while for the fish that lay eggs in autumn and winter to start reproductive activities, the water temperature need to drop to the upper limit of their reproduction temperature. Since metabolism and enzyme activity are affected by temperature, the water temperature determines the period of fish spawning [9]. Studies have shown that only when the temperature of the river water reaches above 18°C, the four major chinese carps can spawn, and the optimum temperature range for spawning is 20-24°C [10].

3.1.2 Raising water conditions

When the water temperature reaches the spawning requirement, another important factor that triggers the spawning of the four major chinese carps is the rising water conditions. A large number of spawning activities monitored are all during the flood period [12]. Based on this result, some domestic scholars began to use ecological hydrology methods to conduct in-depth analysis of the hydrological conditions of the natural reproduction of the four major chinese carps. Li Chong et al. [13] (As shown in Figure 1) calculated the flow data of Yichang Station in 105 years, and analyzed the relationship between the spawning situation of the four major chinese carps and the total number of flood days, the average number of days in each flood process, and the number of flood processes. During the spawning period of the domestic fish, the cumulative number of days of rising water in the spawning field is maintained at 22.1±7.2 days, and the duration of rising water is 6 days or more, which is of great significance to the completion of the spawning activities of the four major chinese carps [14].
3.1.3 Transparency
Transparency is an important hydrological indicator for the reproduction of the four major home fish. When the transparency of the water in the middle and lower reaches of the Han River is higher than 21.4 cm, the four major Chinese carps reproduction activities will stop[12].

3.1.4 Sand content
Changes in sand content affect the reproduction time of the four major Chinese carps. Guo Wenxian et al. [15] quantitatively analyzed the ecological and hydrological conditions of the spawning grounds during the breeding of the four major Chinese carps, and compared them before and after the impoundment of the Three Gorges Reservoir. They found that the flow and sand content of the spawning grounds decreased after the impoundment of the Three Gorges. The sand content dropped by 95%, which also delayed the reproduction time of the four major home fishes by about 10 days.

However, Wang Shanyu et al. [17] compared the eco-hydrological indicators of the middle reaches of the Yangtze River with spawning sites and non-spawning sites, and found that there is no significant difference in hydrological conditions between the two. This shows that the macro-scale hydrological condition is only one of the necessary conditions for the natural reproduction of the four major Chinese carps, but not sufficient conditions. In order to study the triggering mechanism of water flow for the four major Chinese carps spawning, it is necessary to further study the hydrodynamic conditions of fine-scale spawning grounds.

3.2 Research on the hydrodynamic characteristics of fish reproduction
According to the different application scope of the feature quantity, the feature quantity that characterizes the hydraulic conditions of river, fish habitat is divided into single point feature quantity and regional feature quantity. The single point feature quantity reflects the characteristics of the habitat with a point as the research unit, including flow velocity, water depth, Froude number, and Reynolds number. The regional feature quantity reflects the habitat feature with a certain spatial area as the research unit, including average flow velocity, velocity gradient, kinetic energy gradient, vorticity, etc.

3.2.1 Correlation study of single point feature quantity
According to the results of ultrasonic positioning in breeding period of Chinese sturgeon, three-dimensional hydrodynamic model was used to restore the hydrodynamic characteristics of spawning ground during the monitoring period[9]. Through statistical analysis, it was concluded that the suitable range of velocity was 0.73-2.13 m/s; the suitable range of water depth was 5.93-21.29 m; the suitable range of Froude number was 0.028-0.178. Based on the habitat suitability evaluation model and the relationship between spawning and discharge of Chinese sturgeon, the suitable ecological flow range of Chinese sturgeon habitat is 9000-11000 m$^3$/s.
Regarding the four major home fishes, the EFDC three-dimensional hydrodynamic model was used to simulate the hydrological process under the main flow of the three spawning grounds in Zhicheng, Yidu, and Chenglingji during their breeding period [14]. The optimum flow rate for spawning is 0.63-1.53 m/s (as shown in Figure 2); the suitable water depth is 12.77-23.51 m; the suitable Froude number is 0.049-0.119. For other fish, three-dimensional numerical simulation was used to study the influence of hydrodynamic conditions on the growth of crucian carp. It was found that the suitable flow velocity for crucian carp growth was 0.2 m/s, the water flow energy gradient increased, and the relative daily growth rate of crucian carp body weight decreased.

![Fig.2 Suitability curves of velocity for the four major Chinese carps](image)

3.2.2 Related research on regional characteristic quantities

Through Delft3D software flow module, modeling and analyzing the influence of river levee on the velocity, kinetic energy gradient and its increasing rate of Chinese sturgeon spawning ground was simulated and analyzed, and it is concluded that the river regime adjustment has a negative impact on the spawning area. The upper limit of horizontal vorticity in the spawning area is $1.0 \times 10^{-3} \text{s}^{-1}$, and the variation of horizontal vorticity in the bottom layer is not obvious with the increase of discharge [10].

Based on the numerical simulation method, quantitative analysis of the channel morphology and water flow characteristics of the spawning grounds of the four major Chinese carps found that the spawning grounds of the four major Chinese carps have complex topography and flow patterns. The kinetic energy gradient and Froude number in the river section of the spawning ground are small, and the energy loss after the water flows through the spawning ground is large [15].

3.3 Study on fish habitat suitability

Habitat suitability model evaluates the suitability and comprehensive value of each ecological factor for a specific species through suitability equation, and calculates the weighted available area to evaluate the suitability of the environment for the survival and reproduction of this specific species [16]. Domestically, the habitat suitability model is mainly applied to the evaluation of the spawning ground quality of Chinese sturgeon and the four major Chinese carps.

Luo Huihuang [9] used flow velocity, water depth and Froude number as evaluation factors to establish the suitability model of Chinese sturgeon spawning ground, and calculated that the maximum habitat area is 1.069 km² when the flow is 10500 m³/s. Guo Literature etc. [15] used physical habitat simulation models to analyze the relationship between the spawning area flow of the four major Chinese carps under Gezhouba and the weighted available habitat area, and believed that the suitable flow range for the spawning of domestic fishes in the river section is 7500-12500 m³/s, the most suitable flow is 10000 m³/s.

4. Summary and Prospect

4.1 Summary

Foreign scholars have carried out a lot of research work on the habitat of fish spawning grounds. The research on fish habitat in foreign countries started in the 1980s and has risen to the large-scale study
of 21 species of fish. From single to complex, from simple to in-depth, a mature research system was formed.

The research on the habitat characteristics of fish habitat started late in China. The hydrodynamic characteristics of fish habitat were mainly focused on Chinese sturgeon and the four major Chinese carps, and the research focus was on spawning grounds. At present, many studies have been carried out on the hydrodynamic characteristics of the spawning grounds of the Chinese sturgeon and the four major chinese carps. Through the qualitative and quantitative analysis to a certain extent, the understanding of the hydraulic characteristics of the spawning grounds of the Chinese sturgeon and the four major chinese carps has been preliminarily accumulated.

4.2 Prospects

The research methods and means of Chinese sturgeon were extended to the habitat of fish with sticky eggs, and the related research methods and means of four major chinese carps were extended to the study of habitats of fish with drifting eggs, so as to expand the research scope and species.

Large-scale research is carried out in combination with the topography of fish habitats to study the characteristics of various fish habitats in fish-rich areas. Combination of fish habitat research with river landscape ecology research will deepen the understanding of river landscape patterns.

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