Selection of Representative Fish in the Yangtze River Upstream Nature Reserve from the Perspective of Ecosystem Hydrology Regulation

Yan L.[1], Feng S. X. [1], Yang Q. R. [1]

[1] China Institute of Water Resources and Hydropower Research, Beijing, China

[a] Yan L: xiangyangyl@163.com

Abstract. The selection of representative fishes is the first problem to be solved in the ecological scheduling conducted by the downstream cascade reservoir of Jinsha River for the protection of fish species in the Yangtze River Upstream National Nature Reserve for Rare and Endemic Fishes (hereinafter referred to as "the Yangtze River Upstream Nature Reserve"). This paper has presented the basic steps to determine the representative fishes and established the evaluation index system of fish representativeness in Yangtze River Upstream Nature Reserve that serves the ecosystem hydrology regulation. The result showed that Acipenser dabryanus and Myxocyprinus asiaticus could be selected as representative fishes producing demersal eggs and viscid eggs; Coreius guichenoti and Rhinogobio ventralis as representative fishes of class I producing pelagic eggs; Coreius heterokon and "four famous domestic fishes" as representative fishes of class II producing pelagic eggs.

1.Introduction

The Yangtze River Upstream National Nature Reserve for Rare and Endemic Fishes have 189 species of known fishes in the reserve,in which the main protected objects include 3 rare species like Psephurus gladius, Acipenser dabryanus and Myxocyprinus asiaticus and 66 endemic species such as Coreius guichenoti, Rhinogobio ventralis and Prenant's schizothoracin, accounting for 44% of the unique fishes in the Yangtze River. Currently, there are four cascade hydro-power stations in the lower reaches of the Jinsha River. Since the construction of these dams has changed the natural hydrological regime of the river course and adversely affected the survival and reproduction of fish species, how to protect the fish species in Yangtze River Upstream Nature Reserve is an urgent issue to be discussed currently.

The measure of reservoir optimal operation can effectively reduce the negative ecological effects caused by dams, which takes ecological protection into consideration. At present, the Three Gorges Reservoir has launched the experimental ecological scheduling targeting the protection of "four famous domestic fishes" in the middle reaches of the Yangtze River so as to improve its breeding conditions. The premise of ecological scheduling is to determine its subject of ecological protection. There are many rare and endemic fish species in Yangtze River Upstream Nature Reserve. Therefore, the ecological scheduling of cascade reservoirs in the lower reaches of the Jinsha River is expected to play a good protective effect on various fish species in the reserve. Thus, it requires the establishment of a scientific evaluation method to screen out the most representative fishes. Some scholars have studied the selection of representative fishes in Yangtze River Upstream Nature Reserve from different angles. Based on the plant grading index method, Liujun has studied the threatened degree

and protection priority of 16 endemic fish species in the upper reaches of the Yangtze River[1].Xu Wei et al. evaluated the priority protection level of fishes threatened by the development in the upper reaches of the Yangtze River[2]. Wang Bo and Huang Wei discussed the indicative fishes for determining the ecological flow of the section, and selected the Psephurus gladius as an indicative fish to determine the ecological flow in the Yibin section. [3]

This paper has developed the evaluation index system of fish representativeness that serves the ecosystem hydrological regulation. Besides, it also has evaluated the representativeness of various fish species in the Yangtze River Upstream Nature Reserve and determined the representative fish species on the basis of historical documents and recent survey data. All these efforts are made to provide technical support for the ecological scheduling in the downstream cascade reservoirs of Jinsha River.

2.Representative Fish Evaluation Index System

2.1 Establishment principle of index system

The subject of establishing the evaluation index system of fish representativeness is to select the representative fish species concerning the ecological scheduling of the downstream cascade reservoir of Jinsha River from dozens of fish species that need protection in the Yangtze River Upstream Nature Reserve. Representative fishes should have the following characteristics:

(1) Representative fishes should have or have been able to obtain better research achievement concerning the demand for environmental flow through the research

The representative fishes selected will directly serve the ecological scheduling study of the downstream cascade reservoir of Jinsha River. To be specific, they will be directly adopted to establish the quantitative (including various kinds of environmental factors, generally) hydrological and ecological response relationship required for the hydrology regulation of river ecosystems (Including factors like hydrology and water temperature, generally). For certain fish species which are lacking at present, will be difficult to obtain any research results in the future, it is pointless to select such species fish as the representative fish because it is helpless for the study of reservoir ecological regulation. Obviously, it should be the first step to investigate the research results and screen out fish species that are unqualified and also difficult to meet environmental needs in the future.

(2) Representative fishes should have protection value

The ecological scheduling of reservoirs plays an important role in protecting fishes in the reserve via selecting the representative fishes as the ecological protection subjects. Representative fishes should show their special protection values, which may be reflected as the biodiversity value (such as "rare and peculiar") or the economic value of fishes. Ecological scheduling must give priority to the protection of fish species with great values.

(3) Representative fishes should represent the threatened degree of fishes

There are numerous fish species to be protected in the Yangtze River Upstream Nature Reserve, but their threatened degree (“endangered degree”) is diverse from each other. Rare and endangered fish species that are in urgent demand for protection should be given priority. Therefore, representative fishes should include fishes that are more threatened, which should be more representative of the more threatened fishes in nature reserves.

(4) Representative fishes should include fishes with different reproduction habits

Reproduction is one of the most crucial parts in the life cycle of fishes. Moreover, the scale of reproduction directly affects the supplement quantity of juvenile fishes. At the same time, fish reproduction is also the most sensitive process in terms of hydrology and water temperature conditions. The hydrology regulation of river ecosystem serving the fish species protection often primarily manifests itself as the regulatio0n on the process of fish reproduction. The classification of fish groups based on fish reproduction features is the dominant classification method in the research of ecological scheduling. Since the fish species to be protected in Yangtze River Upstream Nature Reserve are in large quantities and have different reproduction habits, upon selecting the representative fishes, the

reproduction habits of those protected fishes should be investigated to scientifically classify the fish groups, ensuring that all groups have their own representative fishes.

The above four aspects can be considered as principles to be followed in establishing the evaluation index system of fish representativeness.

2.2 Fishes included into the evaluation

The protected objects in the Yangtze River Upstream National Nature Reserve for Rare and Endemic Fishes mainly include 3 kinds of rare fishes like Psephurus gladius, Acipenser dabryanus and Myxocyprinus asiaticus as well as 66 kinds of endemic fishes such as Coreius guichenoti and Procypris rabaudi. Previous studies have shown that there are 45 kinds of rare and endemic fishes distributed in the main stream section of Yangtze River reserve; at the same time, the reserve is also the dwelling site for many important economic fishes such as Coreius heterokon and four famous domestic fishes, which occupied a certain proportion of catchment in the upper reaches of the Yangtze River [4]. The hydroelectric development in the lower reaches of the Jinsha River has posed a direct impact on the hydrology, water temperature and fish habitat in the main stream section of the Yangtze River. Therefore, the representative evaluation can only be conducted with the fish species distributed in the main stream section of the Yangtze River reserve, irrespective of fish species distributed in the tributary area. As mentioned above, certain consideration should also be given to the availability of eco-hydrological requirements regarding the crucial process of fish life cycle (mainly reproduction) when identifying the fishes to be evaluated. Some fishes can be included in the evaluation process if there existed some quantitative or semi-quantitative research results regarding their ecological and hydrological requirements at this stage; however, if there is no available results at this stage or it is barely possible to conduct subsequent studies on its ecological and hydrological demand due to small quantities of fish resources (for example, Psephurus gladius has been difficult to be captured in the Yangtze River Upstream Nature Reserve), such fish species need to be excluded from the evaluation process.

This paper systematically collected the research results regarding the fishes in the Yangtze River Upstream Nature Reserve in recent years, and analyzed the availability of ecological and hydrological requirements for fish reproduction in the main stream section of the Yangtze River. there are 20 kinds of fishes included into the evaluation scale of this indicator system. These fish species are: Acipenser dabryanus, Myxocyprinus asiaticus, Schizothorax prenat, Procypris rabaudi, Percocypris pingi, Megalobrama pellegrini, Sinilabeo rendahli, Acrossocheilus monticola, Coreius guichenoti, Gobiobotia boulengeri, Rhinogobio cylindricus, Leptobotia elongata, Jinshaia sinensis, Coreius heterokon and four famous domestic fishes.

2.3 Evaluation index system and standards

In this paper, Analytic Hierarchy Process is used to establish the index system, which is divided into target level, sub-target level and indicator level. The target level is the fish representativeness, which is represented by the fish representative index; the sub-target level includes three aspects: the value of fishes, the endangerment status of fishes and the characteristics of fish reproduction.

2.3.1 Value of fishes

The value of biodiversity includes four aspects: direct use value, indirect use value, existential value and alternative value. As for fish species, this thesis suggests that the value of fishes can be divided into four aspects: economic value, genetic value, ecological value and academic value.

Economic value: It refers to the value of fishes directly consumed or sold on the market after being harvested. The economic value of fishes can be evaluated by the following methods: The highest score is 3 points, of which 3 points are given to important economic fish with the largest size and expensive price; 2 points are given to general economic fish with larger size and higher prices; 1 point is given to fish with less economic value and small size.

Genetic value: It indicates the extent of genetic loss that a particular species of fish might lead to the biodiversity after its extinction. The genetic value of fishes can be scaled according to the species and quantity of certain fishes. The highest score is 3 points, of which 3 points are given to monotypic or endemic genera; 2 points are given to rare genera which only include 2-6 kinds of fishes; 1 point is given to multi-type genera with more than 6 species.

Ecological value: the most important contribution of wild species is that they maintain the integrity, completion and resilience of ecosystems. Although each species has its ecological orientation, their important degrees differ from one another. Generally, the dominant species and key stone species are more important than others. The ecological value of fishes can be scored according to their importance in the community. The score is up to 3 points, of which 3 is the dominant species; 2 is sub-dominant species and 1 is the non-dominant species.

Academic value: refers to guidance and reference value of fishes to the disciplinary research in other areas. The academic value of fishes can be scored according to their classification status (the purpose of the situation). The lower the classification status is, the higher the score will get. The score is up to 3 points, of which 3 points are given to the Acipenseriformes; 2 points are given to the Perciformes, Siluriformes and Schizothoracins; 1 point is given to the Cypriniformes (excluding the Schizothoracins).

Synthesizing the evaluation of the above four aspects, we adopt the value coefficient to characterize the result. The value coefficient (C_v) can be calculated by the following formula:

$$C_v = \sum_{i=1}^{4} x_i / \sum_{i=1}^{4} X_i \quad (1)$$

Wherein, C_v refers to the value coefficient of certain research fishes; x_i refers to the actual score of each evaluation index; X_i refers to the highest score set by each evaluation index.

2.3.2 Endangerment status of fishes

The endangerment extent of fishes reflects the degree how fishes are threatened. The evaluation has been conducted from three aspects: resources distribution, resources status and interference intensity.

Resource distribution: refers to the extensive degree of fish habitat in the river basin. The narrower the distribution is, the higher the score will be. The highest score is up to 3 points, of which 3 points are given to species only distributed in the main stream section; 2 points are given to species distributed in the main stream and some tributaries; 1 point is given to species distributed both in the main stream and tributaries.

Resource status: reflects the scale of current fish population, commonly scored with the daily occurrence rate. In this paper, the scoring system is based on the resource status of the fishery resources to be evaluated and the previous results of resource survey. The lower daily occurrence rate will get a smaller population and a higher score. The highest score is set to 4 points, of which 4 point means unseen, 3 point means rare, 2 points mean occasional and 1 point means common.

Interference intensity: refers to the degree that fish resources are influenced by human interference overfishing, river sand mining, waterway regulation and water conservancy projects. The greater the interference intensity is, the higher the score will be. The highest score was 3 points, of which the 3 points means violent interference; 2 points means moderate interference; 1 point means light disturbances.

Synthesizing the evaluation of the above three aspects, we adopt the endangerment coefficient to characterize the result. The formula of the endangered coefficient ($C_{\text{endangerment}}$) is as follows:

$$C_{\text{endangerment}} = \sum_{i=1}^{3} y_i / \sum_{i=1}^{3} Y_i \quad (2)$$

Wherein, y_i is the actual score of each evaluation index and Y_i is the highest score stipulated by each evaluation index.

2.3.3 Characteristics of fish reproduction

For different types of spawning fish, the evaluation of their reproduction characteristics can be conducted from four aspects: latency period, length of reproductive period, fecundity and reproduction habitat.

Latency period: the score is set according to the first sexual maturity age of female fish. In other words, the older the first sexual maturity age is, the higher the score will be. The highest score was set at 3 points, of which 3 points are given to the species whose first sexual maturity age is older than 4 years; 2 points are given to 3 or 4 years; and 1 point is given to 1 year or 2 years.

Length of reproductive season: the fish reproductive season also means the reproduction length of fish stocks, which has a significant impact on the number of fish stocks. Due to the construction of river dams, the low temperature water discharged from reservoirs may delay the spawning of fish and shorten their breeding period. If the reproductive season becomes shorter, it means the negative effects brought by dams are larger. Therefore, the evaluation score of fishes with shorter reproductive period should be higher. The highest score is 4 points, of which 4 points refers to 2 months of breeding period; 3 points refers to 3 months of breeding period; 2 points refers to 4 months of breeding period; 1 point refers to 5 to 6 months of breeding period; 1 point is also given to fishes whose breeding period is not available.

Fecundity: the score is determined according to the size of relative fecundity of fishes. In other words, the smaller the relative fecundity is, the higher the score will be. The highest score was set at 5 points, of which 5 points are less than 10 particles/g; 4 points are 10-50 particles/g; 3 points are 50-120 particles/g; 2 points are 120-200 particles/g; 1 point is more than 200 particles/g.

Reproduction habitat: the score is determined by the location of fish spawning grounds in the water system. The highest score is set to 5 points, of which 5 points are for fishes whose spawning grounds are completely located in the Yangtze River; 3 points are for the fishes who have spawning grounds both in the main stream and tributaries; 1 point is for fishes whose spawning grounds are completely distributed in the tributaries.

Synthesizing the evaluation of the above four aspects, we adopt the reproduction coefficient to characterize the result. The formula of the reproduction coefficient ($C_{\text{reproduction}}$) is as follows:

$$C_{\text{reproduction}} = \sum_{i=1}^{4} z_i / \sum_{i=1}^{4} Z_i \quad (3)$$

Wherein, z_i is the actual score of each evaluation index and Z_i is the highest score stipulated by each evaluation index.

The scores of three indexes which are fish values, fish endangerment status and fish reproduction characteristics are summed up after being weighted, in which the weight coefficient is determined by experts through consultation. Among them, the weight coefficient of fish value is 0.25, the weight coefficient of fish endangerment status is 0.5, and the weight coefficient of fish reproduction characteristics is 0.25. Finally, the representative index of evaluated fishes is finally obtained.

3.Evaluation and Result Analysis

The evaluation of indexes of fish species has been made on the basis of relevant documents [5-12]. Table 1 shows the individual scores and comprehensive evaluation results obtained from 20 kinds of fish to be evaluated and 11 evaluation indexes. According to the selected principles and methods, Acipenser dabryanus and Myxocyprinus asiaticus are selected as representative fishes of F_1（fishes producing demersal eggs and viscid eggs）; Coreius guichenoti and Rhinogobio ventralis as representative fishes of F_2（fishes of class I producing pelagic eggs）; Coreius heterokon and "four famous domestic fishes" as representative fishes of F_3（fishes of class II producing pelagic eggs）.

Table 1 Evaluation Results of Fish Representativeness in the Mainstream Reserve

Type	Species	score	representative fishes
F1	Acipenser dabryanus	0.70	Acipenser dabryanus Myxocyprinus asiaticus
	Myxocyprinus asiaticus	0.68	
	Schizothorax prenat	0.48	

	Procypris rabaudi	0.58	
	Percocypris pingi	0.54	
	Megalobrama pellegrini	0.48	
	Sinilabeo rendahli	0.42	
	Acrossocheilus monticola	0.44	
	Ancherythroculter nigrocauda	0.38	
F2	Coreius guichenoti	0.57	Coreius guichenoti Rhinogobio ventralis
	Rhinogobio ventralis	0.48	
	Gobiobotia boulengeri	0.34	
	Leptobotia elongata	0.46	
	Rhinogobio cylindricus	0.46	
	Jinshaia sinensis	0.44	
F3	Coreius heterokon	0.48	Coreius heterokon Four famous domestic fishes
	Four famous domestic fishes	0.48	

4.Conclusion

This paper has presented the basic steps to determine the representative fishes in the Yangtze River Upstream Nature Reserve that serves the ecosystem hydrology regulation, and has generally established the evaluation index system to evaluate the fish representativeness. The evaluation index is relatively comprehensive and the evaluation method is quite simple. Since the evaluation was conducted on the fish species in the Yangtze River Upstream Nature Reserve with this method, the results show that the Acipenser dabryanus, Myxocyprinus asiaticus, Coreius guichenoti, Rhinogobio ventralis, Coreius heterokon and four famous domestic fishes can be selected as the representative fishes in the Yangtze River Upstream Nature Reserve. Moreover, the ecological scheduling research in the downstream cascade reservoir of Jinsha River can be carried out to meet fishes protection demand in the upper reaches of the Yangtze River Upstream Nature Reserve. The evaluation results can basically reflect the actual situation, which are also basically consistent with previous research results.

References

[1] Liu J. .A quantitative analysis on threat and priority of conservation order of the endemic fishes in upper reaches of the Yangtze River. *China Environmental Science*, **24**, 4 (2004).
[2] Xu W., Yang Z., Qiao Y.. Evalution on protection priority of special fishes in hydropower development of upper Yangtze River. *Yangtze River*, **44**, 10 (2013).
[3] Wang B., Huang W.. Establishment on Ecological Flow at River Cross Section for Indicative Fishes . *Journal of Yangtze River Scientific Research Institute*, **24**,6 (2007).
[4] Xu W., Qiao Y., Gong Y.. Changes of fish resources in upper Yangtze River and its protection. *Yangtze River*, **43**, 1 (2012).
[5] Duan X. B.. Study on fish resources and the fishes of early life history stage in the upper Yangtze Rive. *Huangzhong agricultural university master's degree dissertation*, (2008).
[6] Zhang C. G., Zhao Y. H. ,Kang J. H. A discussion on resources status of Myxocyprinus asiaticus (Bleeker) and their conservation and the recovery. *Journal of natural resources* , **15**, 2 (2000).
[7] Duan X. B., Liu S. P.,Xiong F., et al. Analysis of fishing structure and biodiversity in the Upper Mainstream of the Yangtze River before and after three years' spring fishing off . *Resources and Environment in the Yangtze Basin*, **17**, 6 (2008).
[8] Han X. H., Liu J. H., Zhen Y. H., et al.. Primary study on the influence of reef blast to the fishery resources in the Tongluoxia Gorge of the Changjiang River. *Journal of Hydroecology*, **3**, 4 (2010).
[9] Cao W. X., Chang J. B., Qiao Y.. Early resources of fish in the Yangtze River, *China Water&Power Press* (2007).
[10] Cheng P.. The biology of coreius guichenoti（sauvage etdabry）in the upper Reaches of the Yangtze. *Huangzhong agricultural university master's degree dissertation*, (2008).

[11] Xin J. F.. Population ecology of Rhinogobio ventralis in the upper reaches of the Yangte River. *Jinan University master's degree dissertation*, (2010).
[12] Yan L..Studies on biology of stocks and genetic diversity of Coreius heterodon.*Huangzhong agricultural university master's degree dissertation*. (2005).