Indicators and criteria for river health evaluation in Zhejiang province

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Abstract. River functions consist of water supply, irrigation, power generation, shipping and entertainment. Human beings have attached great attentions to the development and utilization of the social functions of rivers while ignoring the ecological functions. Various human activities have changed the natural state of rivers, resulting in serious degradation of river ecosystem. In this study, a river health evaluation system has been established. Firstly, the river health evaluation system is composed of physical, chemical and biological integrity. Additionally, human activities are considered as a driving force of the ecological evolution of rivers in the evaluation system. Finally, the service function of rivers which can be provided to human society is also represented in the evaluation system. A comprehensive river health evaluation for Yonganxi river in Zhejiang province is executed, the evaluation result reflects the ideal health status of this river. The advantages of the indicators and criteria of the evaluation system are examined and confirmed. The evaluation system will be extended to the provincial river health evaluation in the future.

1. Introduction
Nowadays, more and more attentions have been paid to the protection of river ecology and the maintenance of river health [1-4]. It is widely recognized that the health of river ecosystem is closely related to the development of human society [4,5]. According to the characteristics of rivers in Zhejiang province as shown in Figure 1, it is urgent and necessary to establish a practical evaluation system which can analyze the health of important provincial rivers [4-8]. A suitable method for evaluating the health of rivers is established in this study, and a typical river is selected as an evaluation case to manifest the advantages of the river health evaluation method in Zhejiang province.

Indeed, the index systems and evaluation methods of river health have been studied extensively in the world. Series of characteristic river health evaluation methods have been formed during last decades [7,8]. Since late 20st century, the methods of river and lake health assessment have made great progress, methods such as RIVPACS, AUSRIVAS, IBI, RCE, ISC, RHS, RHP, have been widely used in different countries [6-10]. As far as the evaluation principle is concerned, these evaluation methods can be roughly divided into Predictive Model and Multimetrics method, some famous river health evaluation methods are shown in Table 1. Figure 2 shows the annual river health evaluation in Canada.
2. Methodology

2.1. Analytic hierarchy process method
Considering both generality and simplicity of river health evaluation in Zhejiang Province, an AHP (Analytic Hierarchy Process) method is introduced in this study as the main evaluation method. As indicated in previous studies, Analytic hierarchy process is a commonly and widely used method to determine relative weights of indices for a certain target [8-11]. Since the scale of AHP judgment matrix is determined based on data, expert opinions and analysts’ experience, it has a small random consistency ratio, and the man-made deviation is also small compared to other methods. The flowchart of river health evaluation in this study is shown in Figure 3.
2.2. Evaluation criteria
According to the principle of AHP method, the weight of a single evaluation indicator in the system is scored, and the final score of each level is summarized. Finally, the total score of river health evaluation is obtained. The scoring equation is given as [8,9,12]:

\[ TG = \sum_{j=1}^{n} \left( \sum_{i=1}^{m} A_i \times P_j \right) C_i \]  (1)

Where \( TG \) is the single level score, \( A_i \) is the weight coefficient of the single indicator, \( P_j \) is the evaluation score for the single indicator, \( C_i \) is the weight coefficient of a certain level. According to the evaluation score, the classification of river health can be divided into 5 levels, as shown in Table 2.

![Figure 3. Methodology of river health evaluation in this study.](image)

**Table 2.** Classification of river health evaluation levels.

| Health level | Score     | Status | Classification colour |
|--------------|-----------|--------|-----------------------|
| I            | (80,100)  | Ideal  |                       |
| II           | (60,80)   | Good   |                       |
| III          | (40,60)   | Fair   |                       |
| IV           | (20,40)   | Bad    |                       |
| V            | [0,20)    | Sick   |                       |

3. Indicators and weight coefficients
The evaluation index system is composed of 4 levels, namely target level, sub-goal level, criteria level and indicator level. In total 17 evaluation indicators are proposed, of which 13 are compulsory and 4 are optional. As shown in Table 3.

The weight coefficient reflects the relative importance of each indicator on its own level. According to the characteristics of rivers in Zhejiang Province, the selection of weight coefficient is
different for different types of rivers, such as mountainous river and plain river. For example, Miaoyuanxi river, Majinxi river and Yonganxi river are typical mountainous rivers in Zhejiang province, while Ruipingtang river, Yunhe river and Changxinggang river are typical plain rivers in Zhejiang province. The weight coefficient for each indicator in this evaluation system can be also seen in Table 3.

| Main target level | Sub-goal level | Criteria level | Indicator level | Weight coefficient | Necessity |
|-------------------|----------------|----------------|-----------------|--------------------|-----------|
| River health      | Natural function | Hydrology | Guarantee rate of ecological flow | 0.7 | compulsory |
|                   |                |                | Variation rate of flow process | 0.3 | compulsory |
|                   |                |                | River sedimentation rate | 0.1 | (optional) |
|                   |                |                | Navigation route guarantee rate | 0.1 | (optional) |
|                   | Environment   | Hydrology | River connectivity status | 0.4 | compulsory |
|                   |                |                | Water quality comprehensive index | 0.6 | compulsory |
|                   |                |                | Riparian zone growth status | 0.2 | (optional) |
|                   | Ecology       | Hydrology | Riparian zone status | 0.4 | compulsory |
|                   |                |                | Habitat diversity | 0.6 | compulsory |
|                   |                |                | Bird habitat status | 0.2 | (optional) |
|                   | Social function | Safety       | Anti-flooding capability | 0.3 | compulsory |
|                   |                |                | Flood protection guaranteed rate | 0.7 | compulsory |
|                   |                | Resource      | Utilization index of water resources | 0.5 | compulsory |
|                   |                |                | Water function area compliance rate | 0.5 | compulsory |
|                   |                | Civilization | Public-water satisfaction | 0.3 | compulsory |
|                   |                |                | Cultural value index | 0.4 | compulsory |
|                   |                |                | Social benefit index | 0.3 | compulsory |

Note, optional indicators are usually calculated and used as additional terms during the evaluation.

4. Case study: Yonganxi River

![Figure 4. Evaluation area of Yonganxi river.](image)

Considering the importance and typicality of the rivers in Zhejiang province, the health evaluation of Yonganxi river is carried out in this study as a typical case, which is shown in Figure 4. The
evaluation year is 2016, social data are mostly obtained from the statistical yearbook of Taizhou city in Zhejiang province, while the other data are obtained by historical monitoring data combined with on-site survey results.

Yonganxi river is 141.30km long and 2704km² drainage area, which is the source of one of the eight largest rivers in Zhejiang province. The cities and towns in the evaluation area are in small scale, therefore, less human disturbing, more remaining space, better water quality and better ecological environment preservation is anticipated during the evaluation in this study. The river health evaluation result of Yonganxi river is shown in Table 4.

As listed in Table 4, most of the indicators behave excellent in the river health evaluation for Yonganxi river, the final score of the health evaluation reaches 90.7. From the perspective of Table 2, the health level of Yonganxi river is blue, which confirms the ideal status of Yonganxi river.

When considering the basic indicator’s score, it is also noticed that the utilization index of water resources is only 60. According to the Taizhou Water Resources Bulletin, the utilization rate of water resources in Yonganxi river basin in 2016 is only 6.01%, revealing a relatively low water resources utilization efficiency in the basin area, which leads to the low score of this index in this evaluation. Hence, a more efficient and accurate utilization of water resources in Yonganxi river basin is anticipated in the future.

5. Conclusions
The definition of healthy river refers to a river that is well adapted to the local environment and social characteristics. Good natural ecological condition is required, in the meantime, the contributions of human economic and social activities for river resources are also desired. Therefore, the health of rivers should reflect two requirements at the same time, namely the natural ecological operation of rivers itself and the stable services to human society.

Table 4. Evaluation of Yonganxi river based on APH method.

| Target level | Criteria | Indicators | Evaluation Weight Score | Evaluation Weight Score | Evaluation Weight Score | Evaluation Weight Score |
|--------------|----------|------------|-------------------------|-------------------------|-------------------------|-------------------------|
| Mai n Sub- | Hydrology | Guarantee rate of ecological variation rate of flow process | 100 0.7 70 | 94 0.2 18.8 | 92.2 0.6 55.3 |
| goa l | 2 | 80 0.3 24 | | | |
| | Environment | River connectivity Water quality comprehensive | 80 0.4 32 | 92 0.4 36.8 | 92.2 0.6 55.3 |
| | Ecology | Riparian zone status Habitat diversity | 80 0.4 32 | 92 0.4 36.8 | 92.2 0.6 55.3 |
| | Safety | Anti-flooding capability Flood protection guaranteed rate | 100 0.3 30 | 86 0.4 34.4 | 90.7 |
| | Resource | Utilization index of water Water function area compliance | 60 0.5 30 | 80 0.3 24 | 88.4 0.4 35.4 |
| | Civilization | Public-water satisfaction Cultural value index Social benefit index | 100 0.3 30 | 100 0.3 30 | 100 0.3 30 |

In this study, the actual situation of rivers in Zhejiang province is considered, taking importance, comprehensiveness and feasibility into account. The river health evaluation system in this study
consists of 17 basic indicators in 4 levels. Different characteristics of different types of rivers are embodied through indicators classification, weight coefficients and differential adjustments.

According to the statistical data of each indicator, the evaluation of Yonganxi river is carried out. The final health evaluation score of Yonganxi river is over 90, which reflects the ideal health status of the river itself. The result of this trial evaluation case is consistent with the natural ecological and social functions of Yonganxi river. This successful river health evaluation is going to ensure the provincial river health evaluation in the future.

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