Development of a new water ecological health assessment method for small river in Shanghai, China

Houtao Xu, Linkui Cao, Liqing Wang and Xiaoyan Zheng

ABSTRACT

Seventeen indices were selected to structure a new water ecological health assessment system, consisting of water quality, ecological system, and ecological landscape, for evaluation of small rivers in Shanghai, China. There are 200 samples taken from 56 rivers distributed in ten districts from 2014 to 2015 in Shanghai, which were selected to constitute the study case, and the mean value of each indicator was used in the evaluation. According to various features, including natural geographical condition, social development level, etc., these rivers were classified as one of three types: central urbanization watercourse (CW), new town watercourse (NW), and village watercourse (VW). The results showed that the investigated rivers were at a medium health level, ranging from 1.79 to 3.59, with the average being 2.95. The ecological health of streams in rural areas is better than that of CW rivers and NW rivers. This study is expected to provide accurate statistics and appraisal for the improvement of river health.

Key words | comprehensive evaluation, ecosystem health condition, indicator system, river, Shanghai

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INTRODUCTION

The ecosystem degradation of small rivers has become a shortcoming for the water environment, which seriously affects the overall urban environment. Rivers gradually deteriorate in many functions, such as drinking water and fisheries, and are vital to economic prosperity (Costanza *et al.* 1997; Xu *et al.* 2005). Simultaneously, how to utilize practical objectives for supporting healthy river ecosystems is also becoming an object of concern for society. The issue of river health research has become one of the heated debates in the field of river ecosystems.

There are two methods for river health assessment currently used: one of which is biological monitoring with indicator species as representative biota; the other is comprehensive indicator methods (Zhao & Yang 2009; Zhang *et al.* 2018). Conventional biological monitoring methods

include the IBI (index of biological integrity) (Karr 1981) and RIVPACS (River Invertebrate Prediction and Classification System) (Wright *et al.* 1984). Comprehensive indicator methods emphasize the ecological integrity (Fairweather 1999; Karr 1999). Such practices include rapid bioassessment protocols (RBPs) (Barbour *et al.* 1992), the Riparian, Channel and Environmental Inventory (RCE) (Robert & Petersen 1992), Index of Stream Conditions (ISC) (Ladson *et al.* 1999), etc. In recent years, China has gradually paid attention to river ecosystems from the perspective of river health and has carried out a series of work on river health evaluation. Research into the assessment index system on river health was used. Liu proposed the Yellow River health evaluation method from the point of view of environment flow and bankfull discharge. Cai recommended the standards of the healthy Yangtze River (Feng *et al.* 2012). Zhao & Yang (2009) utilized an integrative fuzzy hierarchical model to evaluate Yong River health in Ningbo City, China. Zhang *et al.* (2018) established a combined

model for river health evaluation based upon the physical, chemical, and biological elements. Urban rivers are those originating from urban areas or that intersect city river sections, some of which have a history of artificial excavation. In the process of city formation and development, rivers, as the critical carriers of resources in the natural environment, contribute an essential factor influencing the style and beauty of the urban environment and restricting urban development. Urban rivers have numerous functions, not only functions within natural systems but also social and economic services. Therefore, an urban river system is a complex system which is composed of a natural ecology subsystem and a landscape environment subsystem.

River ecosystem health is a relative concept, which is both objective and subjective, including people's individual expectations for the improvement of river ecological conditions. In this paper, the evaluation index system for river health was structured based on chemical, biological, and social elements. Chemical elements include dissolved oxygen (DO), permanganate salt index (COD_{Mn}), chlorophyll a (Chla), total phosphorus (TP), ammonia nitrogen (NH_3-N), and water transparency (SD). Biological elements cover aspects of phytoplankton, benthos, fish, vascular plants, and revetment. Social features are the ecological landscape condition and harmony with the surroundings. The best attainable condition (BAC) (Stoddard *et al.* 2005) was used as the evaluation reference system. A combined model, established and composed of a vague comprehensive evaluation model and an analytic hierarchy process (AHP) (Qin *et al.* 2014) evaluated the health of small rivers in Shanghai, China.

MATERIALS AND METHODS

Study area and data

Shanghai city is surrounded by the Yangtze River delta plain area and contains numerous lakes and rivers. The town includes 697 km^2 of water area, which accounts for 11% of the total area (Figure 1). Around 2000, the Shanghai government implemented a channel improvement project in the form of a 'three-year act on environmental protection.' The project focuses on water quality as well as the aquatic ecosystem (Zhao *et al.* 2013).

Water quality data, biological data, and social data were collected from 56 rivers belonging to ten districts, with 200 samples taken from 2014 to 2015. These rivers are capable of representing all types of small streams in Shanghai. Based on differing characteristics, these 56 rivers were classified as one of three kinds: eight central urbanization watercourses (CW), 20 new town watercourses (NW), and 28 village watercourses (VW). One-way analysis of variance (ANOVA) was used to test the differences among the three types of rivers, and differences were considered statistically significant at $p < 0.05$.

Evaluation indicator system

In this study, 17 indices were selected to structure an evaluation indicator system, which consists of chemical, biological, and social elements.

Chemical elements

Six water quality indices – dissolved oxygen (DO), permanganate salt index (COD_{Mn}), chlorophyll a (Chla), total phosphorus (TP), ammonia nitrogen (NH_3-N), and water transparency (SD) – were selected for water quality evaluation. DO has a closer relationship to aquatic life and is frequently used to evaluate water quality (Sanchez *et al.* 2007; Simoes *et al.* 2008). NH_3-N, TP, COD_{Mn}, SD, and Chla are major water quality evaluation indices frequently recommended for rivers (Miao *et al.* 2009; Liu *et al.* 2011). All the water quality indices were measured four times per year: from the 15th to 20th of February, May, August, and November.

Biological elements

Biological indicators show significant importance in the evaluation of environmental degradation and have a long history of their use (Simon & Lyons 1995). Biological indicators may reflect the intensity of anthropogenic stress and have been used as a tool in risk assessment and evaluation of human-induced changes in the freshwater ecosystem (Toham & Teugels 1999). Nine biological indicators were selected to evaluate the quality and sustainability of river ecological environments, covering aspects of phytoplankton, benthos, fish, vascular plants, and revetment (Fryirs
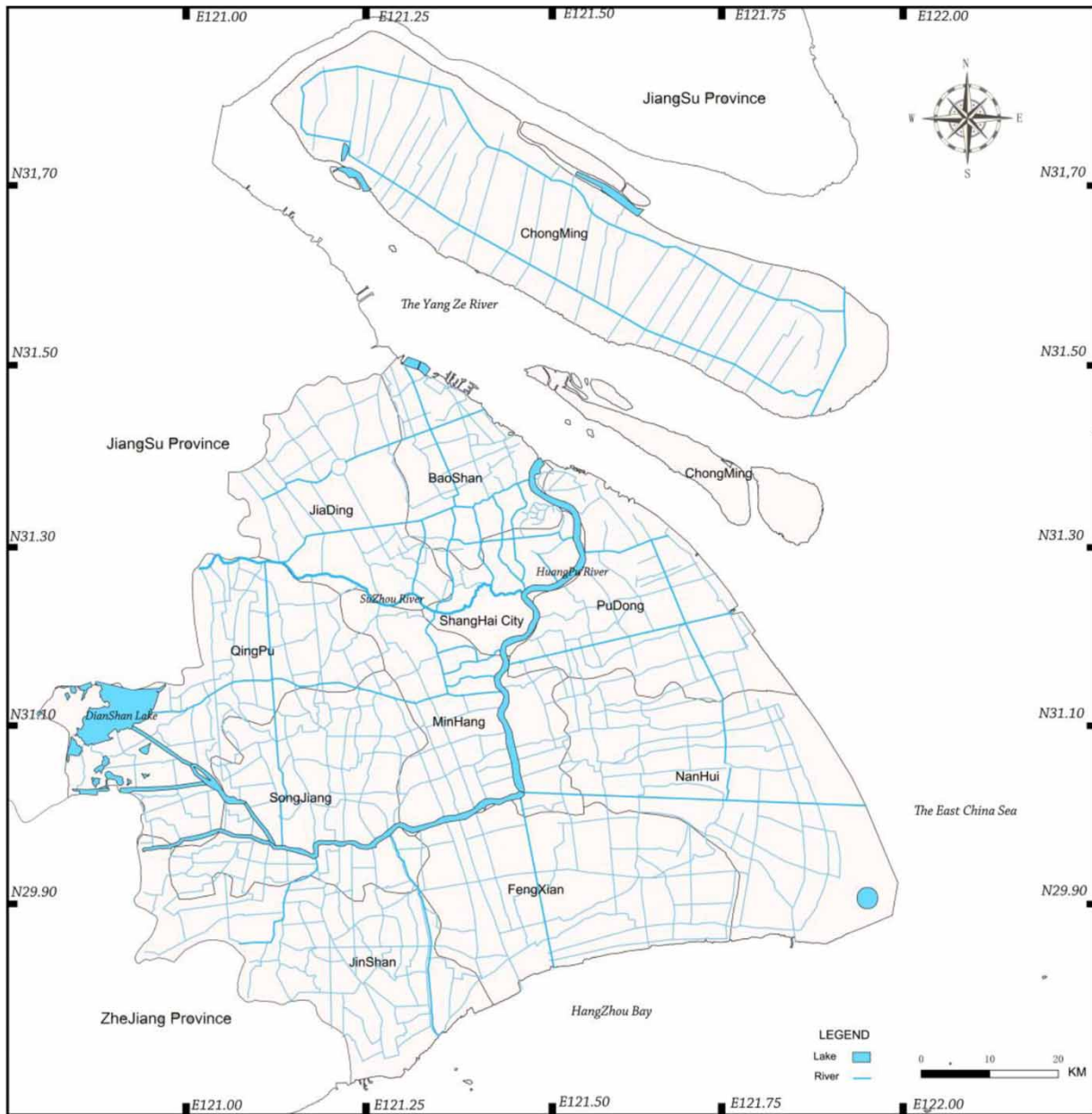
Figure 1 | Location of the Shanghai River Basin.

2003; Grubb *et al.* 2006; Lakra *et al.* 2010). The index of bio-
logical integrity (IBI) is most commonly adapted to assess
stream health based on biological criteria (Mebane *et al.*
2003). Phytoplankton index of biological integrity (P-IBI)
was composed to determine the biotic conditions of water
due to the slow flow velocity of small rivers in Shanghai
(Shen *et al.* 2012; Yin *et al.* 2012; Zhou *et al.* 2013). The
benthic index of biotic integrity (B-IBI) was calculated by

the ratio method (Kerans & Karr 1994; Karr & Chu 2000;
Blockson *et al.* 2002). The plant community is immobile
and, therefore, susceptible to physical, chemical, and bio-
logical changes in the surrounding environment (Wardrop
& Brooks 1998; Mahaney *et al.* 2003). Emergent/floating
plant coverage, submerged plant coverage, and aquatic
plant diversity are commonly used indicators of plant
status. The diversity of fish (D_{G-F}), water indicator species,

riverbank ecology, emergent/floating plant coverage, submerged plant coverage, aquatic plant diversity, and coefficient of terrestrial vegetation were all surveyed from July to September. $D_{G\text{-}F}$ was calculated as follows (Yin *et al.* 2016):

$$D_{G-F} = 1 - \frac{D_G}{D_F}$$

where D_G is diversity of fish genera and D_F is diversity of fish families.

$$D_G = -\sum_{j=1}^{p} D_{G_i} = -\sum_{j=1}^{p} q_j \ln q_j$$

where $q_j = \frac{S_j}{S}$, S_j is the number of species in j, S is the number of species in the list, and p is the number of the genus in the list.

$$D_F = \sum_{k=1}^{m} D_{F_k} = -\sum_{k=1}^{m} \sum_{i=1}^{n} p_i \ln p_i$$

where $p_i = \frac{S_{k_i}}{S_k}$, S_{ki} is the number of species in genus K in the directory, S_k is the number of species in the family k in the directory, n is the number of genera in family k, and m is the number of fish in the directory.

Social elements

This indicator is a qualitative indicator that fully evaluates the ecological landscape condition and harmony with the surroundings. The ecological landscape condition was determined using surveys of nearby residents in the form of a questionnaire, while professionals scored harmony with the surroundings of each river. In consideration of its practical and operability conditions, ten professors and ten graduate students, who are studying river ecology, were invited to conduct an *in situ* ecological landscape evaluation of the referred rivers. Through using a subjective evaluation method, the rationality of plant collocation and visual esthetics were evaluated and divided into five grades with assignments of 1–5 points (Adelson & Mccoach 2010; Weber *et al.* 2014).

Determination of indicator weights

The expert analytical hierarchy weighting method is used to determine the weights of the evaluation indicators based on the information provided by each indicator (Montanari & Lizzani 2001; Zhang & Dong 2009; Xue *et al.* 2012; Alizadeh *et al.* 2018).

1. Determine the judgment matrix. First, the hierarchical structure model regarding the Shanghai river ecological evaluation system as the total object layer is built (A); second, river water quality (B_1), ecosystem (B_2), ecological landscape (B_3) are established as the first sub-object, and each specific index as the third one (C_1, C_2 …… C_{17}) (Table 1).

   Then, more than 20 experts in ecology, environmental science, and hydrology fields were invited to mark the 1–9 scale method proposed by Professor T. L. Satty (Table 2) to construct the judgment matrix.

2. The analytic hierarchy process determines the weight. The weights of every aspect and total hierarchical order of each indicator are rated by the priority order and coherence verification.

   Assuming a normal vector *A* at the same order, so that $XA = \lambda\max A$, *A* in this characteristic equation is the weight of each evaluation factor after being normalized. Due to the complexity of material things and the one-sided understanding of things, the constructed judgment matrix may not be a consistency matrix. Therefore, after obtaining λmax, consistency, and randomness tests need to be performed. The formula is as follows:

$$CI = (\lambda_{\max} - n)/(n - 1)$$

$$CR = CI/RI$$

In the formula *CI* is the consistency index; $\lambda_{\max}$ is the maximum characteristic root; n is the matrix order; *RI* is the average random consistency index; *CR* is the random consistency ratio. A comparison matrix is expected to be consistent if the *CR* value is observed to be less than 0.10 (Table 3) (Triantaphyllou & Mann 1995).

Table 1 | Evaluation indicator system for river health

Ecosystem	Subsystem	Weight	Indicator	Weight
Shanghai river ecosystem evaluation (A)	River water quality conditions B_1	0.33	DO C_1	0.41
			COD_{Mn} C_2	0.22
			Chla C_3	0.07
			NH_3-N C_4	0.12
			TP C_5	0.11
			SD C_6	0.07
	Ecosystem B_2	0.59	P-IBI C_7	0.05
			B-IBI C_8	0.15
			D_{G-F} C_9	0.10
			Water indicator species C_{10}	0.17
			Riverbank ecology C_{11}	0.06
			Emergent/floating plant coverage C_{12}	0.07
			Submerged plant coverage C_{13}	0.17
			Aquatic plant diversity C_{14}	0.15
			Coefficient of terrestrial vegetation C_{15}	0.08
	Ecological landscape B_3	0.08	Ecological landscape condition C_{16}	0.55
			Harmony with the surroundings C_{17}	0.45

Table 2 | The index scale

Scale	Meaning
1	A and B are equally important
3	A is little important than B
5	A is important than B
7	A is significantly important than B
9	A is highly important than B
2, 4, 6, 8	A is vital than B
The reciprocal of the above scale	The scale of element i to j is a_{ij}, contrarily is a_{ji}

The following tables (Tables 4–7) detail the weights and calculation process of each evaluation index in the Shanghai River ecological evaluation model.

Finally, the weight of each factor index was used to determine the final order.

Evaluation standards

The indicators are given a numerical value or rating based on a five-point scale that provides a comparison with healthy conditions, as shown in Table 8 (Zhao & Yang 2009). Choosing a rating system is a balance between providing as much resolution as possible while recognizing there is limited knowledge about the relationship between a change in the indicator and environmental effects (Ladson *et al.* 1999; Chen & Chau 2019).

Indicator system

The evaluation result was calculated as follows:

Index value of the secondary index

$$B = \sum_{i=1}^{17} C_i \times W_i$$

The value of comprehensive evaluation index

$$A = \sum_{j=1}^{3} B_j \times W_j$$

where A is the value of the comprehensive evaluation index, B is the evaluation value of secondary indicators, C is the evaluation value of three-level indicators, W_i is the weight of the three-level indicators, and W_j weight of the secondary

Table 3 | Analytic hierarchy process (AHP) random consistency index of evaluation

Order	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Table 4 │ Judgment matrix A, B results of evaluating the ranking

A	B_1	B_2	B_3	Weight
B_1	1	1/2	5	0.33
B_2	2	1	7	0.59
B_3	1/6	1/5	1	0.08

LB = 3, λ_{max} = 3.1117127254, RI = 0.58, CR = 0.09630407.

Table 5 │ Judgment matrix B_1–C results of evaluating the ranking

B_1	C_1	C_2	C_3	C_4	C_5	C_6	Weight
C_1	1	2	4	3	3	3	0.41
C_2	1/2	1	3	1/2	2	4	0.22
C_3	1/4	1/3	1	1/3	1/5	1	0.07
C_4	1/3	2	3	1	2	4	0.12
C_5	1/3	1/2	1/3	1/2	1	4	0.11
C_6	1/3	1/4	1	1/4	1/4	1	0.07

LB = 6, λ_{max} = 5.97021065, RI = 1.24, CR = 0.00480473.

Table 6 │ Judgment matrix B_2–C results of evaluating the ranking

B_2	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	Weight
C_1	1	1/6	1/5	1/7	1/3	3	1/9	1/3	2	0.05
C_2	2	1	3	1/3	4	3	1/5	1/6	4	0.15
C_3	1/2	1/3	1	1/2	4	3	1/2	1/2	1/2	0.10
C_4	1/3	1/3	2	1	4	3	1/2	2	4	0.17
C_5	1/4	1/4	1/4	1/4	1	2	1/2	1	1/2	0.06
C_6	1/3	1/3	1/3	1/3	2	1	1/4	1	1/2	0.07
C_7	2	1/3	2	1/4	2	2	1	4	3	0.17
C_8	1/3	2	2	1/2	2	1	2	1	2	0.15
C_9	1/4	1/4	2	1/4	1	2	1/3	1/2	1	0.08

LB = 9, λ_{max} = 8.55225269, RI = 1.45, CR = 0.10796028.

Table 7 │ Judgment matrix B_3–C results of evaluating the ranking

B_3	C_1	C_2	Weight
C_1	1	3	0.55
C_2	1/3	1	0.45

LB = 2, RI = 0.

Table 8 │ Five-point scale for indicator measurements

Category	Numerical value
Healthy	5
Sub-healthy	4
Medium	3
Sub-unhealthy	2
Unhealthy	1

index. Evaluation standards were determined by earlier research and the actual conditions of small rivers in Shanghai (Shi *et al.* 2011; Deng *et al.* 2014; Liu *et al.* 2016). In this study, the trophic level index (TLI) method was used to assess the eutrophication status. It is defined by the following equations (Liu *et al.* 2016); the computational formula for each eutrophication index is (CEMS 2001):

$$TLI\ (Chla) = 10(2.5 + 1.0861nChla)$$

$$TLI\ (SD) = 10(5.118 - 1.941nSD)$$

where TLI is trophic level index; the unit for Chla is μg/L, and the unit for SD (transparency) is m.

A series of 0–100 consecutive numbers is adopted to grade the eutrophication level (Table 9).

The other water quality evaluation method (Table 10) was based on the Environmental Quality Standard for Surface Water (EQSSW) (SEPA 2002) and utilized the river health assessment standards of other countries (Tennant 1976; Grubb *et al.* 2006; Zhai *et al.* 2014).

P-IBI and B-IBI are commonly used indices for ecosystem health assessment (Klemm *et al.* 2002; Morley & Karr 2002; Lacouture *et al.* 2006; Bahram *et al.* 2011). P-IBI values above 2.53 indicate that river quality is healthy, whereas a value below 0.63 indicates the poorest in Shanghai (Xu *et al.* 2016). The G-F index method, which reflects the species list, is used to calculate the diversity of the investigated species. The D_{G-F} index of Yuan Dang in Dianshan Lake, was 0.35 with a relatively healthy ecosystem (Hu *et al.* 2014).

Qin *et al.* (2005) conducted a study on Taihu Lake and the composition of the shrimp colony in Gonghu Bay, which showed that the density of *Caridina nilotica* var. *gracilipes* De Man was significantly higher in areas with high submerged plant coverage. It was more likely to live

Table 9 | Classification and evaluation score of each eutrophication level

TLI	[0,30)	[30,50)	(50,60]	(60.70]	(70,100)
Eutrophication level evaluation score	Oligotrophic	Mesotrophic	Slightly eutrophic	Moderately eutrophic	Hypereutrophic

Table 10 | Evaluation standards for river water quality conditions

| | Index | Units | River health levels | | | | |
			Healthy	Sub-healthy	Medium	Sub-unhealthy	Unhealthy
River water quality conditions	DO	mg/L	≥ 5	[3,5)	[2,3)	[1,2)	<1 smelly blackish water
	NH_3-N	mg/L	≤ 1.0	(1.0,1.5)	(1.5,2.0]	(2.0,8.0]	>8.0 smelly blackish water
	TP	mg/L	≤ 0.2	(0.2,0.3)	(0.3,0.4]	(0.4,1.0]	>1.0 smelly blackish water
	COD_{Mn}	mg/L	≤ 6	(6,10)	(10,15]	(15,20]	>20 smelly blackish water
	Chla	μg/L	≤ 10	(10,25)	(25,60]	(60,100]	>100 smelly blackish water
	SD	m	≥ 1.0	[0.7,1.0]	[0.4,0.7)	[0.2,0.4)	<0.2 smelly blackish water

in a habitable environment and it was determined that it could be used as a habitat indicator species. According to records (Shi *et al.* 2011), the coverage of submerged plants was 61.05% in unpolluted water (Dianshan Lake) in the 1980s, but only 0.38% in 2010; we, as a result of this, define submerged plant coverage above 60% as healthy level. Referring to domestic and international evaluation criteria, floating-leaf plant cover above 70% and not more than 90% is healthy. The diversity of aquatic plants reflects the number of local species, and the degree to which aquatic plants respond to different environmental changes in the river; referring to the findings of Tang *et al.* (2013), aquatic plant diversity above 15 is healthy (Table 11).

Using the subjective evaluation method to evaluate the ecological landscape effect (Table 12), the rationality of plant collocation and visual esthetics were evaluated and divided into five grades with a point value of 1 to 5.

COMPREHENSIVE EVALUATION OF HEALTHY ZONES WITHIN THE SHANGHAI SMALL RIVERS

Quality of river water

The output of the evaluation model for water quality of 56 small rivers is shown in Figure 2. Those rivers are in central urbanization, new town, and village areas, respectively. The results show that the water quality scores are between 2.08 and 3.60 in CW, between 1.73 and 4.16 in NW, and between 2.29 and 3.88 in VW. Our results implied that the water quality of CW could be classified as medium; NW and VW can be classified as sub-healthy. Generally, the water quality in the CW was significantly worse than in NW and VW ($p < 0.05$), while there was no difference between NW and VW ($p = 0.15$).

Ecological status

From the samples collected in Shanghai small rivers from 2014 to 2015, the ecological status evaluation results indicated that all the river reaches were at the sub-unhealthy and medium levels. The average scores for CW, NW, and VW were 1.75, 2.30, and 2.45, respectively; the ecological status of CW rivers was dramatically worse than for NW and VW rivers ($p < 0.05$), and the VW rivers had better ecological status scores (Figure 3).

Ecological landscape effect

According to the results of the questionnaire survey and evaluation, public satisfaction with river ecological landscapes is poor in the central urban area, and 62.5% of the rivers were classified as sub-unhealthy or unhealthy. The proportion of the ecological landscape in NW that was classified as sub-unhealthy or unhealthy was as high as

Table 11 | Evaluation standards for ecosystem

	Index	Units	River health levels				
			Healthy	Sub-healthy	Medium	Sub-unhealthy	Unhealthy
Ecosystem	P-IBI		≥2.53	[1.90,2.53)	[1.27,1.90)	[0.63,1.27)	0 ~ 0.63
	B-IBI		≥3.73	[2.80,3.73)	[1.86,2.80)	[0.93,1.86)	<0.93
	DG-F		≥0.35	[0.25–0.35)	[0.15–0.25)	[0.05–0.15)	<0.05
	Water indicator species		Yes	/	No	/	/
	Riverbank ecology		≥90%	[80%, 90%)	[70%, 80%)	[50%, 70%)	<50%
	Emergent/floating plant coverage	%	(70,90]	(50,70)	(30,50]	(10,30]	<10 or > 90
	Submerged plant coverage	%	>60	(30,60)	(20,30]	(5,20]	<5
	Aquatic plant diversity		>15	(10,15)	(5,10]	(1,5]	≤1
	Coefficient of terrestrial vegetation		Three types of vegetation, 35 species, 90% plant coverage	Three types of vegetation, 35 species, 70% plant coverage	Vegetation form, tree or shrub type 2, 15 species, 60% to 70% plant coverage	Less than two types of vegetation, less than 15 species, 60% plant coverage	Less than one type of vegetation, less than 10 species, 50% plant coverage

Table 12 | Evaluation standards for ecological landscape effect

	Indices	River health levels				
		Healthy	Sub-healthy	Medium	Sub-unhealthy	Unhealthy
Ecological landscape effect	Ecological landscape condition	Plant collocation is reasonably well arranged beautiful landscape	Plant collocation is reasonably well arranged beautiful landscape	Plant collocation is reasonable	Plants are mixed and have disorderly distribution on the riversides	Flinty riparian, stiff landscape
	Harmony with the surroundings	Harmonious	Sub-harmonious	Medium	Sub-unharmonious	Unharmonious

55%. Additionally, in rural areas, 25.9% of the rivers were classified as sub-unhealthy or unhealthy; 62.9% of the rivers were at the medium level (Figure 4).

After structuring the evaluation indicator system for river health and calculating the values of the indices, the comprehensive indicator for each reach and the corresponding health level are illustrated in Table 13 and Figure 5, respectively.

As shown in Table 13, among the Shanghai small river ecosystem, most of the CW and NW rivers are in sub-unhealthy to medium state, while the VW rivers are in

medium to sub-healthy state. There was a substantial difference between the three types of river ecological scoring groups ($p = 0.000$). The composite score for CW rivers was 2.50, for NW rivers was 2.88, and for VW rivers was 3.11; overall, less disturbed by social and ecological activities, the rural areas were better than those of CW and NW rivers. The NW located at the junction of the suburbs are less affected by social activities than cities, thus the overall ecosystem health of NW rivers is better than CW rivers, and part of the rivers are in a medium to sub-healthy state.
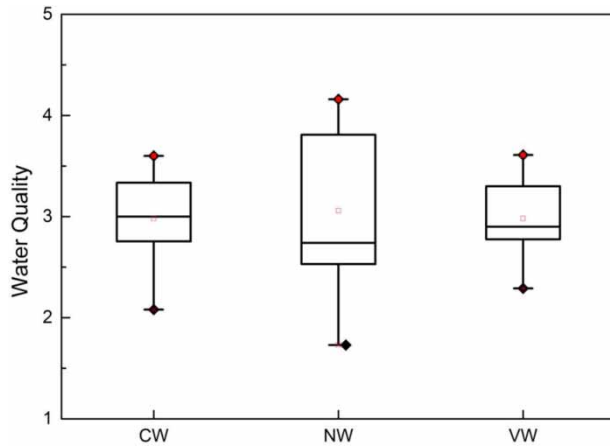
Figure 2 │ The evaluated output of the evaluation model for the water quality of 56 small rivers.
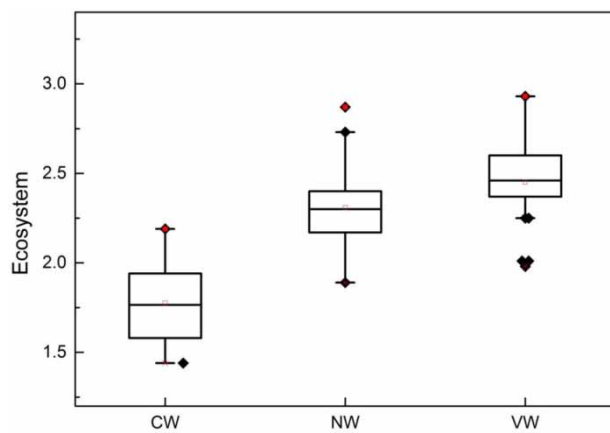

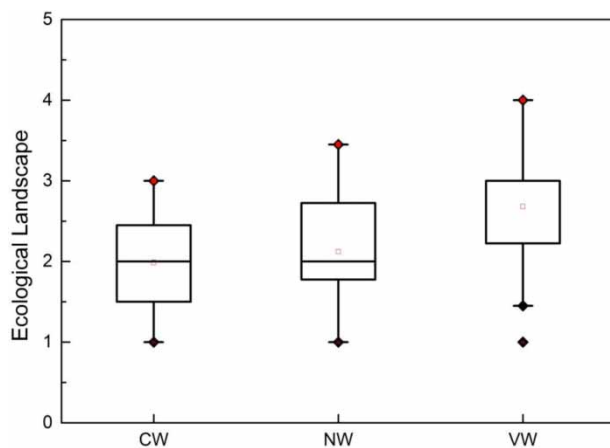**Figure 3** │ The output of the evaluation model for the ecological status of 56 small rivers.

Figure 4 │ The output of the evaluation model for the ecological landscape effect of 56 small rivers.

Table 13 │ Shanghai channel ecological evaluation values

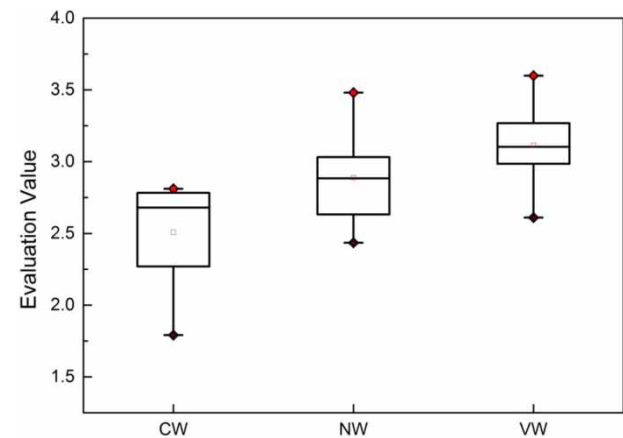| Type	Evaluation value	Type	Evaluation value	Type	Evaluation value
CW1	2.01	NW12	3.48	VW11	3.11
CW2	2.65	NW13	3.41	VW12	3.49
CW3	2.71	NW14	2.68	VW13	2.73
CW4	1.79	NW15	2.43	VW14	2.67
CW5	2.81	NW16	2.47	VW15	2.98
CW6	2.76	NW17	2.47	VW16	3.10
CW7	2.53	NW18	2.90	VW17	3.05
CW8	2.80	NW19	2.52	VW18	3.08
NW1	2.87	NW20	2.60	VW19	2.85
NW2	2.66	VW1	3.09	VW20	3.08
NW3	2.91	VW2	3.60	VW21	2.61
NW4	2.99	VW3	3.46	VW22	3.43
NW5	2.77	VW4	3.08	VW23	3.21
NW6	3.00	VW5	2.99	VW24	3.16
NW7	2.82	VW6	2.85	VW25	3.19
NW8	3.25	VW7	3.20	VW26	3.15
NW9	3.06	VW8	3.17	VW27	3.33
NW10	3.48	VW9	2.67	VW28	3.48

Figure 5 │ Ecological evaluation value range of each channel type.

CONCLUSIONS

Our study structured a new water ecological health assessment, including physical and chemical, biological, and landscape elements for assessing river health, and selected 17 indices to describe these elements. Through a

comprehensive ecological environmental evaluation of river water quality conditions, ecosystem, and ecological landscape, the health of Shanghai small rivers was classified as healthy, sub-healthy, medium, sub-unhealthy, or unhealthy.

Ecological surveys of 56 rivers with nearly 200 sampling sites from 2014 to 2015 were classified as small river ecosystem health conditions in the region into five zones. The results showed the health of the investigated river courses was at a medium level, ranging from 1.79 to 3.59, with the average being 2.95. The ecological health of rivers in rural areas was better than that of CW rivers and NW rivers. According to the features of the river, the emphasis on river management is different. The ecological management of the river in the central urban area focuses on the micro-topography construction, bank protection, water purification, and ecological greening in the river. The management of NW rivers should focus on river habitat construction of diversity, purification of water quality, restoration of aquatic plants, and ecological landscape construction. The focus of ecological management of rural rivers should be on the protection and construction of habitat diversity, restoration of aquatic plants, and ecological greening. However, due to the complexity of the aquatic ecosystem, more scientific and systematic research needs to be further optimized and deepened due to the influence of sample quantity and data accumulation.

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