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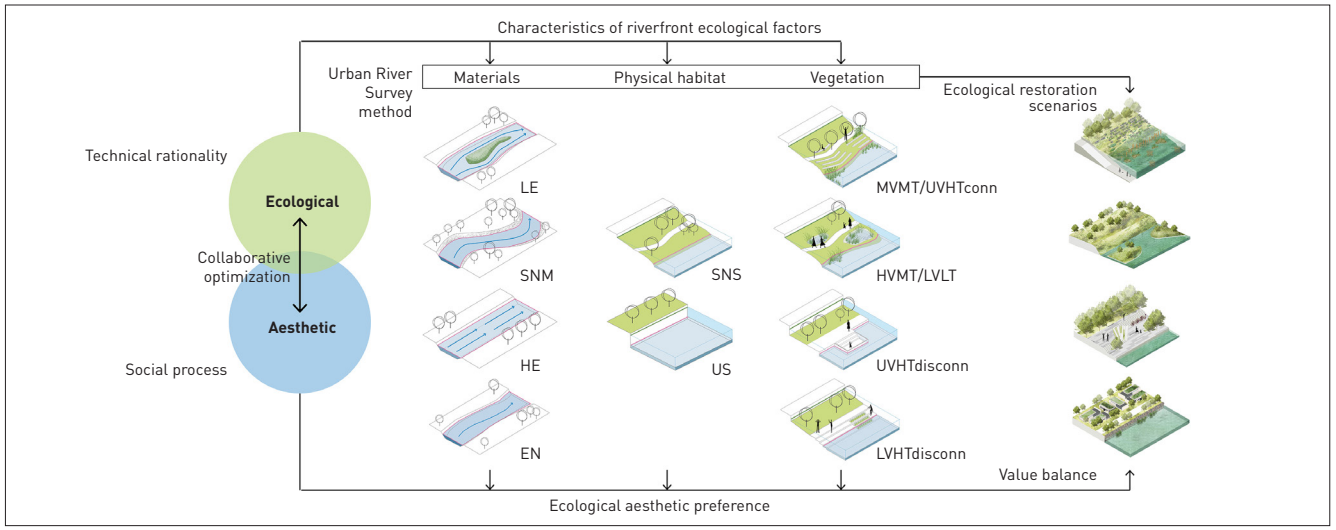
Influencing Mechanism of Ecological Aesthetic Preference on Urban River Ecological Restoration: A Case Study of Kunshan, Jiangsu Province

WANG Min[1,2], HOU Xiaohui[3], WANG Fangxinyi[1,2], WANG Jieqiong[1,2,4,*]

1 College of Architecture and Urban Planning, Tongji University, Shanghai 200092, China
2 Eco-SMART LAB attached to Key Laboratory of Ecology and Energy-saving Study of Dense Habitat (Ministry of Education), Tongji University, Shanghai 200092, China
3 Shanghai Urban Planning and Design Research Institute, Shanghai 200011, China
4 Technology Innovation Center for Land Spatial Eco-restoration in Metropolitan Area, Ministry of Natural Resources, Shanghai 200003, China

***CORRESPONDING AUTHOR**
Address: 1239 Siping Road, Yangpu District, Shanghai, 200092, China
Email: echowangwang@qq.com

GRAPHICAL ABSTRACT



HIGHLIGHTS

- Ecological aesthetic preference is comprehensively affected by three factors
- Ecological awareness and knowledge level affects aesthetic preference the most
- Vegetation impacts more on ecological preference than material and physical habitat
- Combinations of ecological factor characteristics optimize overall benefits of river restoration

ABSTRACT

To balance the ecological–aesthetic relationship in urban river ecological restoration, the research analyzed the ecological aesthetics performance of related practice. By defining "ecological aesthetic preference" and establishing a triple framework of ecological aesthetic preference on urban riverfronts, the research summarized three major factors that impact ecological aesthetic preference. With the Urban River Survey method, 24 typical river section samples in Kunshan, Jiangsu Province were selected. Through correlation analysis and optimal scaling regression model, relevant characteristics and influencing mechanisms were analyzed. The results include that: 1) Individuals' ecological awareness and knowledge level has the most significant impact, followed by ecological factor characteristics of riverfronts and individuals' social–cultural characteristics; 2) The respondents having higher cognition on ecosystem services show a stronger aesthetic preference for urban riverfronts; and 3) Vegetation characteristics impact ecological aesthetic preference more than material and physical habitat characteristics, and different combinations would lead to various overall benefits of urban riverfronts. Therefore, urban river ecological restoration should better integrate ecological values and aesthetic values by flexibly combining spatial elements, meanwhile fully consider social demands for urban riverfronts, to promote people's ecological awareness and knowledge level and provide them with better landscape perception of ecosystem services.

KEYWORDS

Urban River; Riverfront; Ecological Aesthetics; Ecological Restoration; Influencing Mechanism; Public Aesthetic Preference; Kunshan City

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1 Research Background and Objective

With the promotion of green transformation and lifestyle[1][2] and the public's raising awareness about environmental and ecological protection, cities strengthen holistic development of urban waterfronts. With a prominent positive externality[3], waterfronts have become engines for urban regeneration and community revitalization[4]. A large number of ongoing research and practice projects on ecological restoration of urban rivers and waterfronts[5]~[8] emphasize response to the public's social, recreational, aesthetic, and ecological demands for quality waterfronts[5][9] through spatial improvement that enhances ecosystem services overall capacities[10], so as to achieve the goal of ecological civilization that "sound ecological environment is the most inclusive benefits to people's wellbeing."[11]

Existing research and practice on urban river ecological restoration concentrate more on improving landscape aesthetics, enhancing community identity, and providing open and recreational spaces for residents[12][13], while less on ecosystem health. Most research explores the methods and technologies of ecological restoration[14], but lacks perspectives on the public's perception[6]. This hinders the human–city–nature integration and the ecological–aesthetics coordination in river ecological restoration process. For example, native plants growing in waterfronts are often misunderstood as "wild grasses" and lack of maintenance and management[15][16]; instead, colorful ornamental grass species such as *Muhlenbergia capillaris* Trin. may be more attractive for citizens[17]. To study and address the incoordination between ecological and aesthetic values, Paul H. Gobster, et al. introduced the concept of "landscape perception" in the ecological aesthetic theory[15]. Different from traditional dualistic aesthetic ideas[18], the landscape perception process emphasizes the combination of the public's aesthetic demands and ecological knowledge, and the interplay between humans and ecosystems in ecological aesthetic experience processes[19][20]. Unlike traditional landscape aesthetics evaluation, which aims to explain general rules of landscape aesthetics through the visual quality of landscape elements (form, color, and vegetation), ecological aesthetic evaluation attempts to explore the ecological processes of landscape as well as the correlation between ecosystem services and landscape aesthetics[21][22].

This research emphasizes the importance of the ecological aesthetic experience process based on the belief that ensuring the health of ecosystem should be part of primary goals in river ecological restoration. This paper combines methods of river health assessment and research approaches to ecological aesthetic preference, integrates the goals of ecosystem health and public aesthetic demands in urban river restoration, and constructs a framework of the influencing mechanism of ecological aesthetic preference on urban riverfronts. Based on this framework, the paper proposes three major affecting factors of ecological aesthetic preference—ecological characteristics of the riverfront, social and cultural background characteristics of the visitor, and the visitor's ecological awareness and knowledge level—and carries out empirical research with 24 typical riverfront samples in Kunshan City, Jiangsu Province, China. With the outcome of correlation analysis and the optimal scaling regression model, the affecting factors and their influencing mechanisms are revealed, which explores the collaborative optimization of ecological and aesthetic values in urban river ecological restoration practice.

2 Research Methods

2.1 Research Framework

Ecological aesthetic theory points out that individuals' ecological awareness and knowledge level affects their aesthetic experience[18]. Defined by ideas about biodiversity and ecological balance, ecological awareness goes beyond anthropocentric value consciousness and standards, as well as "human aesthetic preference"①; knowledge here refers to natural science knowledge, especially ecological knowledge[18]. Raising ecological awareness facilitates people's mindset change from traditional aesthetics towards ecological aesthetics, and ecological knowledge can affect ecological aesthetic experience[18][23] and so as impact on their aesthetic preference. Therefore, the research defines "ecological aesthetic preference" as the aesthetic experience generated through interactions between humans and the perceptible ecological landscape pattern. It can be understood as a subjective and rational landscape spatial evaluation determined by individuals' physiological and psychological capacities, aesthetic preference, cognition, and knowledge level.

In addition, existing literature illustrates that the public's aesthetic preference for urban riverfronts is affected by both

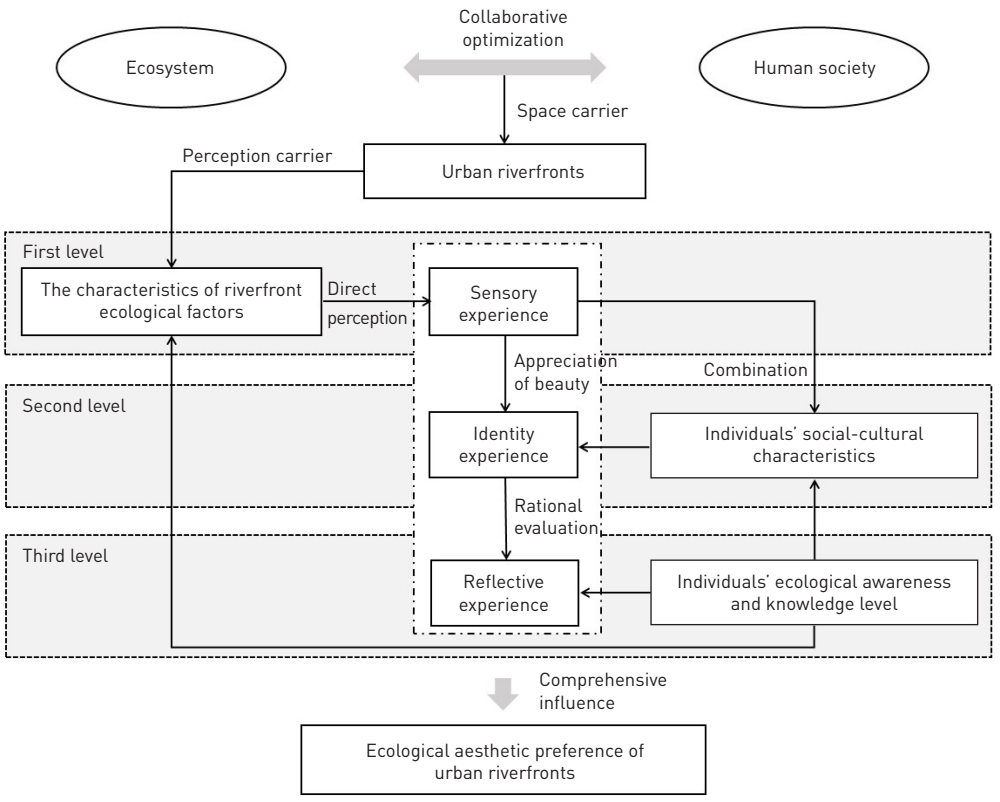
① The term "human aesthetic preference" refers to the anthropocentric aesthetics that ignores ecological values or even confuses benefits and adverse impacts caused by traditional aesthetic activities (regarding protecting biodiversity and ecosystem dynamic balance as benefits). For example, humans appreciate the beauty of *Eichhornia crassipes* which often causes biological invasion and ecological disasters, illustrating a tradional aesthetie preference over loss of living spaces for native species (Source: Ref. [18]).

environmental and subject factors[24][25]. The environmental factors include: 1) physical elements (e.g. water, vegetation, animals, artificial facilities, and buildings)[24][26]; 2) structural characteristics (e.g. spaciousness, straight to curved, coherence, and complexity)[12][27]; and 3) site context (e.g. urbanization degree, land use, and socio-economic status)[12][25]. Such factors determine the aesthetic value, ecological functions, and social and cultural services of urban riverfronts[15]. In this research, physical elements and structural characteristics are collectively referred to as ecological factors. The subject factors include physiological characteristics such as age[28] and gender, as well as social-cultural characteristics such as education level[29], income, occupation[30], place of usual residence, religious beliefs, cultural values, and environmental protection experience[31][32]. All characteristics of subject factors in this research are collectively referred to as social-cultural characteristics.

Based on the model of human-environmental interactions and the influencing mechanism of landscape aesthetic preferences proposed by Gobster et al.[15], the research constructs a triple framework of ecological aesthetic preference on urban riverfronts (Fig. 1). 1) the sensory experience defined by individuals' direct perception on the characteristics of riverfront ecological factors; 2) the identity experience generated from the appreciation of beauty according to individuals' social-cultural characteristics; and 3) the reflective experience rooting in individuals' rational evaluation of ecological awareness and knowledge level. The characteristics of riverfront ecological factors, individuals' social-cultural characteristics, and their ecological awareness and knowledge level are the three affecting factors to their ecological aesthetic preference.

2.2 Riverfront Sample Selection

Urban riverfronts in Kunshan were selected as the study samples in this research. Kunshan sits in the downstream area of Taihu Lake watershed with a dense water network shaped by numerous lakes, rivers, and ponds—the area of rivers and lakes accounts for 16.58% of the total area of the city[33]. Impacted by human activities, rivers in Kunshan have suffered from varied ecological problems, such as morphological damage, water quality deterioration, hydrological changes, and habitat degradation. Through water environmental management and ecological restoration over recent years, the riverfronts in the city have mostly been restored into multi-leveled, multi-typed waterfronts with diversified landscapes. In this research, river sections with typical characteristics and combinations of ecological factors were selected as study samples and displayed with photographs in order to avoid the disturbance



1. The triple framework of ecological aesthetic preference on urban riverfronts

caused by landscape disparity to the respondents' direct perception experience, and to improve the credibility of the research.

Based on terrain data and remote sensing images, the width regulations for all level of the river in Kunshan River Blue Line Protection Plan[33], as well as the characteristics of river ecological factors, the research team conducted a preliminary screening to select rivers with a width of 20 ~ 100 m, and then further selected river sections of 300 ~ 500 m in linear length referring to the Urban River Survey (URS)[34], a highly operable and applicable method—It is one of the international mainstream urban river evaluation methods[34][35] developed from the UK River Habitat Survey (RHS) and already been used in Chinese urban river health assessment[35][36]. Consisting of two parts, i.e. classification and index, this method assesses the urban river health status impacted by humans—A total of 62 section samples from 27 rivers in 5 levels② in Kunshan were chosen, covering riverfronts with various urbanization degree and representative characteristics for different parts throughout the city.

Research team carried out a field survey in July 2018, and observation points on the river section samples were set at each 50-meter interval. Using cameras with positioning functions and mobile phones, and with visual inspection method, researchers collected URS data, including basic site information, engineering type and ecological factor characteristics of section samples, and indicator measurement. Then, to avoid negative impacts of similar riverfront landscapes on the respondents' aesthetic preference, the research compared the characteristics of ecological factors of each sample, including different characteristics in materials, physical habitats, and vegetation (Table 1), and finally selected 24 typical and heterogeneous river section samples (Fig. 2)③, covering 4 material types, 2 physical habitat types, and 6 vegetation types.

2.3 Variables Setting

Developed on previous research on the aesthetic preference of urban riverfronts, the research defines characteristics of riverfront ecological factors, individuals' social–cultural characteristics, and their ecological awareness and knowledge level as independent variables, and takes ecological aesthetic preference as the dependent variable (Table 1) to analyze the affecting factors and the influencing mechanisms of ecological aesthetics on urban riverfronts.

2.3.1 Characteristics of Riverfront Ecological Factors

Referred from three decision trees of the URS method, the research measures the characteristics of riverfront ecological factors with 14 indicators, concerning material characteristics, physical habitat characteristics, and vegetation characteristics, to evaluate the perceivable ecological quality; then, according to the decision trees, the research classifies, evaluates, and assigns each indicator[34].

2.3.2 Individuals' Social–Cultural Characteristics

Based on literature review[12][18][28]~[32], individuals' social–cultural characteristics that affect their ecological aesthetic preference include social–economic factors and environmental background factors. The former covers age, gender, education level, occupation, industry, average monthly income, registered household type, and place of usual residence; and the latter covers environmental protection experience, the closest walking distance between home and rivers, frequency of accessing river, and activity diversity.

2.3.3 Individuals' Ecological Awareness and Knowledge Level

Ecosystem services link the ecosystem with human society. Enhancing people's awareness of various ecosystem services to human well-being helps harmonize the human–nature relationship[37][38]. Therefore, the research applies individuals' cognition level of the importance of ecosystem services to measure their ecological awareness and knowledge level. The ecosystem services include four types, namely regulating, cultural, provisioning, and supporting services, which were subdivided into 10 specific indicators: stormwater regulation and storage, water purification, and soil and water conservation[39] for regulating services; aesthetic appreciation, education, recreation and eco-tourism, and city image and identity[40] for cultural services; fresh water supply and aquatic products for provisioning services; and maintaining biodiversity for supporting service. The research adopts the mean values of the 10 indicators in related calculations.

2.3.4 Ecological Aesthetic Preference

Gobster pointed out that "landscape patterns are perceptible instantiations of interrelated, interdependent, environmental phenomena."[15] He defined landscape aesthetic experience as "a feeling of pleasure attributable to directly perceivable characteristics of spatially and/or temporally arrayed landscape patterns."[15] Cheng

② According to Kunshan River Blue Line Protection Plan, rivers in Kunshan are classified into 5 levels.

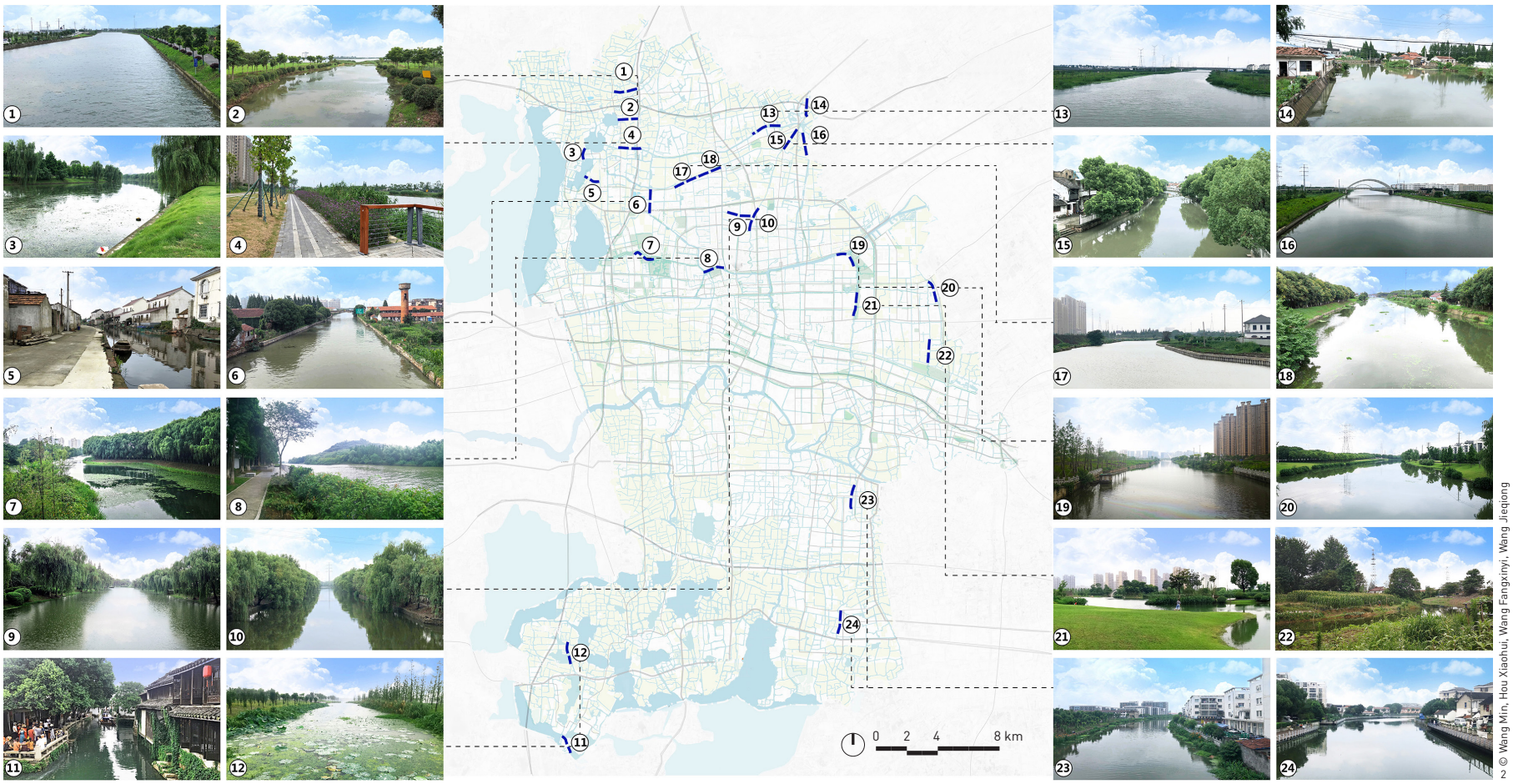
③ Most river sections in central city area are large channels that exceed the width range for sample selection; also these sections are relatively homogeneous, so only a small number representative sections were selected.

Table 1: The independent and dependent variables impacting the ecological aesthetic preference of urban riverfronts

Variable type	Group	Factor	Indicator	Data source/data collection method
Independent variable	X: Ecological factor characteristics of urban riverfronts	X1: Material characteristics	Proportion immobile substrate Proportion no bank protection Bank sediment caliber index Bed sediment caliber index Dominant bank material type	On-site investigation
		X2: Physical habitat characteristics	Count of vegetated side bars Proportion natural bank profiles Count of in-channel habitats	
		X3: Vegetation characteristics	Proportion of glides Complexity tree cover Count of tree features Average channel vegetation cover Dominant channel vegetation type Complexity bank face structure	
	Y: Individuals' social–cultural characteristics Socio–economic factors	Y1: Age Y2: Gender Y3: Education level Y4: Occupation Y5: Industry Y6: Average monthly income Y7: Registered household type Y8: Place of usual residence		Structured questionnaire
	Environmental background factors	Y9: Environmental protection experience Y10: The closest walking distance between home and river Y11: Frequency of accessing river Y12: Activity diversity		
	Z: Individuals' ecological awareness and knowledge level	Z1: Cognition level of the importance of ecosystem services	Regulating service cognition level Cultural service cognition level Provisioning service cognition level Supporting service cognition level	Likert scale questionnaire
Dependent variable	Ecological aesthetic preference	EAV: Ecological aesthetic value		Likert scale questionnaire

NOTE The specific calculation methods and formulas for X1, X2, and X3 used in this paper were sourced from Ref. [34].

Xiangzhan et al. also argued that only in perceptible environments, human beings can acquire aesthetic experience[41]. Thus, this paper shows that ecological aesthetic preference is different from the separated experience of "appreciation" and "beauty" which may confuse benefits and adverse impacts in human aesthetic preference; it highlights Ecological Ethics as the ideological basis and enriches people's imagination and emotions with ecological knowledge. It is a new aesthetic method and aesthetic value alternating from traditional human aesthetics[18]. The research takes ecological aesthetic value to measure the respondents' ecological aesthetic preference for urban riverfronts, which means that ecological aesthetic value is adopted in this research. Since the research only explores the respondents' ecological aesthetic preference through visual evaluation, the influence of other sensory perceptions such as sound and smell on aesthetic preference is not be discussed.



2. The map of section samples of urban riverfronts in Kunshan

Table 2: Characteristic of ecological factors of the riverfront samples

Material	SNM: Semi-natural (mixed)
	LE: Lightly engineered
	EN: Engineered
	HE: Heavily engineered
Physical habitat	SNS: Semi-natural (stable)
	US: Uniform stable
Vegetation	UVHTconn: Un-vegetated channel; high bank tree cover, connected to channel
	MVMT: Medium channel vegetation cover; medium bank tree cover
	HVMT: High channel vegetation cover; medium bank tree cover
	LVLT: Low channel vegetation cover; low bank tree cover
	LVHTdisconn: Low channel vegetation cover; high bank tree cover, but disconnected from channel
	UVHTdisconn: Un-vegetated; high bank tree cover, but disconnected from channel

2.4 Data Collection

According to the decision trees in URS, the research collected data of each indicator from the 24 section samples, and analyzed the corresponding specific material, physical habitat, and vegetation characteristics (Table 2).

Existing research proves that the evaluation results have no significant differences between indoors and in the field[42]. The influence of irrelevant variables (e.g. weather and time) on preference can be eliminated by photo editing (for example, using Photoshop to adjust light and color), so as to better meet the needs of visual preference evaluation in this study. So this research systematically photoshopped the photos of the section samples to ensure the normalized presentation of the three ecological factor characteristics of urban riverfronts (Table 1).

From September to October 2018, questionnaires were nationwide distributed to collect data of the respondents' social–cultural characteristics, ecological awareness and knowledge level, and ecological aesthetic preference. Single-choice questions were adopted for all indicators of individuals' social–cultural

characteristics except for activity diversity (multiple-choice question adopted). In terms of ecological awareness and knowledge level, the respondents' cognition level of the importance of ecosystem services was measured with five-point Likert scale (1 for not important, 5 for very important) by 10 sub-indicators of four types of ecosystem services, and the mean value of every sub-indicator was calculated. Finally, to enhance the reliability and generality of the result[43], the research probed into the differences in the respondents' ecological aesthetic preferences and improved the results of optimal scaling regression model by asking the respondents to randomly evaluate and rate the photographs of 12 section samples by seven-point Likert scale (1 for strongly dislike, 7 for strongly like, and the mean score of each photograph was adopted). A total of 504 valid questionnaires were collected in the survey, and each photograph was evaluated by 222 ~ 272 respondents.

Results of the questionnaires (Table 3) show that the numbers of male and female respondents are approximated. The overall education level of the respondents was relatively high, nearly 60% of them had a bachelor's degree, and 20.44% had a graduate or higher degree. Respondents come from a wide variety of industries and occupations. The overall income level of the respondents was relatively high. Only 6.94% of the respondents had a monthly income of less than 2,000 yuan, and that of most respondents was higher than the national median per capita income level of 2,295 yuan in 2020[44]. Most respondents were urban registered households. Only 36.71% of the respondents were living in the Yangtze River Delta (YRD) region, and Kunshan residents accounted for 18.06%—which is also conducive to exploring whether there is a significant disparity in ecological aesthetics between residents from different cities/regions. Nearly half of the respondents had environmental protection experience before. Most respondents lived within a 10-minute walking distance from rivers. They had a high frequency of accessing river overall, and 85% of them had 2 or more activities in riverfronts.

The average score of the respondents' overall cognition level of the importance of ecosystem services is 4.260 (Table 4), indicating generally the respondents were aware of the importance of ecosystem services provided by urban riverfronts to human well-being. The mean values of four ecosystem services by 10 sub-indicators are, from high to low, 4.460 for supporting services, 4.420 for regulating services, 4.190 for cultural services, and 4.070 for provisioning services, which is in consistent with the result of previous research that provisioning services are less likely to be cognized by the public[40].

The evaluation results of ecological aesthetic preference of 24 samples are analyzed with SPSS (Fig. 3). Overall, the score of each photo ranges from 3.84 to 6.08, with an average of 4.97, and the median values range from 4 to 6. It shows that the urban riverfronts in Kunshan are generally attractive to respondents. Among them, Sample 21 was the most popular one with the minimal evaluation discrepancy, while Sample 12 saw the opposite.

2.5 Optimal Scaling Regression Model

With SPSS, the research conducted a chi-square test of significance on the variables and ecological aesthetic value. This research used Spearman correlation analysis with two variables because the data of individuals' ecological awareness and knowledge level and that of ecological aesthetic value are not in a continuously and linear distribution. Analysis results reveal that ecological factor characteristics of urban riverfronts, individuals' social-cultural characteristics, and their ecological awareness and knowledge level all have a significant impact on ecological aesthetic value ($p \leq 0.001$). Therefore, in the establishment of optimal scaling regression model, the research used ecological factor characteristics of riverfronts, individuals' social-cultural characteristics, and their ecological awareness and knowledge level as independent variables, and ecological aesthetic value as the dependent variable (Table 1). According to the nature of each independent variable, age, education level, average monthly income, the closest walking distance between home and river, frequency of accessing river, and ecological aesthetic value were classified as ordinal variables; activity diversity, and cognition level of the importance of ecosystem services are interval variables; and the rest are nominal variables. In order to quantitatively analyze the nominal variables, the optimal scaling regression model was used, in which dependent and independent variables represent categorical variables of different types. Based on this model, the original categorical variables were transformed into appropriate quantitative scores by applying the nonlinear transformation approach to replace the original variables for regression analysis, so repeated in a loop.

3 Research Results and Discussion

3.1 Overall Affecting Characteristics

The optimal scaling regression model is statistically significant and has high significance ($p < 0.001$) (Table 5), indicating that three independent variables all have significant impacts on ecological aesthetic preference. The adjusted goodness of fit of the model is 0.222, meaning that about 22.2% of evaluation results

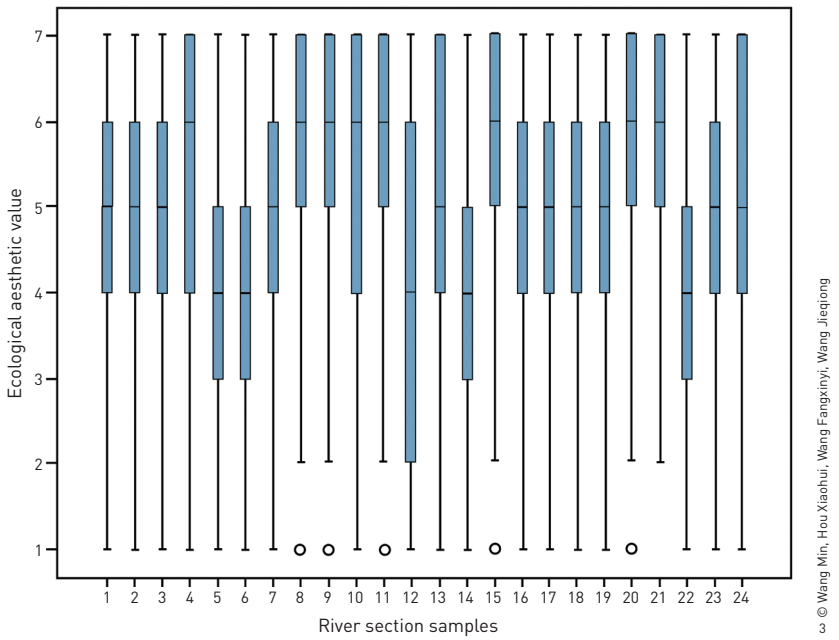
Table 3: Questionnaire outcomes of the respendent social–cultural characteristics

Age	Percentage (%)
16 ~ 25	14.49
26 ~ 35	20.83
36 ~ 45	26.79
46 ~ 65	37.89
Gender	**Percentage (%)**
Male	48.21
Female	51.79
Education level	**Percentage (%)**
Primary or middle school	2.18
High school	7.34
College or professional training	11.51
Bachelor's degree	58.53
Graduate or higher degree	20.44
Occupation	**Percentage (%)**
Institution and enterprise worker	23.81
Business manager	18.45
Technician	12.90
White collar or clerical worker	13.89
Education, health, or sport professional	11.11
Labor, retail, or service worker	1.59
Self-employed	3.37
Unemployed or retired	2.58
Student	6.15
Others	6.15
Industry	**Percentage (%)**
Agriculture and forestry	6.15
Production, supply, and transportation	6.75
Planning, construction, and real estate	23.61
Public and social management	7.74
Others	55.75

Average monthly income	Percentage (%)
2,000 yuan or less	6.94
2,000~5,000 yuan	24.21
5,001~10,000 yuan	39.09
10,001~20,000 yuan	17.06
More than 20,000 yuan	12.70
Registered household type	**Percentage (%)**
Urban	88.29
Non-urban	11.71
Place of usual residence	**Percentage (%)**
Kunshan	18.06
Shanghai	11.31
YRD	7.34
Non-YRD	63.29
Environmental protection experience	**Percentage (%)**
Have participated before	47.42
Never participated	52.58
The closest walking distance between home and river	**Percentage (%)**
Within 5 minutes	29.37
5~10 minutes	31.94
11~30 minutes	19.44
More than 30 minutes	19.25
Frequency of accessing river	**Percentage (%)**
Nearly everyday	38.49
Weekly	30.75
Monthly	21.63
Almost never	9.13
Activity diversity	**Percentage (%)**
Only 1 type	15.00
2 or 3 types	53.00
4 or 5 types	24.00
More than 5 types	8.00

Table 4: Cognition level of the importance of ecosystem services

	Overall	Regulating service	Cultural service	Provisioning service	Supporting service
Average score	4.260	4.420	4.190	4.070	4.460
Standard Deviation	0.615	0.664	0.707	0.849	0.811



3. Box plot result of ecological aesthetic preference

can be explained by these factors and that some other affecting factors were not included. The tolerance values of each factor were all considerably greater than 0.1, showing a high reliability of regression model with no significant collinearity among independent variables. In terms of the regression coefficient and significance of each independent variable, factors except average monthly income and registered household type were all important to affect ecological aesthetic preference. By calculating the mean value of the importance level, the three independent variables can be ranked in order as: individuals' ecological awareness and knowledge level (0.409), ecological factor characteristics of urban riverfronts (0.085), and individuals' social–cultural characteristics (0.034).

Table 5: Results of optimal scaling regression model for ecological aesthetic preference

Independent variable	Factor	Regression coefficient	Significance	Importance	Tolerance	
					After conversion	Before conversion
X: Ecological factor characteristics of urban riverfronts	X1: Material characteristics	0.156	0.000*	0.101	0.993	0.448
	X2: Physical habitat characteristics	0.120	0.000*	0.019	0.796	0.434
	X3: Vegetation characteristics	0.210	0.000*	0.135	0.795	0.871
Y: Individuals' social–cultural characteristics	Y1: Age	0.101	0.000*	0.040	0.573	0.615
	Y2: Gender	0.019	0.000*	0.010	0.889	0.888
	Y3: Education level	0.135	0.000*	0.052	0.796	0.745
	Y4: Occupation	0.101	0.000*	0.085	0.865	0.853
	Y5: Industry	0.019	0.000*	0.050	0.860	0.850
	Y6: Average monthly income	0.135	0.306	0.000	0.866	0.864
	Y7: Registered household type	0.101	0.859	0.001	0.778	0.743
	Y8: Place of usual residence	0.019	0.004	0.003	0.884	0.874
	Y9: Environmental protection experience	0.135	0.000*	-0.022	0.739	0.830
	Y10: The closest walking distance between home and river	0.101	0.000*	0.035	0.825	0.785
	Y11: Frequency of accessing river	0.019	0.000*	0.008	0.740	0.722
	Y12: Activity diversity	0.135	0.000*	0.075	0.905	0.899
Z: Individuals' ecological awareness and knowledge level	Z1: Cognition level of the importance of ecosystem services	0.296	0.000*	0.409	0.948	0.941
Optimal scaling regression model		Adjusted goodness of fit	0.222			
		Variance test	42.063			
		Significance	0.000*			

NOTE * means $p < 0.001$.

3.2 Influence Analysis of Individuals' Ecological Awareness and Knowledge Level

Respondents' ecological awareness and knowledge level is the factor that impacts ecological aesthetic preference the most with a significant positive correlation (0.296)—the respondents who have higher cognition on ecosystem services, show a stronger aesthetic preference for urban riverfronts. Therefore, enhancing the public's awareness about the importance of ecosystem services can positively influence the public's ecological aesthetic preference for urban riverfronts.

3.3 Influence Analysis of Ecological Factor Characteristics of Urban Riverfronts

Ecological factor characteristics of urban riverfronts can positively affect individuals' ecological aesthetic preference. Vegetation characteristics had the most significant impact, followed by material characteristics and physical habitat characteristics. The public's perception of different ecological factors is various. So ecological and environmental quality improvement, especially in vegetation and material conditions of riverfronts, can more effectively enhance people's affection for urban riverfronts.

3.3.1 Suggestions on the Design of Different Ecological Factor Characteristics

The scores of the optimal scaling regression model of material characteristics, physical habitat characteristics, and vegetation characteristics are shown in Table 6.

1) In terms of material characteristics, SNM and LE have the lowest and highest scores respectively, showing that moderate engineered riverfronts is more popular by the public. According to the decision trees in URS, corresponding suggestions for landscape design practice would be a riverfront with non-hardened eco-banks and of a moderate engineered level. In the research, Sample 21 is a LE riverfront and had a higher popularity; while Sample 12 is a SNM riverfront with the opposite evaluation result (Fig. 2).

2) In terms of physical habitat charasteristics, SNS is appreciably less popular than US. In other words, generally the public prefer tidy riverfronts with less changes in riparian habitat and a lower natural ratio in cross bank section, according to the decision trees in URS. In the research, compared with Sample 12, Sample 21 is a typical tidy and less-changed riverfront, and is more appreciated by the public (Fig. 2).

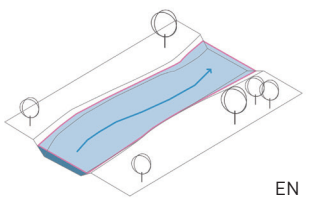
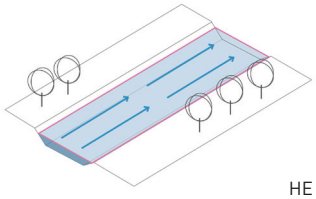
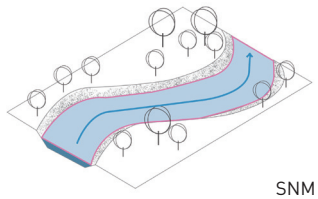
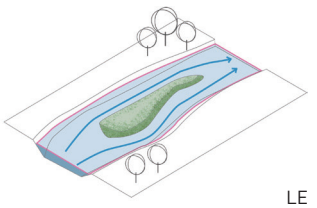
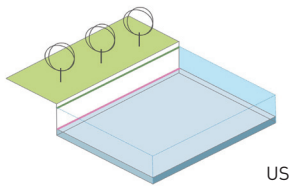
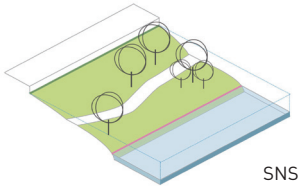
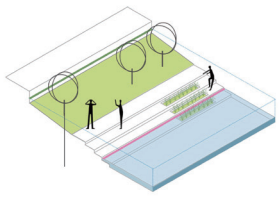
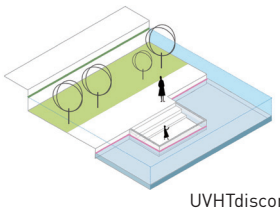
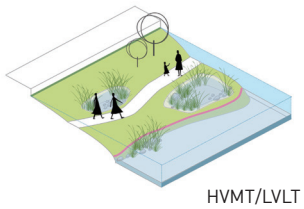
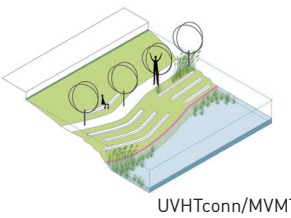
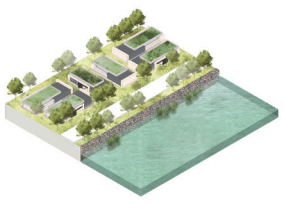
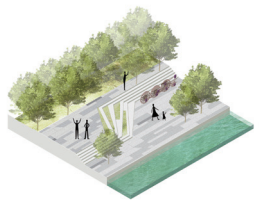
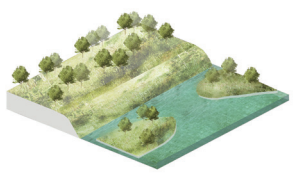
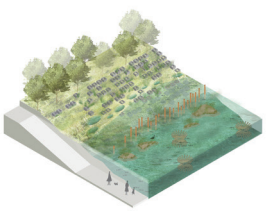
And 3) in terms of vegetation characteristics, HVMT, and LVLT were less popular than MVMT, UVHTdisconn, and UVHTconn, while MVMT has the highest popularity. In general, the public prefer moderate or relatively low channel vegetation cover and high tree cover—higher tree cover complexity and moderate count of tree features, accordingly to the decision trees in URS. In the research, Sample 21 has moderate channel vegetation cover and tree cover that creat a more inviting landscape effect. On the contrast, Sample 12 is suffering from water bloom, with high channel vegetation cover and moderate or low tree cover, seeming lack of proper management. The evaluation result that Sample 21 was more popular to the respondents than Sample 12 (Fig. 2) proves the outcome of the regression model.

3.3.2 Typical Combinations of Spatial Elements

In spatial design practice, the result of aesthetic preference evaluation is usually used as an important reference to aesthetic value measurement. In ecological aesthetics, urban river ecological restoration projects are usually in the form of combination of different ecological factor characteristics (Fig. 4). Through the selection and combination of varied materials, physical habitats, and vegetation, ecological value and aesthetic value can be better integrated that helps maximize the overall benefits of urban riverfronts. Ecological restoration practice should prioritize those combinations with high ecological and aesthetic values. In cases with spatial limitations, combinations need be selected in accordance with functional demands of the specific conditions of

Table 6: Scores of optimal scaling regression model of material, physical habitat, and vegetation charasteristics

Ecological factor characteristics	Name	Score of optimal scaling regression model
Material	SNM	-2.0
	LE	1.6
	EN	-0.6
	HE	-0.2
Physical habitat	SNS	-2.2
	US	0.4
Vegetation	UVHTconn	0.8
	MVMT	2.6
	HVMT	-1.0
	LVLT	-0.8
	LVHTdisconn	0.1
	UVHTdisconn	0.6

		Low ecological and aesthetic value	Low ecological value, high aesthetic value	High ecological value, low aesthetic value	High ecological and aesthetic value
Ecological factor characteristics	Material	 EN	 HE	 SNM	 LE
	Physical habitat		 US	 SNS	
	Vegetation	 LVHTdisconn	 UVHTdisconn	 HVMT/LVLT	 UVHTconn/MVMT
Ecological restoration scenarios		 	 	 	 
Riverfront site conditions		Limited riverfront spaces with high requirement in flood control	Abundant riverfront spaces, dense population, and high demand for leisure and recreation	Ecologically sensitive and important, and high demand for ecological protection	Good ecological resources and moderate demand for urban construction

4. Typical combinations of ecological factor characteristics of riverfronts in urban river ecological restoration practice

riverfront sites, to make trade-offs or alleviate value conflicts with engineering techniques, design methods, and social resources[45]. The characteristics of ecological factors of attractive urban riverfronts often include: 1) lightly engineered and non-hardened banks; 2) less changes in riparian habitats and lower natural ratio of cross bank section, creating a tidy physical environment; and 3) high tree cover with diverse and complex vegetation communities.

3.4 Influence Analysis of Individuals' Social-Cultural Characteristics

In order to further explore the deviation of ecological aesthetic preference by individuals' social-cultural characteristics and related impacts, the ecological aesthetic deviation (EAD) is measured by the absolute value of the normalized difference between the evaluation results of ecological factor characteristics of urban riverfronts with

the URS method and ecological aesthetic value. The value of EAD represents the degree of difference between evaluation results of Ecomorphology quality and the public's ecological aesthetic preference—the higher the EAD value, the greater the difference between the public ecological aesthetic preference and the ecological quality of the riverfront.

The research conducted a Kruskal Wallis (K-W) or nonparametric Spearman test on individuals' social-cultural characteristics and EAD, and the results (Table 7) show that age, education level, occupation, industry, average monthly income, place of usual residence, and activity diversity can lead to significant differences in EAD ($p < 0.05$), while gender, registered household type, environmental protection experience, the closest walking distance between home and river, and frequency of accessing river had no significant correlation with EAD. However, there are great differences in the K-W test result for place of usual residence and EAD between respondents from Kunshan and Shanghai, and between respondents from Shanghai and non-YRD regions, while the EAD of rest combinations in terms of place of usual residence had no significant difference (Table 8). Table 9 discovered that Shanghai respondents had the lowest EAD while that of the respondents from other regions was relatively high. This might result from the construction of urban ecological riverfront projects in Shanghai in recent years, which promotes public ecological education and improves citizens' ecological aesthetics.

The research further conducted Spearman correlation analysis of four ordinal and interval variables with significant differences (Table 10). The results evidenced that age ($r = 0.214$) is positively correlated with EAD, while education level ($r = -0.228$), average monthly income ($r = -0.091$), and activity diversity ($r = -0.189$) are negatively correlated with EAD, suggesting that the respondents who are younger, with a higher education level, a higher income, and more diverse environmental protection activities normally have a lower EAD. Strengthening ecological education and developing diverse activity programs can promote people's understanding and awareness of ecological aesthetics.

4 Conclusions and Implications

By defining the concept of "ecological aesthetic preference," this research explores the public's ecological aesthetic preference for urban riverfronts. Based on the triple framework of the influencing mechanism of ecological aesthetic preference, 24 typical river sections in Kunshan City, Jiangsu Province were analyzed through the correlation analysis and with the optimal scaling regression model to study the affecting factors and related influencing characteristics.

In conclusion, individuals' ecological awareness and knowledge level is the most important factor to ecological aesthetic preference, followed by ecological factor characteristics of urban riverfronts and individuals' social-cultural characteristics. Here are several suggestions for urban river ecological restoration practice.

1) Differing from traditional aesthetic paradigms, ecological restoration projects that improve urban river health should integrate and assess ecological factor characteristics in the process of aesthetic evaluation. Riverfronts of inviting landscapes and with ecological factor characteristics of both high ecological and aesthetic values (such as lightly engineered material, tidy physical habitat, and high bank tree cover) can be created to optimize spatial environment, and improve riverfront aesthetic quality as well as the overall ecosystem services capacities.

2) Prioritizing the enrichment of aesthetic experience, future practice should provide the public with better landscape perception of river ecosystem services, in order to enhance their ecological

Table 7: Test outcome of social-cultural characteristics and EAD of the respondents

Social and cultural background characteristics	Y1: Age	Y2: Gender	Y3: Education level	Y4: Occupation	Y5: Industry	Y6: Average monthly income	Y7: Registered household type	Y8: Place of usual residence	Y9: Environmental protection experience	Y10: The closest walking distance between home and river	Y11: Frequency of accessing river	Y12: Activity diversity
Significance	0.000***	0.461	0.001**	0.000***	0.000***	0.010*	0.483	0.000***	0.728	0.069	0.833	0.003**

NOTE

* means $p < 0.05$; ** means $p < 0.01$; *** means $p < 0.001$.

Table 8: Results of K–W test of EAD and place of usual residence of the respondents

Place of usual residence	Kunshan–Shanghai	Kunshan–YRD	Kunshan–Non-YRD	Shanghai–YRD	Shanghai–Non-YRD	YRD–Non-YRD
Significance	0.005*	0.496	1.000	1.000	0.000*	0.215

NOTE * means $p < 0.001$.

Table 9: Mean value of respondents' EAD with different place of usual residence

Place of usual residence	Kunshan	Shanghai	YRD	Non-YRD
Mean value of EAD	0.494	0.417	0.454	0.495

Table 10: Spearman correlation test results of the social–cultural characteristics and EAD of the respondents

Individuals' social–cultural characteristics	Y1: Age	Y3: Education level	Y6: Average monthly income	Y12: Activity diversity
Spearman correlation analysis				
Correlation coefficient (r)	0.214	–0.228	–0.091	–0.189
Significance	0.000*	0.000*	0.041	0.000*

NOTE * means $p < 0.001$.

aesthetic experience. When ecological and aesthetic needs conflict, restoration projects should prioritize primary goals by using ecological engineering approaches (e.g. building multi-layered banks) that can improve both ecological quality and aesthetic experience to meet various demands.

And 3) optimizing value cultivation, by acknowledging the public's ecological aesthetic deviation, related practice should employ spatial design methods in accordance with traditional aesthetics in the short term, and promote the public's ecological awareness and knowledge level through ecological education (for example, displaying the beauty of "weeds" or "wildness") in the long run. Coordinating ecological and aesthetic values of urban riverfronts is means to enable the endogenous power for sustainability.

There are still deficiencies in this research. In the model establishment, the incompleteness of affecting factors determination and the limited sample size of respondents might cause bias in representing the public's ecological aesthetic preferences; Besides, the URS method might be localized in the application of ecological evaluation of China's urban riverfronts, because different from the UK where the URS method developed, China's river ecological restoration practice started late and dominated with heavily engineered river banks. Future research needs to explore empirical evidences that test the rationality of the URS method, or make appropriate adjustments adapted to local conditions of China's urban riverfronts, such as introducing indicator species of specific habitats and adjusting the length of river section samples.

REFERENCES

[1] Huang, Q., Zeng, Y., & Jiang, Q. (2015). Progress and prospect of the study on “Making Great Efforts to Promote Ecological Civilization Construction”. *China Population Resources and Environment*, 25(02), 111-120. doi:10.3969/j.issn.1002-2104.2015.02.015

[2] Ren, J., & Ma, Y. (2020). Research progress and prospects of green development from the perspective of geography. *Progress in Geography*, 39(7), 1196-1209.

[3] Liu, B. (2018). Urban waterfront era is coming: New growth from urban rivers. *City Planning Review*, 42(3), 72-79. doi:10.11819/cpr20180311a

[4] Wang, M., Ye, Q., & Wang, J. (2019). The development and paradigm shift of city betterment and ecological restoration of waterfront spaces: Analysis and insights from Suzhou River and Emscher River. *Chinese Landscape Architecture*, 35(11), 24-29. doi:10.19775/j.cla.2019.11.0024

[5] Gou, F., & Zhou, Y. (2018). The eco-restoration of suburban river landscape—A case study on Dreisam River, Freiburg, Germany. *Chinese Landscape Architecture*, 34(8), 33-38. doi:10.3969/j.issn.1000-6664.2018.08.007

[6] Wang, M., Ye, Q., & Held, T. (2017). Riparian zones management with effective eco-services provision under the interaction of stakeholders: A case study of the Emscher River in Germany. *Chinese Landscape Architecture*, (1), 52-59. doi:10.14085/j.fjyl.2017.01.0052.08

[7] Yu, K., & Gong, Y. (2021). Exploration on ecological restoration model for the improvement of ecosystem services of yellow river floodplains—A case study of Zhengzhou Yellow River Floodplain Park planning and design. *Landscape Architecture Frontiers*, 9(3), 86-97. doi:10.15302/J-LAF-1-040025

[8] Yuan, X., Xiang, L., Hu, Y., Chen, W., Huang, Y., Xiong, S., Yan, J., & Wang, F. (2021). Ecological design across interface: Ecosystem restoration of Pengxi River/Reservoir in Three Gorges Reservoir Area, Chongqing. *Landscape Architecture Frontiers*, 9(3), 12-27. doi:10.15302/J-LAF-1-020048

[9] Zhang, M., & Sun, J. (2017). Exoteric dailiness Shanghai Huangpu River wharfs and urban waterfront space. *Time Architecture*, (4), 44-47.

[10] Wang, J., Peng, H., Zhuo, C.,& Calhoun, S. (2016). Radar chart evaluation of overall eco-services provided by sponge community: Empirical study of Stanform Community in Melbourne. *Journal of Chinese Urban Forestry*, 14(4), 28-33. doi:10.3969/j.issn.1672-4925.2016.04.006

[11] Li, G. (2019, June 3). Maintaining a good ecological environment - the most universal well-being of the people. *People’s Daily*.

[12] Chang, C. T., & Huang, S. (2011). Reclaiming the city: Waterfront development in Singapore. *Urban Studies*, 48(10), 2085-2100. doi:10.1177/0042098010382677

[13] Wang, M., Piao, S., & Wang, J. (2020). Factors analysis of landscape preference in the ecological perception of urban waterfront spaces: Case studies of Houtan Park and Hongkou Riverside Park in Shanghai. *Architecture & Culture*, (11), 157-159. doi:10.19875/j.cnki.jzywh.2020.11.052.

[14] Wang, J., Ge, J., & Cheng, S. (2018). Urban river ecological restoration based on improving the overall capacities of water-related ecosystem services. *Journal of Human Settlements in West China*, 33(6), 54-58. doi:10.13791/j.cnki.hsfwest.20180608

[15] Gobster, P. H., Nassauer, J. I., Daniel, T. C., & Fry, G. (2007). The shared landscape: What does aesthetics have to do with ecology?. *Landscape Ecology*, 22(7), 959-972. doi:10.1007/s10980-007-9110-x

[16] Gobster, P. H., Hang, D., & Cheng, X. (2010). Development of ecological aesthetics in the West: A landscape perception and assessment perspective. *Academic Research*, (4), 2-14. doi:10.3969/j.issn.1000-7326.2010.04.001

[17] Li, J., & Nassauer, J. I. (2021). Designing aesthetic experiences for the cultural sustainability of ecological health. *Landscape Architecture Frontiers*, 9(5), 72-79. doi:10.15302/J-LAF-1-030029

[18] Cheng, X. (2013). On the four points of ecological aesthetics. *Tianjin Social Sciences*, 5(05), 120-125. doi:10.16240/j.cnki.1002-3976.2013.05.011

[19] Yu, Y., & Zeng, Z. (2015). Ecological aesthetics—A new perspective of urban planning aesthetics and design. *New Normal: Inheritance and Change—Proceedings of 2015 Annual Meeting of Urban Planning Society of China (07 Urban Ecological Planning)*. Guiyang, China: Urban Planning Society of China.

[20] Cheng, X. (2013). *Ecological Aesthetics and Ecological Assessment and Planning*. Henan People’s Publishing House.

[21] Hu, W., Yang, F., Shi, Y., & Bao, Z. (2020). Research Progress on Landscape Aesthetic Evaluation of Urban Park Green Space. *2020 Annual Meeting Proceedings of Chinese Society of Landscape Architecture (Part 1)* (pp. 51-59). Beijing, China: Chinese Society of Landscape Architecture.

[22] Ma, Y., Yuan, Q., & Leng, H. (2017). Review and enlightenment of landscape aesthetics service evaluation from the perspective of ecosystem service. *Chinese Landscape Architecture*, 33(6), 99-103.

[23] Cheng, X. (2016). Ecological aesthetics: The legal connection of ecology and aesthetics—An answer to Mr. Berlint. *Exploration and Free Views*, (12), 52-57. doi:10.3969/j.issn.1004-2229.2016.12.015

[24] Junker, B., & Buchecker, M. (2008). Aesthetic preferences versus ecological objectives in river restorations. *Landscape & Urban Planning*, 85(3-4), 141-154. doi:10.1016/j.landurbplan.2007.11.002

[25] Zhao, J., Jia, P., Wang, R., & Cai, Y. (2013). Correlations between aesthetic preferences of river and landscape characters. *Journal of Environmental Engineering & Landscape Management*, 21(2), 123-132. doi:10.3846/16486897.2012.695738

[26] Nassauer, J. I. (2004). Monitoring the success of metropolitan wetland restorations: Cultural sustainability and ecological function. *Wetlands*, 24(4), 756-765. doi:10.1672/0277-5212(2004)024[0756:MTSOMW]2.0.CO;2

[27] Herzog, T. R. (1985). A cognitive analysis of preference for waterscapes. *Journal of Environmental Psychology*, 5(3), 225-241. doi:10.1016/S0272-4944(85)80024-4

[28] Yamashita, S. (2002). Perception and evaluation of water in landscape: Use of Photo-Projective Method to compare child and adult residents’ perceptions of a Japanese river environment. *Landscape & Urban Planning*, 62(1), 3-17. doi:10.1016/S0169-2046(02)00093-2

[29] Hu, L., Li, W., Cao, M., Che, Y., & Yang, K. (2014). Study of urban waterfront landscape and public preference: A case study of Suzhou Creek in Shanghai. *Environmental Science & Technology*, 37(S1), 412-418. doi:10.3969/j.issn.1003-6504.2014.6N.089

[30] Li, D., & Yao, C. (2005). Research on the aesthetic quality of urban water landscape with the support of systematic landscape aesthetics. *Proceedings of the Annual Meeting of the Urban Planning Society* (pp. 1102-1105). China Water & Power Press.

[31] van den Berg, A. E., & Koole, S. L. (2006). New wilderness in the Netherlands: An investigation of visual preferences for nature development landscapes. *Landscape & Urban Planning*, 78(4), 362-372. doi:10.1016/j.landurbplan.2005.11.006

[32] de Groot, M., & de Groot, W. T. (2009).“Room for river” measures and public visions in the Netherlands: A survey on river perceptions among riverside residents. *Water Resources Research*, 45(7), 45-55. doi:10.1029/2008WR007339

[33] Kunshan City Water Conservancy Bureau, & Suzhou Water Conservancy Design and Research Institute. (2015). *River blue line protection plan in Kunshan City*.

[34] Gurnell, A., Shuker, L., & Wharton, G. (2014). *URS classifications and indices: 2014*.

[35] Zeng, P., Wang, Y., Liu, Y., Wang, H., Chen, Shi., & Che, Y. (2020). A river stretch scale assessment of urban river habitat in the Taihu Lake Basin. *Chinese Journal of Applied Ecology*, 31(2), 581-589. doi:10.13287/j.1001-9332.202002.006

[36] Wang, Q.,& Yuan, X., Liu, H., & Zhang, Y. (2011). Rapid assessment model for mountain stream habitat and its application. *Shuili Xuebao*, 42(8), 928-933. doi:10.13243/j.cnki.slxb.2011.08.014

[37] Yang, Q., & Dobbie, M. F. (2019). Importance-satisfaction analysis of cultural ecosystem services of multifunctional landscapes designed for stormwater management. *Landscape Architecture Frontiers*, 7(1), 52-67. doi:10.15302/J-LAF-20190105

[38] Liu, Y., Zhang, Y., & Jia, Q. (2017). Study on the methods of ecosystem services valuation. *Environmental Protection*, 45(6), 64-68. doi:10.14026/j.cnki.0253-9705.2017.06.015

[39] Ouyang, Z., Zhao, T., Wang, X., & Miao, H. (2004). Ecosystem services analyses and evaluation of China terrestrial surface water system. *Acta Ecologica Sinica*, 24(10), 2091-2099. doi:10.3321/j.issn:1000-0933.2004.10.001
[40] Zhai, X., & Lange, E. (2020). Using social media to explore perceptions of ecosystem services by Nature-Based Solution Projects. *Landscape Architecture Frontiers*, 8(3), 58-77. doi:10.15302/J-LAF-1-020030
[41] Cheng, X., & Li, L. (2020). A study on the relationship between aesthetic values and ecological values. *Social Science Front*, (10), 165-173, 282.
[42] Daniel, T. C., & Boster, R. S. (1976). *Measuring landscape aesthetics: The scenic beauty estimation method*. USDA Forest Service Research Paper RM-167.
[43] Miller, P. A. (2013). Visual preference research: An approach to understanding landscape perception. *Chinese Landscape Architecture*, 29(5), 22-26.
[44] National Bureau of Statistics. (2021). Residents' income and consumption expenditure in 2020. *National Bureau of Statistics*.
[45] Wang, M., & Hou, X. (2018). The value conflicts and tradeoffs in the ecological revival of urban waterfront landscape: Practical experience and enlightenment of the Isar River, Germany. *Urbanism and Architecture*, (33), 26-30. doi:10.19892/j.cnki.csjz.2018.33.006

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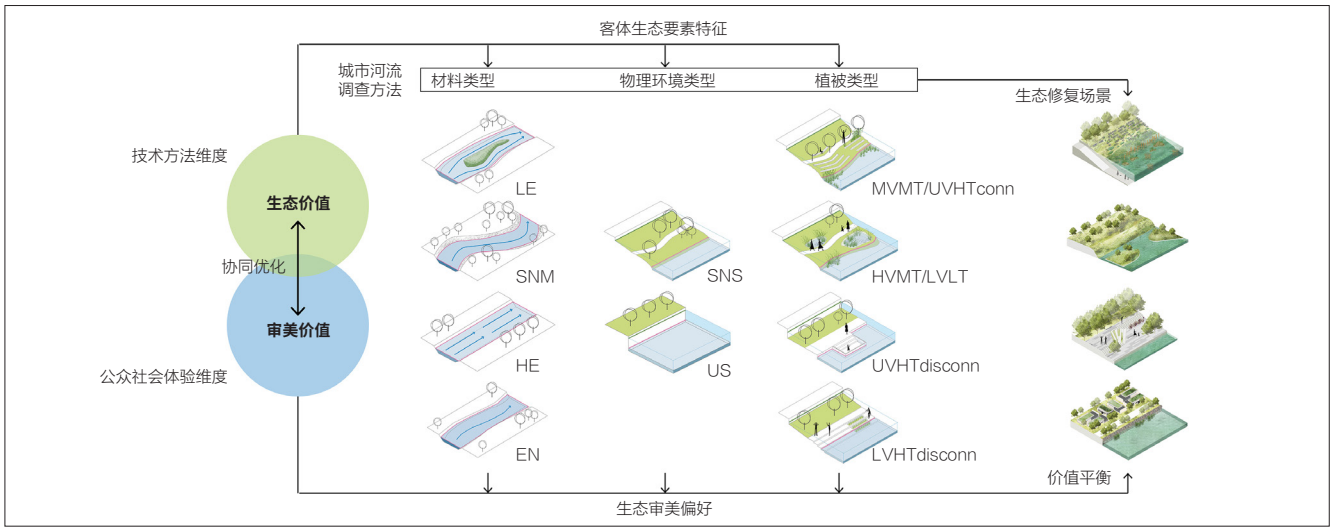
城市河流生态修复的生态审美偏好影响机制研究：基于江苏省昆山市的实证研究

王敏[1,2]，侯晓晖[3]，汪方心怡[1,2]，汪洁琼[1,2,4,*]

1 同济大学建筑与城市规划学院，上海 200092
2 高密度人居环境生态与节能教育部重点实验室（同济大学）水绿生态智能分实验中心，上海 200092
3 上海市城市规划设计研究院，上海 200011
4 中国自然资源部大都市区国土空间生态修复工程技术创新中心，上海 200003

***通讯作者**
地址：上海市杨浦区四平路1239号
邮编：200092
邮箱：echowangwang@qq.com

图文摘要



文章亮点

- 城市河流空间生态审美偏好受三重因子综合影响
- 生态意识与知识水平对城市河流空间生态审美偏好影响最为显著
- 植被类型对生态审美偏好的影响比材质类型、物理环境类型更显著
- 客体生态要素特征类型的选择与组合提升城市河流生态修复综合效益

摘要

为缓解城市河流生态修复中的“生态－审美”不协调关系，研究从生态审美的角度来剖析城市河流生态修复的绩效。本研究界定了“生态审美偏好”的概念，并构建了城市河流空间的生态审美偏好三重框架，总结了影响生态审美偏好的三大因子，即客体生态要素特征、审美主体社会文化背景和生态意识与知识水平。本文采用城市河流调查方法和调查问卷法，针对江苏省昆山市的24个典型样本河段展开实证研究，通过相关性分析与最优尺度回归，分析相关特征要素及其作用规律。研究结果表明：1）影响受访者生态审美偏好程度由强到弱依次为生态意识与知识水平、客体生态要素特征和审美主体社会文化背景；2）受访者对生态系统服务重要性的认知水平越高，对城市河流空间的喜爱程度越高；3）植被类型对生态审美偏好的影响比材质类型、物理环境类型更显著，且不同的组合类型会影响城市河流修复的综合效益。基于此，在城市河流生态修复规划设计与实施落地过程中，应考量生态与审美的综合价值，灵活组合客体生态要素类型，充分考虑社会需求，强化河流生态系统服务感知体验，同时提升公众生态意识与知识水平。

关键词

城市河流；河流空间；生态审美；生态修复；影响机制；公众审美偏好；昆山市

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· 国家重点研发计划课题“绿色基础设施生态系统服务功能提升与生态安全格局构建”（编号：2017YFC0505705）
· 国家自然科学基金面上项目“基于多重价值协同的城市绿地空间格局优化机制：以上海大都市圈为例”（编号：52178053）

编辑 冉玲于，张晨希，田乐
翻译 汪方心怡，侯晓晖，田乐，张晨希

1 研究背景与目标

随着国内外城市生产生活方式的绿色转型[1][2]与公众环境意识的提升，城市加强对滨水空间的综合开发利用——滨水空间由于其显著的正外部性[3]，成为城市复兴、社区振兴的引擎[4]。大量城市河流与滨水空间生态修复的研究与实践项目正在进行[5]~[8]，这些项目强调回应公众对高品质滨水空间的诉求[8]，并关注其功能性与社会性的提升[5]，提倡空间的物理属性优化需回应行为主体的内在需要，在提升生态服务综合效能（ecosystem services overall capacities）[10]的同时，满足公众审美需求，实现“良好生态环境是最普惠的民生福祉”的生态文明目标[11]。

现有的城市河流生态修复研究与实践主要关注提升美感、增强城市认同感，以及为城市居民提供开放空间和休闲场所等议题[12][13]，较少关注生态系统健康；且多聚焦于生态修复的方法与技术[14]，针对公众感知的研究较少[6]。这极大限制了“人－城－自然”关系的有效弥合，且导致河流生态修复过程中存在生态－审美关系不协调问题。若在滨水岸带种植“野草”等乡土植物，容易被误解为此处缺乏维护与管理[15][16]；而若种植如粉黛乱子草（*Muhlenbergia capillaris* Trin.）等色彩缤纷的观赏草，可能更受人们喜爱[17]。为研究并改善生态价值与审美价值不协调的问题，保罗·戈比斯特等人在生态审美理论中引入“景观感知”概念[15]，此概念强调公众审美诉求应与生态知识结合，改变传统主客二分的审美方式[18]，强调人类与生态系统双向影响、彼此交融的生态审美体验过程[19][20]。不同于传统的景观美学评价，生态审美评价方法较少关注形式、色彩和植被等景观要素呈现的视觉质量，其目的并非解释景观美学存在的一般规律，而是强调探究景观的生态过程及生态系统服务与景观空间审美的关联性[21][22]。

基于此，本研究认为，在河流生态修复中应将保证生态系统健康作为重要目标之一，并以此为前提强调生态审美体验过程的重要性。本研究结合河流健康评估方法与生态审美偏好研究方法，整合城市河流生态修复中的生态系统健康目标与公众审美诉求，构建了针对城市河流及其滨水空间（以下简称“河流空间”）的生态审美偏好影响机制框架。本文选取江苏省昆山市的24个典型样本河流空间展开实证研究，并借由上述影响机制提出了影响生态审美偏好的三大因子——客体生态要素特征、主体社会文化背景和生态意识与知识水平——通过相关性分析与最优尺度回归模型，揭示了主要影响因子及其作用规律，有效推进城市河流空间生态修复的生态价值与审美价值协同优化的生态实践探索。

2 研究方法

2.1 研究框架

生态审美理论指出，人们的生态意识及知识水平会影响其审美体验过程[18]。其中，生态意识以生物多样性和生态平衡为准则，超越人类中心主义的价值判断标准和“人类审美偏好”①；而此理论中的“知识”即为自然科学知识，特别是生态知识[18]。人类具有生态意识后，传统审美逐渐转为生态审美，同时生态知识可影响生态审美体验[18][23]，进而对审美偏好产生影响。因此，本研究将“生态审美偏好”定义为在人与可感知的生态景观格局互动过程中产生的审美体验，是一种在特定条件下，人类在生理和心理能力与审美倾向、个体认知和知识水平在共同作用下做出的感性与理性共存的景观空间评价。

此外，现有文献表明，影响公众对于城市河流空间审美偏好的因素主要包括客体特征和主体特征[24][25]。其中，客体特征包括：1）物质空间要素（如水体、植物、动物、人工设施和建筑等）[24][26]；2）结构特征（如开阔性、曲直性、连续性和复杂性等）[12][27]；3）环境背景（如城乡梯度、用地性质及社会经济条件等）[12][25]。这些客体特征决定了城市河流空间的审美价值、生态功能、社会功能与文化精神氛围[15]，而在此研究中，客体的物质空间要素与结构特征统称为生态要素。主体特征则包括年龄[28]和性别等生理特征，以及学历[29]、收入、职业[30]、居住地、宗教信仰、文化价值观和环保工作经历等社会文化背景[31][32]。在本研究中，上述所有主体特征统称为社会文化背景。

基于戈比斯特等人所提出的“人－环境互动模式”及景观审美偏好的影响机制[15]，本研究构建了针对城市河流空间的生态审美偏好三重框架（图1）：1）基于审美客体生态要素特征“直接感知”的感官体验；2）基于审美主体社会文化背景“审－美交融”的认同体验；3）基于生态意识与知识水平“理性评估”的反思体验。因此，审美客体生态要素特征、审美主体社会文化背景和生态意识与知识水平是对生态审美偏好产生综合影响的三个核心特征因子。

2.2 研究对象

本文选取江苏省昆山市河流空间作为实证研究对象。昆山市地处太湖下游平原河网地区，水网密布、湖荡众多且河港纵横，河湖水体面积占全市总面积的16.58%[33]。受人类活动影响，昆山市河流存在不同程度的生态问题，如形态结构破坏、水质恶化、水文条件改变和生境恶化等。近年的水环境治理与生态修复已将昆山市河流空间恢复为多层次、多类型、差异鲜明的景观。因此，本研究通过实地河段样本照片表征研

① “人类审美偏好”一词指的是人类在传统审美活动中存在忽视生态价值标准的“不辨益害”（此处以有利于生物多样性及生态系统的动态平衡为益），乃至“以害为益”情况的人类中心主义审美取向——如人类偏好凤眼莲（*Eichhornia crassipes*）之美，却导致生物入侵并造成生态灾害——即遵循了传统审美取向却造成对本土物种生存空间的掠夺（参见参考文献[18]）。

表 1：影响城市河流空间生态审美偏好的自变量与因变量

变量类型	特征分组	特征因子	具体指标	数据来源
自变量	X：客体生态要素特征	X1：材质类型	固定基质比例 护岸存在比例 河岸沉积能力 河床沉积能力 主要护岸类型	通过现场调研获得基础数据
		X2：物理环境类型	植被堆积边数量 河岸自然断面比例 河道生境类型数量 缓流比例	
		X3：植被类型	乔木覆盖复杂度 乔木特征数量 河道植被覆盖平均值 主要河道植被类型 河岸表面结构	
	Y：主体社会文化背景	Y1：年龄 Y2：性别 Y3：学历 Y4：职业 Y5：行业 Y6：平均月收入 Y7：户籍 Y8：居住地		结构化调查问卷获取
	环境背景因子	Y9：生态环保经历 Y10：住所与河流最近步行距离 Y11：接触河流频率 Y12：活动方式多样性		
	Z：生态意识及知识水平	Z1：生态系统服务重要性认知水平	调节服务认知水平 文化服务认知水平 供给服务认知水平 支持服务认知水平	李克特量表法问卷获取
因变量	生态审美偏好	生态审美偏好平均值（EAV）		李克特量表法问卷获取

注 表格中特征因子 X1、X2 和 X3 的具体计算方法与公式参见文献 [34]。

究所需的生态要素特征及组合，避免非研究所需的景观条件差异干扰受访者的直接感知体验，提升研究可信度。

结合相关基础资料，研究团队依据昆山地形数据和遥感图像对昆山市河流进行初步筛选：根据《昆山市河道蓝线保护规划》中河道各级的蓝线控制宽度数据[33]，以及河流生态要素特征的需求，选择平均宽度为20 ~ 100m的河流。后参考英国河流生境调查（RHS）中的城市河流调查（URS）方法[34]（此方法由分类和指标两部分组成，常用于评估受人类不同程度干扰的城市河流的健康状况，具有较高的可操作性和实用性，是国际主流的城市河流评价方法之一[34][35]，在中国城市河流生境评价中也有应用[35][36]），在已选择的河流上截取长度为300 ~ 500m的河段。此阶段共选取昆山市5个级别②27条河流的62个河段为样本，涉及昆山市北部湖荡区、中心城区和南部水乡区等不同城乡梯度与水系特征的河流空间。

研究团队以约50m为单位将每个样本河段划分为若干个小样段，作为观测样点，并于2018年7月开展田野调查——通过具有定位功能的相机、手机及目测等方式，采集数据，并填写URS调研信息表，具体内容包括场地信息、河段工程类型、河段生态要素特征和测量指标等。为避免过多无明显差异的河流空间对审美偏好评价造成干扰，研究通过比较各样本河段的城市河流空间的客体生态要素特征——材质类型、物理环境和植被类型（表1），最终遴选出24个典型且异质的样本河段（图2）③，共涵盖4种材质类型、2种物理环境类型和6种植被类型。

2.3 变量设定

研究基于国内外的城市河流空间审美偏好研究，将客体生态要素特征、主体社会文化背景和生态意识及知识水平定义为自变量，将生态审美偏好作为因变量（表1），解析影响城市河流空间的生态审美的因子及其作用规律。

2.3.1 客体生态要素特征（X）

参考URS方法中涉及的三类决策树，研究选取材质类型（X1）、物理环境类型（X2）、植被类型（X3）三方面因子的14个具体的客体生态要素特征评价指标作为城市河流空间能够反映生态质量可感知的特征，并依据决策树对各指标分类、评价和赋值[34]。

2.3.2 主体社会文化背景（Y）

根据文献梳理[12][18][28]~[32]，总结影响生态审美偏好的主体社会文化背景，包含社会经济背景因子和环境背景因子。其中，社会经济背景因子包括受访者的年龄（Y1）、性别（Y2）、学历（Y3）、职业（Y4）、行业（Y5）、平均月收入（Y6）、户籍（Y7）和居住地（Y8）；而环境背景因子包括生态环保经历（Y9）、住所与河流最近步行距离（Y10）、接触河流频率（Y11）和活动方式多样性（Y12）。

2.3.3 生态意识及知识水平（Z）

生态系统服务强调生态系统与人类社会之间的联系，公众可以通过增强各类生态系统服务对人类福祉重要性的认知，重构人与自然的关系与个体生态价值观[37][38]。因此，本研究将审美主体对生态系统服务重要性认知水平（Z1）作为其生态意识及知识水平的衡量因子。研究中涉及的生态系统服务包括调节、文化、供给与支持服务四大类，并依据服务类型细分为10个子项：调节服务包括雨洪调蓄、水质净化、水土保持[39]，文化服务包括美学欣赏、教育、休闲和生态旅游及展示城市形象文化特色[40]，供给服务包括提供淡水和水产品等，以及支持服务包括支持生物多样性等。此10个子项将在具体计算中分类计算均值。

2.3.4 生态审美偏好

戈比斯特指出景观格局（patterns）是多个可感知的、相互关联又相互依存的环境现象示例（instantiations），人类的景观审美体验可通过直接感知空间/时间层面组合的景观格局特征产生愉悦的感受，[15]程相占等人也提出“人类只能从可感知到的环境现象中感知审美体验”[41]。基于以上观点，本研究认为，生态审美偏好不同于“人类审美偏好”中“不辨益害”的“审-美”分离式体验，强调以生态伦理学为思想基础，借助生态知识丰富人们的想象与情感，是一种旨在突破人类传统审美的新型审美方式和审美观[18]。研究以生态审美偏好平均值（EAV）——即受访者对城市河流空间喜爱程度评分的平均值——作为生态审美偏好的表征因子。本研究仅探究公众基于视觉进行的评价，故暂不讨论声音和气味等其他感官因素对审美偏好的影响。

2.4 数据收集

研究团队通过采集24个样本河段的指标数据，基于URS方法中的决策树，将各指标结果所对应的材质类型、物理环境类型和植被类型（表2）。

表2：样本客体生态要素特征类型

材质类型	近自然混合（SNM）
	轻度工程化（LE）
	工程化（EN）
	重度工程化（HE）
物理环境类型	近自然稳定（SNS）
	规整稳定（US）
植被类型	无河道植被，河岸乔木高覆盖率且与河道相连接（UVHTconn）
	河道植被与河岸乔木中覆盖率（MVMT）
	河道植被高覆盖率，河岸乔木中覆盖率（HVMT）
	河道植被与河岸乔木低覆盖率（LVLT）
	河道植被低覆盖率，河岸乔木高覆盖率且不与河道相连接（LVHTdisconn）
	无河道植被，河岸乔木高覆盖率且不与河道相连接（UVHTdisconn）

② 《昆山市河道蓝线保护规划》将昆州市的河道划分为5级。

③ 中心城区河段大多属于航道类型，河流较宽，超出选择范围；且河段相对同质化，少量样本已具有代表性。

已有研究表明，人们在室内评价与在野外（现场）评价的结果没有显著差异[42]，并通过照片编辑处理（如利用Photoshop调光调色）可摒除不相关变量（如天气和时间）对偏好评价的影响，以更好满足本研究基于视觉评价偏好的需求。研究对用于调查生态审美偏好的河流空间照片进行系统化处理，以确保在样本中呈现表1中客体生态要素特征所包含的三种特征因子相对应的空间特征（具体指标）。

2018年9~10月，研究面向全国发放调查问卷，采集主体社会文化背景、生态意识及知识水平和生态审美偏好三方面的信息。其中，主体社会文化背景信息除活动方式多样性（Y12）采取多选题的形式外，均采取单选题的形式收集。对于生态意识及知识水平，受访者对生态系统服务重要性认知的相对水平采用五分制李克特量表法（1分代表很不重要，5分代表很重要），对四个服务类型下属的10个子项进行调查，而所有子项的平均分值代表该审美主体对整体生态系统服务重要性的认知水平。最后，为强化公众生态审美偏好差异，增强结果的可靠性与普适性[43]并优化后续最优尺度回归模型结果，受访者需通过七分制李克特量表法随机评价12张样段照片——受访者根据个人对照片所反映的城市河流空间喜爱程度评分（1分代表很不喜欢，7分代表很喜欢），最终计算出每张照片评分的平均值。研究最终回收有效调查问卷共计504份，每张照片获得222～272人次评价。

问卷调查结果显示（表3），受访者性别分布较均衡；近六成受访者为本科学历，20.44%的受访者为硕士及以上学历，整体受教育水平较高；受访者的行业和职业类型多样；仅有6.94%的受访者月收入低于2 000元，大部分高于2020年全国居民人均收入水平中位数2 295元[44]，整体收入水平较高；受访者多为城镇户籍；对于居住地，长三角地区受访者仅占36.71%，其中昆山市居民占18.06%，这也有利于探究不同居住地背景是否存在生态审美的明显差异；有生态环保相关经历的受访者接近半数；多数受访者住所与河流的距离在10分钟步行距离范围以内；受访者接触河流频率总体较高；85%的受访者会在河流空间进行2种及以上的活动。

受访者对整体生态系统服务重要性认知水平均值为4.260（表4），表明受访者已普遍认识到城市河流空间所提供的生态系统服务对于人类福祉的重要性。对10个生态系统服务子项根据其对应服务类型分类的均值计算结果显示，城市河流生态系统的支持服务（均值4.460）、调节服务（均值4.420）和文化服务（均值4.190）比供给服务（均值4.070）更受社会的重视。此结果与以往研究中，供给服务较不易被公众感知的研究结果相一致[40]。

研究借助SPSS软件分析24张样段照片的生态审美偏好评价结果（图3）。总体上看，所有照片均值分布在3.84～6.08分之间，生态审美偏好平均值为4.97分，中位数分布在4～6分之间，表明照片所代表的昆山市河流空间普遍受到受访者喜爱。其中，样本21最受喜爱且评价差异最小；样本12受喜爱程度最低且评价差异最大。

2.5 最优尺度回归模型构建

研究借助SPSS平台，对多分类变量与生态审美偏好平均值（EAV）进行列联表卡方检验；生态意识及知识水平与EAV不满足连续且线性分布特征，因而选用Spearman双变量进行相关性分析。分析结果表明，城市河流空间的客体生态要素特征、主体社会文化背景和生态意识及知识水平均是影响偏好的因素且显著性指标小于0.001，即影响显著。由此，定义客体生态要素特征（X）、主体社会文化背景（Y）和生态意识与知识水平（Z）为三组解释变量（自变量），EAV为被解释变量（因变量），以此构建最优尺度回归模型（表1）。并根据各解释变量的数据特征，将年龄（Y1）、学历（Y3）、平均月收入（Y6）、住所与河流最近步行距离（Y10）、接触河流频率（Y11）和EAV定义为定序变量，活动方式多样性（Y12）和生态系统服务重要性认知水平（Z1）定义为定距变量，其余为定类变量。为量化定类变量，本研究选取最优尺度回归模型进行分析——该模型允许因变量和自变量为不同类型的分类变量。在此基础上，应用非线性变换方法将原始分类变量转换成适当的量化评分代替原变量进行回归分析，以此反复迭代。

3 研究结果与讨论

3.1 整体影响特征

回归分析结果表明，此最优尺度回归模型有统计学意义且显著性高（$p<0.001$）（表5），说明三组自变量均对生态审美偏好产生显著影响；模型的调整拟合优度为0.222，表明本研究中的特征因子可解释约22.2%的生态审美偏好结果，仍有其他影响因素未纳入分析。各特征因子的容差值均显著大于0.1，表明各因子间无较强共线性关系，回归模型结果可信度较高。根据模型中各特征因子回归系数及显著性水平可知，除平均月收入（Y6）和户籍（Y7）之外的其他因子均是影响生态审美偏好的重要因素。根据重要性数据均值可得此三类自变量的影响程度（未计算平均月收入和户籍的重要性数据），由强到弱依次为：生态意识及知识水平（0.409）、客体生态要素特征（0.085）和主体社会文化背景（0.034）。

3.2 生态意识与知识水平影响特征

受访者的生态意识及知识水平是影响城市河流空间生态审美偏好的首要因素，两者显著正相关关系（回归系数为0.296），表明越重视生态系统服务的受访者，对城市河流空间的喜爱程度越高。由此可见，生态意识及知识水平能够显著影响生态审美感知，提升公众对生态系统服务重要性的认知可改变公众对城市河流空间的生态审美偏好。

3.3 客体生态要素影响特征

客体生态要素特征对生态审美偏好结果具有正向影响，即客观生

表 3：受访者社会文化背景信息

年龄	比例（%）
16 ~ 25	14.49
26 ~ 35	20.83
36 ~ 45	26.79
46 ~ 65	37.89
性别	**比例（%）**
男	48.21
女	51.79
学历	**比例（%）**
初中及以下	2.18
高中、中专和技校	7.34
大专和职高	11.51
本科	58.53
硕士及以上	20.44
职业	**比例（%）**
机关、事业单位	23.81
企业管理人员	18.45
专业技术人员	12.90
普通白领和文职人员	13.89
教师、卫生和体育工作者	11.11
工人、营业员及其他社会服务人员	1.59
个体经营者	3.37
无业、待业人员及离退休人员	2.58
学生	6.15
其他	6.15
行业	**比例（%）**
农、林、牧、渔业	6.15
生产、供应、运输相关行业	6.75
规划、建造、地产相关行业	23.61
公共、社会管理相关行业	7.74
其他行业	55.75

平均月收入	比例（%）
2 000 元以下	6.94
2 000 ～ 5 000 元	24.21
5 001 ～ 10 000 元	39.09
10 001 ～ 20 000 元	17.06
20 000 元以上	12.70
户籍	**比例（%）**
城镇户籍	88.29
非城镇户籍	11.71
居住地	**比例（%）**
昆山市	18.06
上海市	11.31
长三角其他地区	7.34
非长三角地区	63.29
生态环保相关经历	**比例（%）**
是	47.42
否	52.58
住所与河流最近步行距离	**比例（%）**
5 分钟以内	29.37
5 ～ 10 分钟	31.94
11 ～ 30 分钟	19.44
30 分钟以上	19.25
接触河流频率	**比例（%）**
经常，几乎每天都会	38.49
中等，每周都会	30.75
偶尔，大约一个月一次	21.63
几乎没有接触	9.13
活动方式多样性	**比例（%）**
单一活动	15.00
2、3 种活动	53.00
4、5 种活动	24.00
5 种以上活动	8.00

表 4：受访者生态系统服务重要性认知水平

	总体	调节服务	文化服务	供给服务	支持服务
平均值	4.260	4.420	4.190	4.070	4.460
标准差	0.615	0.664	0.707	0.849	0.811

表 5：生态审美偏好最优尺度回归模型分析结果

自变量	特征因子	回归系数	显著性	重要性	容差	
					转换后	转换前
X：客体生态要素特征	X1：材质类型	0.156	0.000*	0.101	0.993	0.448
	X2：物理环境类型	0.120	0.000*	0.019	0.796	0.434
	X3：植被类型	0.210	0.000*	0.135	0.795	0.871
Y：主体社会文化背景	Y1：年龄	0.101	0.000*	0.040	0.573	0.615
	Y2：性别	0.019	0.000*	0.010	0.889	0.888
	Y3：学历	0.135	0.000*	0.052	0.796	0.745
	Y4：职业	0.101	0.000*	0.085	0.865	0.853
	Y5：行业	0.019	0.000*	0.050	0.860	0.850
	Y6：平均月收入	0.135	0.306	0.000	0.866	0.864
	Y7：户籍	0.101	0.859	0.001	0.778	0.743
	Y8：居住地	0.019	0.004	0.003	0.884	0.874
	Y9：生态环保经历	0.135	0.000*	-0.022	0.739	0.830
	Y10：住所与河流最近步行距离	0.101	0.000*	0.035	0.825	0.785
	Y11：接触河流频率	0.019	0.000*	0.008	0.740	0.722
	Y12：活动方式多样性	0.135	0.000*	0.075	0.905	0.899
Z：生态意识及知识水平	Z1：生态系统服务重要性认知水平	0.296	0.000*	0.409	0.948	0.941
最优尺度回归模型		调整拟合优度	0.222			
		方差检验	42.063			
		显著性	0.000*			

注 *代表 $p < 0.001$。

态环境品质的提升有助于提高公众对整体河流空间的喜爱程度。其中，植被类型（X3）对公众审美偏好的影响最为显著，其次为材质类型（X1），而物理环境类型（X2）的影响最弱，表明公众对不同生态审美客体生态要素特征的感知程度存在差异，改善河段植被条件及材质条件可更高效地提升公众对城市河流空间的喜爱程度。

3.3.1各类生态要素特征设计建议

材质类型（X1）、物理环境类型（X2）与植被类型（X3）的最优尺度回归模型量化评分见表6。

1）材质类型方面，近自然混合类型（SNM）的评分明显低于不同程度工程化的材质类型，而轻度工程化（LE）的评分明显高于工程化（EN）和重度工程化类型（HE），表明河流空间适度的工程化更易受到公众喜爱。根据URS方法的决策树反推对应的具体指标——护岸存在比例适中、以非硬质化生态驳岸为主的护岸类型等特征更受人欢迎。同样的，在研究中，样本21属轻度工程化类型，评分较高，更受公众喜爱；

表 6：材质、物理环境与植被类型的最优尺度回归模型量化评分表

生态要素特征	名称	最优尺度回归模型量化评分
材质类型	近自然混合	-2.0
	轻度工程化	1.6
	工程化	-0.6
	重度工程化	-0.2
物理环境类型	近自然稳定	-2.2
	规整稳定	0.4
植被类型	无河道植被，河岸乔木高覆盖率且与河道相连接	0.8
	河道植被与河岸乔木中覆盖率	2.6
	河道植被高覆盖率，河岸乔木中覆盖率	-1.0
	河道植被与河岸乔木低覆盖率	-0.8
	河道植被低覆盖率，河岸乔木高覆盖率且不与河道相连接	0.1
	无河道植被，河岸乔木高覆盖率且不与河道相连接	0.6

表 7：受访者主体社会文化背景与 EAD 的检验统计量

主体社会文化背景	Y1: 年龄	Y2: 性别	Y3: 学历	Y4: 职业	Y5: 行业	Y6: 平均月收入	Y7: 户籍	Y8: 居住地	Y9: 生态环保经历	Y10: 住所与河流最近步行距离	Y11: 接触河流频率	Y12: 活动方式多样性
显著性	0.000***	0.461	0.001**	0.000***	0.000***	0.010*	0.483	0.000***	0.728	0.069	0.833	0.003**

注 * 代表 $p < 0.05$；** 代表 $p < 0.01$；*** 代表 $p < 0.001$。

表 8：受访者居住地与 EAD 的 K-W 检验成对比较

居住地	昆山市－上海市	昆山市－长三角其他地区	昆山市－非长三角地区	上海市－长三角其他地区	上海市－非长三角地区	长三角其他地区－非长三角地区
显著性	0.005*	0.496	1.000	1.000	0.000*	0.215

注 * 代表 $p < 0.001$。

样本12属近自然混合类型，评分较低，且公众感知差异较大（图2）。

2）物理环境类型方面，近自然稳定类型（SNS）的评分明显低于规整稳定类型（US），表明人们更加偏好规整的河流空间，根据URS方法的决策树反推具体指标——即偏好具有较少河道生境类型变化和较低自然断面比例等特征的城市河流空间。本研究中样本21较样本12更加规整，呈现出稳定与秩序感，因而评分更高（图2），更符合公众喜好。

3）植被类型方面，河道植被高覆盖率且河岸乔木中覆盖率（HVMT）、河道植被与河岸乔木低覆盖率（LVLT）的评分明显低于河道植被低覆盖率，河岸乔木高覆盖率且不与河道相连接（LVHTdisconn）、无河道植被，河岸乔木高覆盖率且不与河道相连接（UVHTdisconn）和无河道植被，河岸乔木高覆盖率且与河道相连接（UVHTconn），而河道植被与河岸乔木中覆盖率（MVMT）的评分最高。总体而言，人们偏好适中或相对较低的河道植被覆盖率与较高的河岸乔木覆盖率，根据URS方法的决策树反推对应的具体指标——乔木覆盖复杂度较高、乔木数量特征适中等。本研究中，样本21河道植被与河岸乔木中覆盖率，景观效果好；样本12河道遍布绿萍，河道植被高覆盖率，河岸乔木中低覆盖率，呈现缺乏管理之感。样本21较样本12评分高（图2），更受公众喜爱，佐证了回归模型的量化评分。

表 9：受访者居住地的 EAD 均值

居住地	昆山市	上海市	长三角其他地区	非长三角地区
生态审美偏差平均值	0.494	0.417	0.454	0.495

表 10：受访者部分主体社会文化背景与 EAD 双变量 Spearman 检验结果

主体社会文化背景		Y1: 年龄	Y3: 学历	Y6: 平均月收入	Y12: 活动方式多样性
Spearman 相关性分析	相关系数（r）	0.214	–0.228	–0.091	–0.189
	显著性	0.000*	0.000*	0.041	0.000*

注 * 代表 $p < 0.001$。

3.3.2 典型设计组合

在空间设计实践中，通常以审美偏好的评价结果作为衡量某一项目审美价值的重要指征。城市河流生态修复的生态审美对象是不同客体生态要素特征类型的组合（图4），通过材质类型、物理环境类型和植被类型之间的选择与组合促进生态价值与审美价值融合，是使城市河流空间综合效益最大化的有效空间手段。在生态修复实践中，应优先选择生态价值和审美价值高的组合类型；在条件受限情况下，可依据河流空间的主要功能需求与场地特点进行价值让渡或结合工程技术、设计手法及社会途径缓和并转换价值冲突的空间特征[45]。具有较高吸引力的城市河流空间客体生态要素应具备如下特征：1）采用轻度工程化、非硬质化的护岸形式；2）避免大量河道环境类型变化和自然断面，营造规整稳定的物理环境；3）河岸乔木覆盖率较高，植被类型多样、复杂且富有变化。

3.4 主体社会文化背景影响特征

为进一步探究主体社会文化背景导致的生态审美偏好差异，以及此偏差产生的影响，本研究计算客体生态要素特征经URS综合评价后结

果与生态审美偏好平均值（EAV）二者归一化后差值的绝对值以此作为生态审美偏差（Ecological Aesthetic Deviation，EAD）。EAD的大小表征了生态形态学（Ecomorphology）质量评价结果与公众生态审美偏好程度的差异程度，即EAD越大，公众生态审美偏好与河流空间的生态质量差异越大。

研究对主体社会文化背景与生态审美偏差（EAD）进行Kruskal Wallis（K-W）或Spearman非参数检验，结果表明（表7）：年龄（Y1）、学历（Y3）、职业（Y4）、行业（Y5）、平均月收入（Y6）、居住地（Y8）和活动方式多样性（Y12）的结果可导致EAD（$p<0.05$）的差异显著，而受访者的性别（Y2）、户籍（Y7）、生态环保经历（Y9）、住所距河流最近步行距离（Y10）和接触河流频率（Y11）的结果对EAD无显著影响。对居住地与EAD进行K-W检验，发现昆山市与上海市的受访者和上海市与非长三角地区的受访者间的EAD差异显著，而其余不同居住地组合的受访者EAD趋于一致（表8）。在表9中，居住于上海市的受访者EAD最低，其余地区受访者EAD相对较高，可以推测近年来上海将生态纳入城市河流空间的建设考量中，强调其生态价值，公众在潜移默化中接受到生态教育，促进了当地居民生态审美的提高。

研究进一步提取4个存在显著差异表现的定序、定距变量进行Spearman相关性分析（表10）：年龄（Y1）（r=0.214）与EAD呈正相关。学历（Y3）（r=－0.228）、平均月收入（Y6）（r=－0.091）和活动方式多样性（Y12）（r=－0.189）与EAD呈负相关，即年龄越小、学历越高、平均月收入越高、活动方式越多样，受访者EAD越小。因此，强化生态教育并增加活动方式多样性可促进公众对生态美的理解与感知。

4 结论与实践启示

研究通过“生态审美偏好”概念的界定，探究了公众对城市河流空间的生态审美偏好，在三重框架的生态审美偏好影响机制模型的基础上，以江苏省昆山市24个典型河段作为研究对象，通过相关性分析与最优尺度回归模型，解析了城市河流空间生态审美偏好的影响因子与作用规律。

研究结果表明，总体上影响生态审美偏好的要素依次为生态意识及知识水平、客体生态要素特征和主体社会文化背景。研究结果对城市河流空间生态修复实践的启示如下：

1）以促进河流健康为导向，在城市河流空间生态转型过程中突破原有美学范式，将生态要素纳入审美评价范畴；在进行生态修复时，优先选用生态价值与审美价值均较高且具有高吸引力的河流空间对应的客体生态要素特征（如轻度工程化的河段材质、规整稳定的物理环境和高乔木覆盖的植被类型）优化物理空间，在改善河流空间生态品质的同时，提升河流空间的审美价值以及其生态系统服务的综合效能。

2）以提升审美体验为导向，丰富公众对河流空间生态系统服务的感知体验，引导公众形成不同于传统审美的生态审美体验。若生态需求与审美需求矛盾，则应根据场地生态或审美需求的优先级合理让渡部分价值，结合生态工程技术手段进行空间优化（如营建多层复合护岸），在保护生态环境的同时提升审美体验，权衡河流空间的不同价值关系。

3）以优化价值培育为导向，尊重公众生态审美偏差的现实意义，短期内适度保留符合传统审美的空间设计方式，加强生态教育（如倡导“野草”“野趣”之美），促进中长期公众生态意识与知识水平的提高，引导河流空间生态与审美价值从权衡走向协同，为河流空间可持续发展提供内生动力。

本研究对生态审美偏好的影响机制及具体实践探索方面仍存在一定不足。在模型构建中，存在多种问题，如影响因子不够全面、现有受访者无法全面反映公众的偏好特征，以及URS方法未能完全适用于中国河流空间的生态价值评价。由于URS方法最初以英国城市河流为样本进行研究，且中国生态修复实践起步较晚、河流人工化程度高，因此中国河流空间的研究与此方法适配程度或许仍有不足。未来可通过更多实证研究检验其合理性，或针对中国城市河流空间景观的具体情况适当调整，如增加指示物种生境因素的考量，以及调整适宜的河流评价分段长度等。

图 1. 针对城市河流空间的生态审美偏好三重框架
图 2. 昆山市河流空间河段样本分布图
图 3. 生态审美偏好问卷调查结果箱形图
图 4. 城市河流空间生态修复中客体生态要素特征组合类型与应用