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Aoshima, Ippei

Nakao, Ryohei

Minamoto, Toshifumi

Ushimaru, Atushi

Sato, Masayuki

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Heterogeneous preference for biodiversity in Japanese urban blue spaces based on people's nature experiences: Analysis using eDNA and satisfaction data

Ippei Aoshima [a,*], Ryohei Nakao [b], Toshifumi Minamoto [a], Atushi Ushimaru [a], Masayuki Sato [a,c]

[a] Graduate School of Human Development and Environment, Kobe University, 3-11 Tsurukabuto, Nada-ku, Kobe City, Hyogo 657-8501, Japan
[b] Graduate School of Sciences and Technology for Innovation, Yamaguchi University, Tokiwadai 2-16-1, Ube, Yamaguchi 755-8611, Japan
[c] Advanced Research Center for Well-being, Kobe University, 3-11 Tsurukabuto, Nada-ku, Kobe City, Hyogo 657-8501, Japan

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ABSTRACT

This study focused on rivers as an urban blue space and investigated how urban residents perceive the biodiversity of rivers around their homes to understand whether people's evaluation of biodiversity changes depended on the extent of their nature experiences. Quantitative data measured by the environmental DNA method were used as an indicator of biodiversity, while urban residents' perceptions of the river and their experiences of nature were ascertained by conducting a social survey. A regression analysis of 312 responses of people living in the catchment areas around 20 rivers showed that for participants with more childhood nature experiences, their satisfaction with their neighborhood waterfront areas tended to increase as river biodiversity increased. However, for those who have had fewer childhood experiences with nature, an increase in biodiversity resulted in lower satisfaction with waterfront areas. These results indicate that modern urban residents with little experience with nature tend to prefer concrete paved rivers for their recreational value and walkability rather than rivers with high biodiversity.

1. Introduction

Since Millennium Ecosystem Assessment [27] highlighted the importance of ecosystem services, several studies have analyzed how these services increase human well-being [3,16]. The critical importance of ecosystem conservation for humans is now widely recognized [10]. In particular, urban ecosystems are receiving increasing attention, given today's rapid urban population growth [5,26] and because they contribute to the mental health of residents in their stressful city lives [2,14].

The natural environment can be broadly divided into green and blue spaces, both of which are also present in urban areas. Although the number of papers on green space is larger than that on blue spaces, scholars have started evaluating the ecological resources present in urban blue spaces in recent years. For example, urban residents have reported that walking beside rivers and lakes can provide spiritual healing and enhance their sense of well-being through recreational activities, such as fishing and camping [8,22]. Blue spaces are increasingly recognized as an important factor in improving urban residents' quality of life [25,41]. Urban planners have the potential to improve the residents' quality of life by creating blue spaces in the urban area.

Studies have shown that the richer the biodiversity surrounding them, the more positive impacts urban ecosystems have on humans [9,23,33]. Carrus et al. (2015) evaluated biodiversity in Italian urban greens space by establishing a panel of 15 independent experts from the urban forestry sector and found that the richer the biodiversity, the better the self-reported well-being of the residents. Dennis and James (2016) evaluated differences in vegetation in urban green spaces in England through careful field surveys and found a high degree of synergy between site use and biodiversity. However, the lack of research on urban biodiversity, especially in blue spaces, can be attributed to the difficulty in quantifying it [45]. Observing and ascertaining the number of species inhabiting a field is a time-consuming process. In recent years, however, the environmental-DNA (eDNA) metabarcoding method has emerged as an innovative method to easily determine the biodiversity in blue spaces broadly [6]. Together with conventional social assessments, this method has also enabled scholars to analyze people's attitudes and reactions to blue-space biodiversity, which have been difficult to examine in the past.

* Corresponding author.
E-mail address: ippei_ao@yahoo.co.jp (I. Aoshima).

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In valuation research on urban ecosystems, the declining nature experience of urban residents is considered problematic [42]. Urban residents' mental health and well-being have been negatively affected by reduced opportunities to interact with nature, and their willingness to conserve biodiversity and emotional affinity toward nature have declined [11,35,38,43]. This decline in urban residents' awareness of nature conservation may lead to a vicious cycle, making it more difficult to conserve and create natural environments in urban areas, and further reducing people's nature experiences [37,44]. This decline can degrade ecosystem services, quantitatively and qualitatively, which, in turn, can reduce urban residents' well-being.

In cities, ecosystem disservices are more easily recognized by residents than positive ecosystem services [15]. This is also because of the heterogeneity of people's preferences in the city. What may be a positive ecosystem service for one person may be viewed as a disservice by another [1]. Soga et al. [43] surveyed elementary school students in Tokyo and found that children who visited riverbeds and green spaces less frequently had lower affinities for familiar creatures. These studies indicate that urban residents with reduced nature experiences may no longer desire a natural environment around their homes. This disincentivizes the development of natural environments in the urban areas around them, even if urban ecosystem services enhance their well-being. Research on how urban residents perceive the nature in their neighborhoods is important for designing the cities they want, but not enough research has been conducted in this area.

Therefore, this study investigated how urban residents perceive the biodiversity of these blue spaces. Specifically, this study focused on how neighborhood residents' satisfaction with their neighborhood waterfront area varies with the amount of biodiversity in the river. Previous studies have investigated urban residents' preferences for the natural environment and living organisms by asking direct questions such as, "Do you like living organisms?" However, this study used quantitative biodiversity data for each river, measured by the eDNA method, to analyze its impact on residents' satisfaction with the neighborhood waterfront area. By asking about their satisfaction levels rather than whether they like organisms, enables researchers to analyze whether urban residents would be open to having more biodiversity around their homes. This is because, some people may like living organisms but may not want to actually have a highly biodiverse environment near their residence. Therefore, choosing areas with rivers around the participants' homes as a research setting is of tremendous significance.

In addition, this study focuses on the impact of the participants' reduced nature experiences on their natural environmental assessment. The experience of nature is especially relevant to this study, given that urban residents with a reduced experience of nature have a lower emotional affinity toward nature. Therefore, residents' perception of the natural environment around their homes is likely to change depending on the extent of their experiences with nature. Fisher et al. [12] found that the degree to which waterways contribute to the residents' subjective well-being is greater when waterways are perceived as more natural than artificial. However, this study was conducted in Georgetown, the capital of Guyana, which is surrounded by a lush nature and not in a large city. Contrary Fisher et al.'s [12] findings, urban residents with reduced nature experience may prefer artificial rather than natural elements around them. Therefore, this study tests the hypothesis that the more extensive someone's nature experience is, the more positive is the relationship between satisfaction with the urban waterfront area and river biodiversity.

Thus, considering existing research and its gaps, this study analyzes whether the impact of biodiversity on residents' satisfaction with waterfront areas varies depending on the extent of their experiences with nature. Given rapid global urbanization, clarifying how urban residents perceive the natural environment as a source of ecosystem services is extremely meaningful for planning the future of our cities.

2. Study area

This study focuses on 20 rivers flowing through Kobe, Ashiya, and Nishinomiya cities in Hyogo Prefecture, Japan. This area is part of the Kinki-region, the second-largest megacity in Japan. Fig. 1 provides a detailed view of the study area. As of 2016, when the survey was conducted, Kobe (552 km^2) had a population of 1.537 million, Ashiya (18 km^2) had 95 thousand, and Nishinomiya (100 km^2) had 488 thousand [19]. Based on the population density, this area is highly urbanized and populated. In the three cities and towns covered by this study, the average annual income per taxpayer in 2016 was 3.72 million yen, compared to a national average of 3.21 million yen [28].

To the north of the study area lies Mt. Rokko, which stretches approximately 30 km from the east to the west. Its highest point is 931 m above sea level, and the ridges running east to west are approximately 700–900 m high. The water flowing out of this mountain drains through rivers in the urban area to the Seto Inland Sea in the south. The distance from the ridgeline to the coast was the shortest in Tarumi Ward, Kobe City, the westernmost part of the target area, at approximately 4 km, and the longest in Nishinomiya City, the easternmost part of the target area, at approximately 10 km [29]. The area between the ridge to the sea has almost no flat land and steep slope.

Mt. Rokko was designated as a national park in 1956 because of its rich nature and recreational functions, and is a valuable place with a rich natural ecosystem despite its proximity to the city. This mountain range is home to more than 100 bird and 1,700 plant species, many of which are endangered and endemic species [32]. The rivers in this study, which run along the southern slope of Mt. Rokko, used to serve as a recreational area for urban residents to get in touch with nature. However, after the Great Hanshin-Awaji Earthquake (magnitude of 7.3 ML) occurred in January 1995, many rivers were damaged. After the disaster, revetment work using masonry and concrete retaining walls was conducted, and based on the lessons learned from the disaster, rivers were made disaster-resistant. Meanwhile, in some places, trees were planted along rivers and parks were established [17]. Considering this background, different rivers have different levels of biodiversity, making this an appropriate area for analyzing the impact of biodiversity on the residents' valuation of rivers.

3. Methodology

3.1. Data on eDNA

This study analyzes the relationship between 20 rivers and urban residents living in catchment areas surrounding these rivers. The 20 catchments shown in Fig. 2 are identified based on the Geographic Information System (GIS) data published by the Ministry of Land, Infrastructure, Transport, and Tourism [29]. As this study aims to analyze the impact of river biodiversity on people's satisfaction with waterfront areas surrounding these 20 rivers, it is preferable that conditions other than biodiversity do not differ significantly when comparing the 20 rivers. In this respect, the study area is appropriate both geographically, with a similar topography from east to west, and socially, with an insignificant variation in population density and resident demographics. The 20 rivers used as case studies in this study are all classified as "second class rivers" by Japanese standards, and do not differ greatly in size [21]. Most of these rivers are 3–15 m wide, are familiar to residents, and blend into their living space. The river length data in Table 1 were obtained from the Hyogo Prefecture [20] and the Hyogo Prefectural Land Development Department [18].

The biodiversity of the rivers were ascertained using eDNA metabarcoding, which is an exhaustive method to detect the taxa of a species such as fish or mammals [6]. To perform eDNA metabarcoding on fish, first, the eDNA collected from an environment such as river water is amplified by polymerase chain reaction (PCR). The DNA sequence can then be determined using an instrument called a next-generation

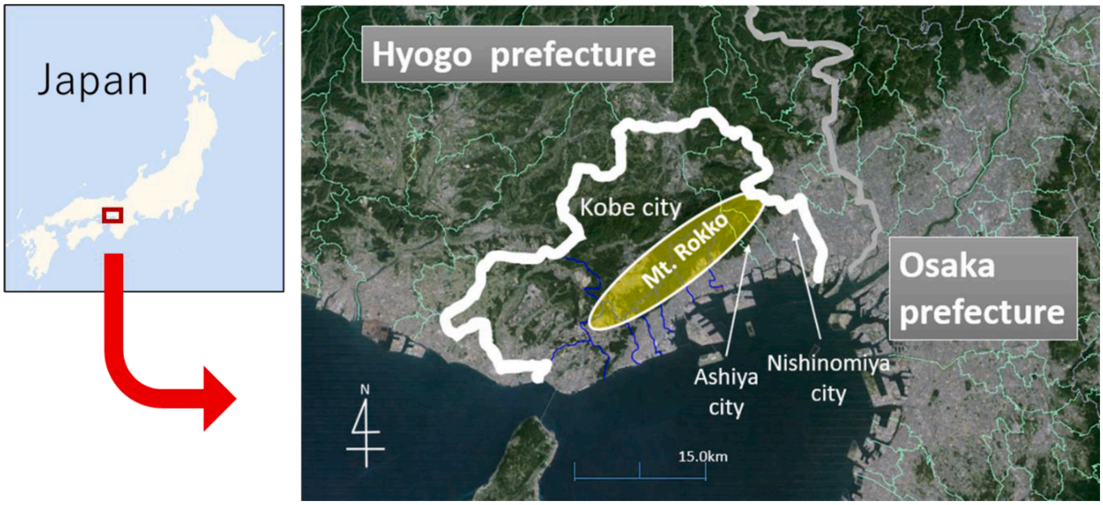

Fig. 1. Location of the study area.

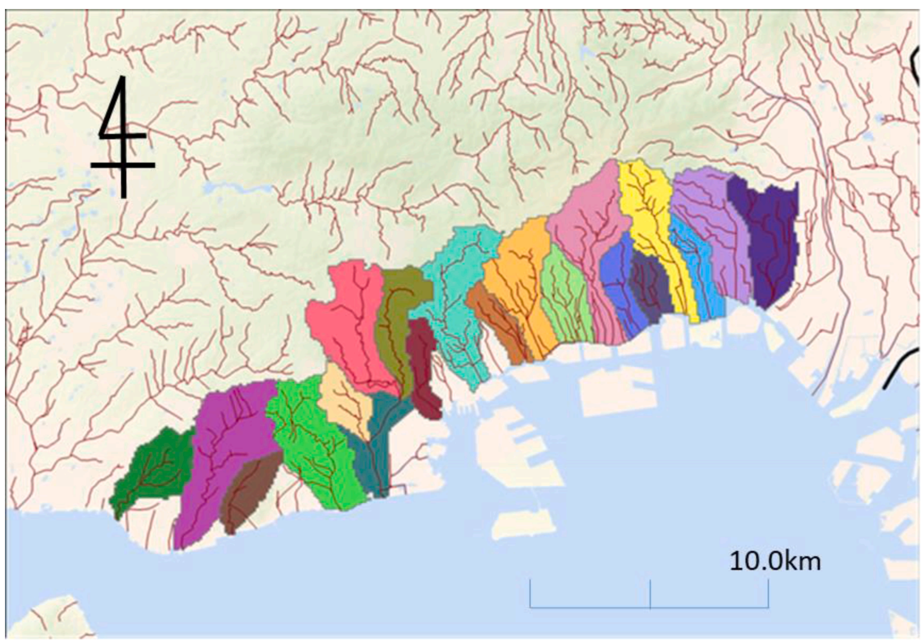

Fig. 2. Location of the 20 catchment areas.

sequencer to estimate the species of fish inhabiting the study area. Determining the DNA sequence enables us to determine which fish species live in the rivers simply by collecting approximately 1 L of environmental water at the study site, without using fishing gear, such as hand nets or cast nets, as is done in conventional capture surveys. Studies on biodiversity monitoring using eDNA metabarcoding have been conducted worldwide, focusing on rivers, lakes, coastal areas, and open oceans [4,31,34]. In addition, although this study focuses on fish, the river water includes various targeted taxonomic groups, including amphibians, mammals, birds, and crustaceans [24,36,46,47]. The focus on fish is significant because previous studies have shown that fish diversity is an important indicator of diversity around a river [40,39].

This study used our eDNA data, measured at 90 sites in 20 rivers flowing through the study area, between October and November 2016. At each study site, 1 L of river water was collected using a polyethylene bucket, which was brought back to the laboratory. After filtering the water samples, the filter papers were kept frozen. DNA was then purified from the filter paper and the resulting DNA sample was used for eDNA metabarcoding. As this study targets fish, a primer set called MiFish [31] was used to comprehensively amplify the eDNA of the fish in the DNA samples. The DNA sequences of the fish in each sample were determined using a next-generation sequencer (MiSeq). Dedicated analysis software (MiFish pipeline), [30] was used to identify the fish species corresponding to the DNA sequences in each sample, which helped estimate the number of fish species present at each study site.

For each river, measurements were taken at three or more points: upstream, midstream, and downstream. However, because this study is focused on the relationship between rivers and neighborhoods, measurements were not taken in upstream areas where few people live. Consequently, the mean and median values of fish species for each river measurement site were both 4.5. As shown in Table 1, the 312 survey respondents resided across 20 river catchments, with a mean (median) value of 15.6 (15.5) participants residing in each catchment.

Biodiversity was quantified in terms of the average number of species at several measurement points along each river. For example, if eDNA is measured at three sites, the biodiversity level of that river was calculated

Table 1
Biodiversity points in each river.

River	Length (km)	Analyzed residents of each watershed	Biodiversity point
Higashi River	5.29	35	11.5
Araiebisu River	1.86	31	9.0
Miya River	3.07	15	10.7
Ashiya River	4.54	9	11.4
Takahashi River	1.41	16	10.7
Tenjou River	2.51	10	5.8
Sumiyoshi River	3.60	17	9.2
Tenjin River	2.88	31	6.7
Toga River	1.79	19	5.2
Saigou River	2.32	12	6.0
Ikuta River	1.79	16	14.6
Uji River	2.27	3	9.8
Shinminato River	4.70	17	15.8
Karumo River	0.44	3	6.5
Ishii River	2.20	11	4.0
Tennoudani River	4.12	3	4.5
Myouhouji River	6.98	19	4.3
Shioyadani River	3.46	11	7.5
Hukuda River	7.41	21	7.0
Yamada River	3.84	13	7.7
Median	2.98	15.5	7.6
Averege	3.32	15.6	8.4
Total	66.48	312	167.7

as the total number of species identified at each site divided by three. Using the average values measured at multiple sites, rather than only at one site, allows us to capture trends in biodiversity across the river, rather than using local values. In addition, as this study focuses on biodiversity, we do not focus on the number of individuals per species, but only on the number of species.

Table 1 shows the biodiversity points in each river obtained from the eDNA measurements. Each river has an average of 8.4 fish species living in it. The most abundant species were freshwater fishes such as *Rhinogobius flumineus*, found in 70 of the 90 sites, followed by *Nipponocypris temminckii* and *Cyprinus carpio,* found at 64 and 49 sites, respectively. The *Thunnus albacares* was the most commonly found saltwater fish species (18 sites). As expected, pristine rivers had the higher biodiversity (Images 1 and 2 in Fig. 3), than artificial rivers paved with concrete (Images 3 and 4 in Fig. 3).

3.2. Data on social survey

To analyze the relationship between the biodiversity in the neighborhood river and urban residents' satisfaction, we utilized data from a social survey to determine urban residents' perceptions of and satisfaction with the natural environment. The data were extracted from an Internet-based survey targeting residents in December 2016. All the content of the surveys was prepared by the authors, and Nikkei Research prepared the response format, distributed it to the respondents, and compiled the data. Nikkei Research conducted the survey based on its own ethical standards, and in addition, the survey was ethically reviewed by the Research Ethics Review Committee of Kobe University, to which the authors belong (Review No. 132), to ensure that there were no ethical issues with the survey content and methods. To prevent a sampling bias, prefectural demographics such as population, sex, and age ratios were considered during the survey. Of the original 1,013 responses received for this survey, 465 were used for subsequent analyses after excluding respondents who did not provide their addresses and did not live in the 20 catchment areas. After excluding those who did not respond to the indicators that served as control variables, a total of 312 responses were included in the analysis. Table 2 shows the number and ratio of respondents classified by sex, age, and address. The respondents' addresses were identified at the Zip-code level. The 312 final respondents resided in 208 zip codes.

3.3. Model for estimation

Using the eDNA and social data introduced in the previous sections, the extent to which biodiversity contributes to people's satisfaction with waterfront areas is statistically analyzed. Descriptive statistics for each variable, including the control variables, are presented in Table 3. The dependent variable is the respondents' satisfaction with their neighborhood waterfront area, which was captured using the question, "Are

Fig. 3. Images of the rivers.

Table 2
Demographic statistics for survey respondents.

			Obs.	Ratio(%)
Sex	Male		180	58%
	Female		132	42%
Age	20 s		27	9%
	30 s		58	19%
	40 s		83	27%
	50 s		78	25%
	60 s		49	16%
	70 s		11	4%
	80 s		6	2%
Address	Kobe city	Higasinada ward	61	20%
		Nada ward	44	14%
		Hyogo ward	10	3%
		Chuo ward	19	6%
		Nagata ward	14	4%
		Suma ward	24	8%
		Tarumi ward	37	12%
		Kita ward	13	4%
	Ashiya city		26	8%
	Nishinomiya city		64	21%

Table 3
Descriptive statistics.

Variable	Unit	Mean	Std. Dev.	Min.	Max.
Satisfaction with waterfront area	Index	5.41	2.22	0	10
Female dummy	–	0.423	0.495	0	1
Age	Year	48.3	13.7	20	87
Income	10,000-Yen	379	343	100	1750
Distance to the river	Meter	219	166	2.32	898
Distance to the sea	Meter	1941	1300	186	6490
Frequency of visits (to blue spaces)	Index	1.55	0.772	1	4
Knowledge of the river	Index	20.6	5.17	6	30
Nature experience in the past	Index	0.516	0.501	0	1
Biodiversity point of river	Species	8.74	3.20	4.0	15.8

you satisfied with the waterfront area within a 10 min walk from your home where you can go and play?" The participants responded on a scale ranging from 0 (extremely unsatisfied) to 10 (extremely satisfied). The subjective measures of satisfaction have been used in numerous previous studies as dependent variables when conducting a regression analysis [7,13].

The main independent variables in this study are "river biodiversity" and "nature experiences." River biodiversity data were obtained using the procedure described in Section 3.1. The respondents' level of nature experiences was ascertained through the social survey. Using responses obtained from the social survey, a dummy variable was created using the procedure described below. Respondents were asked to recall their experiences relating to nature prior to attending junior high school, "How often did you experience picking, breeding, or raising animals and plants?" "How often did you experience playing in mountainous, river, or ocean environments?" "How often did you experience visiting relatives or friends in the countryside with natural environments?" "How often did you experience seasonal events such as *Setsubun*, *Higan*, and *Sekku* at home?" They responded to these four questions on a scale ranging from 1 (not at all) to 4 (often). Those who responded positively (3 or 4) to all four questions were scored 1, and all others were scored 0. For this dummy variable, 161 respondents scored 1, while 151 scored 0. Similar indicators have been used in previous studies as factors that can influence people's perceptions of and attitudes toward the environment [38].

In addition, the impact of "nature experiences" on the relationship between "satisfaction with the neighborhood waterfront area" and "river biodiversity," was analyzed by incorporating a cross term between "river biodiversity" and "nature experiences" into the model. Prior research suggests that the richer a person's experiences with nature in their childhood, the more they will love nature as an adult [43]. Accordingly, we assume that the more extensive someone's nature experience is, the more positive is the relationship between satisfaction with the waterfront area and river biodiversity.

We use the following control variables in this study. First, as we expect the respondents' satisfaction with blue spaces to increase with the increase in the frequency of their visit to such spaces, we use a four-point scale of frequency as an independent variable. Next, as the distance to blue spaces is another important factor, the GIS-measured values of the linear distance from the residence to the river and to the sea are also included in the regression analysis. Knowledge of the river can also influence river satisfaction. Therefore, we prepared six questions regarding river functions and obtained the index level of knowledge of river functions by simply summing the five levels (5: deep knowledge, 1: lack of knowledge) of subjective knowledge on each function. Diener [7] reported that factors such as gender, age, and income can influence satisfaction indices. Hence, these indices are also employed as independent variables in this study. Gender is a dummy variable with 1 for females and 0 for males.

The estimation model is shown in equation (1). As this indicator is an ordinal scaled variable, we apply the ordinal probit model for the estimation. X_k is an independent variable, which is the quantified biodiversity of a river as ascertained by eDNA methods, as well as the control variables, such as socioeconomic characteristics of the survey respondents. i is the individual to be surveyed, ε is the error term, and α and β are the parameters to be estimated by regression analysis.

$$Y_i = \alpha + \sum_{k=1}^{n} \beta_k X_{ki} + \varepsilon_i \tag{1}$$

4. Results

Before estimating equation 1, the correlations for each variable are shown in Table 4. Except for the cross term, the correlations between any variables do not exceed an absolute value of 0.5. Therefore, the problem of multicollinearity is negligible. There seems to be a high correlation between nature experience in the past and frequency of visits to blue spaces, but the absolute value is less than 0.1. Some previous studies have shown that people with more past nature experiences have more current contact with nature [37], but the correlation analysis do not show such a trend in this study. This may be partly due to the fact that urban blue spaces are surveyed in this study, but additional research is needed on this topic in the future.

The results of estimating Eq. (1) are presented in Table 5. The estimated model was an ordinal probit with 312 observations. The estimated model's pseudo R-squared is 0.0435, which is acceptable for a regression analysis with subjective indicators as dependent variables. All explanatory variables are significant except for age, income, and the distance from home to the sea. The coefficient for the female dummy variable was positive, indicating that women were more satisfied with the neighborhood waterfront area. General happiness and life satisfaction are also higher for women, which is consistent with Diener's [7] finding. The coefficient of the distance from home to the river was estimated to be negative, indicating that as expected, the greater the distance to the river, the lower the respondents' satisfaction with their neighborhood waterfront area. The coefficient for the frequency of visits to blue spaces was positive. This result was expected, because we assumed that those who are satisfied with blue spaces are likely to visit them more often. The coefficient for knowledge about the river was also positive.

As the model includes a cross term between river biodiversity and nature experiences, the coefficients of the three terms must be interpreted in a composite manner, which allows us to check whether the

Table 4
Correlation coefficients of variables.

	Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.
1.	Female dummy	1								
2.	Age	−0.131	1							
3.	Income	−0.470	0.132	1						
4.	Distance to the river	0.004	−0.002	−0.047	1					
5.	Distance to the sea	−0.054	−0.000	0.047	0.087	1				
6.	Frequency of visits (to blue spaces)	−0.040	0.125	0.079	−0.065	−0.047	1			
7.	Knowledge of the river	−0.077	0.176	0.117	−0.082	0.020	0.145	1		
8.	Nature experience in the past	0.012	0.079	0.030	0.008	0.075	0.069	0.123	1	
9.	River biodiversity (eDNA)	0.071	−0.020	0.003	0.020	−0.238	−0.071	−0.096	0.003	1
10.	Cross term (eDNA X Nature experience)	0.015	0.065	0.032	−0.006	−0.026	0.067	0.087	0.883	0.343

Table 5
Results of the regression analysis.[a]

Variable	Coef.	Std. Err.	t-value
Female dummy	0.30103**	0.13397	2.25
Age	−0.00004	0.00433	−0.01
Income	0.00005	0.00019	0.25
Distance to the river	−0.00064*	0.00035	−1.80
Distance to the sea	−0.00002	0.00005	−0.45
Frequency of visits (to blue spaces)	0.44933***	0.07909	5.68
Knowledge of the river	0.02371**	0.01169	2.03
Nature experience in the past	−0.72970**	0.34087	−2.14
River biodiversity (eDNA)	−0.06507**	0.02713	−2.40
Cross term (eDNA X Nature experience)	0.07946**	0.03661	2.17

[a] Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

impact of biodiversity on satisfaction varies depending on the amount of nature experiences. As shown in Fig. 3, this study focuses on the sum of the coefficients of nature experiences, river biodiversity, and the cross term of the two. As nature experience is a dummy variable, Fig. 3 distinguishes between the trends for those with rich and poor childhood nature experiences. The coefficient for river biodiversity is negative, suggesting that the higher the biodiversity, the lower the satisfaction with the waterfront area for those with poor natural experiences. However, the coefficient of the interaction between nature experiences and biodiversity is positive, and its absolute value is greater than the absolute value of the coefficient of river biodiversity. Thus, for those with rich nature experiences, the higher the biodiversity, the higher their satisfaction with the waterfront area. The coefficient of nature experiences is negative, and in Fig. 3, the vertical axis intercept for those with rich nature experiences is also negative.

As shown in Fig. 3, the sum of the coefficients of the above three variables (nature experience, river biodiversity, and their interaction term) are negative in almost all ranges. Negative values indicate that the combination of biodiversity and nature experiences negatively impact satisfaction. Theoretically, the horizontal axis intercept for those with rich nature experiences is 50.7. It indicates that the combination of biodiversity and nature experiences positively impacts satisfaction only when the biodiversity point exceeds 50.7. Note that the biodiversity point of 50.7 is not a realistic value, because even the river with the highest biodiversity measured in this study had a biodiversity point of 15.8, as shown in Table 1. Fig. 3 also shows the intersection of people with rich and poor childhood nature experiences when the biodiversity of the river was 9.18. This indicates that theoretically, people with poorer childhood nature experiences are more satisfied with the river when the river biodiversity is less than 9.18, whereas people with more childhood nature experiences are more satisfied with the river when its biodiversity is greater than 9.18. As the median biodiversity of the river in this study is 7.6, 9.18 is slightly above the median, as shown in Table 3.

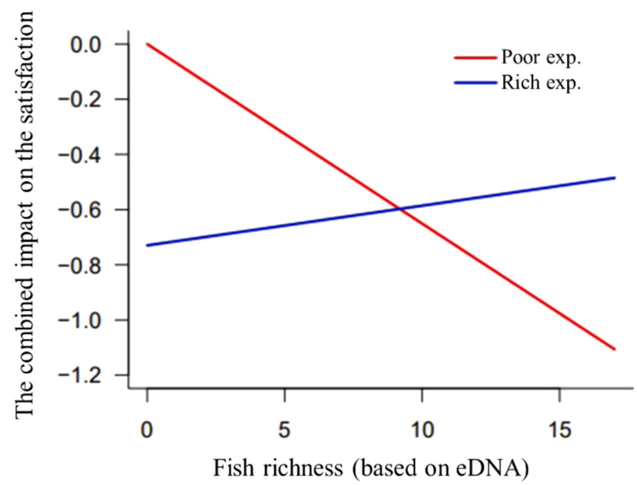

Fig. 4. The combined impact of the three variables (nature experiences, river biodiversity, and their cross term) on satisfaction with waterfront area.[1]

5. Discussion

First, the results suggest different effects of river biodiversity on satisfaction between people with rich and poor nature experiences. As presented in the hypothesis, the study found that people with fewer childhood experiences with nature tended to prefer rivers with lower biodiversity. Therefore, even if a river with high biodiversity is created in a residential area, it may result in lower satisfaction for those with limited childhood experiences with nature. For many residents living in large cities, blue spaces are used for feeling mentally refreshed [25,41] and are valued more for their convenience and recreation opportunities rather than for their biodiversity. Prior studies have shown that those with more nature experiences in childhood are more nature loving as adults [37]. Our results also suggest that childhood experiences with nature are important as a factor in forming preferences for nature in adulthood.

As shown in Fig. 4, people with rich nature experiences are not satisfied with the current biodiversity levels. Even when considering the rivers with the highest biodiversity in this study (at 15.8 points), the impact of river biodiversity on satisfaction with the waterfront area is negative. The number of fish species would have to be approximately triple for the river biodiversity to have a positive impact on satisfaction. Someone with a rich experience of nature will find it difficult to derive satisfaction from the biodiversity in their neighborhood's urban river. However, this does not mean that the biodiversity of urban rivers should be neglected; creating and preserving a rich natural environment is

[1] The vertical axis in Fig. 4 is the sum of the three coefficients, in other words, the combined impact of the three variables on satisfaction with waterfront area. The horizontal axis, fish richness, refers to river biodiversity as determined by the eDNA method. As childhood nature experience is a dummy variable, the two straight lines reflect two trends for those with rich and poor childhood nature experiences.

important because urban rivers are one of the few places where urban residents can interact with nature.

The target area of the study is a part of the megacities in Japan, and most of the rivers analyzed are paved with concrete, except in the upper reaches. While previous studies have shown that rivers rich in nature contribute to people's well-being in rural areas [12], this study focused on highly populated urban areas. Some rivers are paved with concrete but have walking paths and other facilities that allow neighborhood residents to engage in recreational activities, whereas others are overgrown with grass and sediment on top of the concrete, leaving no room for residents to enter. Rivers with bare concrete tended to have low biodiversity, whereas rivers with thick grass tended to have high biodiversity. Therefore, well-maintained rivers with high recreational capacity seemed to have lower biodiversity than wild rivers with low recreational capacity.

Previous studies have shown that creating biodiversity-rich natural environments in urban areas can greatly increase residents' life satisfaction [10]. However, this study suggests that rich biodiversity does not necessarily increase neighborhood residents' satisfaction. Depending on their experiences with nature, some residents might value a river more for its recreational capacity rather than its rich biodiversity. If this is the case, then it is desirable for rivers to have both rich biodiversity and recreational capacity. However, these two characteristics are often in a trade-off relationship. To preserve urban biodiversity, residents' understanding of biodiversity should be deepened through recreational activities on rivers. However, presently biodiversity conservation appears to be neglected in rivers that emphasize recreational capacity. One recommendation is to intentionally create both types of rivers separately so that residents can use the rivers according to their intended use. Further research is required to explore the ways in which the rivers' recreational capacity and biodiversity can be balanced by analyzing the relationship between these aspects.

6. Conclusion

This study found that the relationship between the biodiversity of blue spaces and neighborhood residents' satisfaction with waterfront areas varies significantly depending on the extent of their childhood nature experiences. Previous studies have shown that the decline in urban residents' nature experiences is a critical issue for the conservation of urban ecosystems, and this study reinforces the results of previous studies. However, many of these studies have analyzed the impact of reduced nature experiences on people's emotional affinity toward nature, not on their perceptions and feelings toward biodiversity. In this regard, this study focused on biodiversity measured quantitatively using the eDNA method. The model output shows that the relationship between biodiversity and satisfaction with neighborhood rivers is influenced by childhood nature experiences. This analysis shows that the decrease in nature experience lowers not only people's subjective emotional affinity toward nature, but also their objectively measured appreciation of biodiversity.

The dilemma facing policymakers and conservation experts is that while biodiversity positively impacts people's well-being and mental health, urban residents who have had little experience with nature in their childhood may not want a highly biodiverse natural environment around their homes. In the long run, this dilemma can be resolved by expanding urban residents' nature experiences and fostering an emotional affinity toward nature. However, encouraging residents to experience nature in urban areas is difficult, and given this decline in people's nature experiences has been happening for some time already. For instance, parents who have had little experience with nature are not likely to promote positive nature experiences for their children [42]. Thus, policymakers should strive to create a natural environment that those who derive low satisfaction from high biodiversity would want to visit with their children. However, as discussed in the Discussion section, too much emphasis on recreational capacity to attract people may lead to neglect of the natural environment's biodiversity. Thus, understanding how to strike a balance between these two aspects requires further research on the relationship between the urban biodiversity and urban residents.

It is important to note, however, that the results of this study do not provide definitive information on why rivers with lower biodiversity are satisfying for some residents. As mentioned above, there may be a trade-off between biodiversity and recreational capacity. A more detailed discussion of this issue would require quantification of recreational capacity, and analysis of its relationship with waterfront satisfaction. Although this study focused only on underwater biodiversity, it would also be useful to investigate biodiversity such as vegetation. If it becomes clear what factors contribute to the level of waterfront satisfaction, it will be possible to make more concrete policy recommendations regarding the creation of urban rivers.

CRediT authorship contribution statement

Ippei Aoshima: Conceptualization, Methodology, Formal analysis, Writing – original draft, Project administration. **Ryohei Nakao:** Conceptualization, Investigation, Resources, Data curation, Writing – review & editing. **Toshifumi Minamoto:** Conceptualization, Writing – review & editing. **Atushi Ushimaru:** Conceptualization, Writing – review & editing. **Masayuki Sato:** Conceptualization, Writing – review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: [Masayuki Sato reports financial support was provided by Japan Society for the Promotion of Science (JSPS)].

Data availability

The data that has been used is confidential.

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