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River Connectivity is Crucial for Safeguarding Biodiversity but May be Socially Overlooked. Insights From Spanish University Students

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The social value of natural aquatic ecosystems is very important to set management priorities. River connectivity is essential for the conservation of freshwater ecosystems because barriers alter both abiotic conditions and the biotic communities, compromising biodiversity; however, the appreciation of this river feature has been insufficiently considered in socio-environmental studies that are mainly focused on the acceptance of new dams. Here we used a willingness to pay approach to estimate the value of connectivity, native species, fish diversity (measured as functional diversity or as species richness), fish abundance and environmental quality in three groups of students of different educational background in Asturias (NW of Spain). As in other studies where they are more sensitive to environmental issues, educational sciences students would pay more to conserve and improve river conditions than students of other disciplines. Connectivity was the least valued river feature by students of educational and natural sciences, and the third (before biodiversity and fish abundance) by engineering students. We measured the same features on lowland reaches of four coastal rivers in the Bay of Biscay, and applied declared will amounts to model their appreciation. Differences between the river ranks obtained from functional diversity (that changes with non-native species) and species richness, and small differences between students of different disciplines in the gap between most and least preferred rivers arise from the model. This indicates the importance to involve diverse stakeholder sectors in decisions about rivers. The importance of river connectivity in the conservation of local biodiversity should be explained to general public, perhaps through environmental campaigns.

Keywords: fish diversity, fish abundance, willingness to pay, river connectivity, exotic species, public awareness 3

INTRODUCTION

Rivers are dramatically transformed to obtain energy and water supply for drinking and industrial uses (Malmqvist and Rundle, 2002). The construction of dams and reservoirs is necessary to exploit river resources. One of the main consequences of these infrastructures is that rivers' connectivity, an essential feature in streams and population ecology (Jansson et al., 2007), is interrupted. Connectivity disruption affects not only physical-chemical components in rivers (e.g., Leibowitz et al., 2018), but also community composition and diversity patterns (Altermatt et al., 2013). One of the most documented effects of river barriers is the obstruction of upstream access for many valued migratory fish species. European species such as the Atlantic salmon (*Salmo salar*), brown trout (*Salmo trutta*), European eel (*Anguilla anguilla*) and lamprey (*Petromyzon marinus*) have been threatened, especially upstream impassable dams where most populations have become extinct (e.g. Garcia de Leaniz, 2008; Holmquist et al., 2008; Limburg and Waldman 2009). Most studies about the impact of river fragmentation are focused on big impassable barriers (e.g. Winfield, 2016; Buddendorf et al., 2019), but small barriers, often not inventoried (Garcia de Leaniz et al., 2019), are important for many species. For example, the life cycles of benthic invertebrates and amphibians that use the river water in larval stages can be altered by small barriers that are otherwise passable for bigger species (Clauzel et al., 2015; Branco et al., 2017).

Su et al. (2021) identify river fragmentation and introduction of non-native species as the main drivers of biodiversity changes, especially functional diversity in temperate rivers whose fish biodiversity has changed the most. These two drivers, fragmentation and non-native species, are interrelated. In addition to the loss of upstream habitat, river wildlife is also impacted by flow alteration and abnormal sedimentation patterns both inside the reservoirs and downstream, significantly deteriorating water quality (e.g. Fernandez et al., 2019), and facilitating the establishment of exotic and invasive species (Clavero et al., 2004; Johnson et al., 2008; Santos et al., 2017). For this, large reservoirs created by big dams are considered to be reservoirs of exotics (Letnic et al., 2014; Santos et al., 2017). Moreover, since native biodiversity protects against biological invasions (Kennedy et al., 2002), when barriers impede the passage of species and make native biodiversity decrease, exotic species may find empty niches and get established in the sectors affected. Exotic species are a menace for native biodiversity as competitors for habitat and food resources, reducing their habitat and forcing them to move upstream (e.g. Milardi et al., 2018). Lowland areas of fragmented rivers are of great concern, since fish communities tend to be there taxonomically homogenized, with native species not contributing much to diversity (Gavioli et al., 2019).

The impacts caused by the fragmentation of rivers underline the importance of restoring rivers' connectivity. To incorporate connectivity restoration in conservation programs, it is crucial to improve societal awareness about the importance of maintaining continuous rivers (Couvet et al., 2008). However, so far studies have been focused on the public acceptance of new dams and other river infrastructures in relation with energy and water supply (Cohen et al., 2014; Boyé and De Vivo, 2016; Kellner, 2019; Schulz et al., 2019), rather than on the consideration of connectivity. Reservoirs provide hydroelectric power, reducing the dependence from fossil oils, and provide water supply and recreation that are important services for the population and increase their public acceptance (Arabatzis and Myronidis, 2011). Contrasting attitudes toward dams can be briefly described as economically (favorable to dams) or ecologically (opposed to dams) oriented views of water policies (Schulz et al., 2019). These authors found that those who hold more ecological and cultural values prefer to keep some rivers free of dams.

Here we will explore attitudes towards river connectivity based on people's willingness to pay for it. In an effort to increase the public appreciation of nature, two decades ago Costanza et al. (1997) estimated the total value of ecosystem services (ES) in 33.3 trillion (10^{12}) $US/year. In a further revision, Costanza et al. (2014) found water ecosystem services to be three times higher. Attempts to assign a value to water ecosystem services have followed diverse approaches often considering both ecological knowledge and socioeconomic issues (Hackbart et al., 2017). A method of economic quantification of a natural good is based on the willingness of the users to pay for it, or willingness-to-pay (WTP). This method has been applied in different assessments (e.g. Moreno-Sanchez et al., 2012; Nicosia et al., 2014; Siew et al., 2015; Resende et al., 2017). It has been demonstrated that putting an economic value to ecosystem services serves to support the conservation of certain areas (Resende et al., 2017).

On the other hand, there are differences among users for the appreciation of ecosystem services. For example, owners of recreational houses will pay more for improved water services than smallholder peasants in Colombia (Moreno-Sanchez et al., 2012); high-income visitors will pay more for the conservation of wetlands in Malaysia than visitors of low income (Siew et al., 2015); young females are significantly more willing to pay for restoration of a degraded coastal watershed of New Jersey than old males (Nicosia et al., 2014). Thus heterogeneity of users has to be taken into account when using WTP to estimate the social appreciation of ES. This issue has been much studied in university students. Environmental attitudes differ among students of different disciplines. For example, students from business courses have limited awareness about environmental issues (Cezarino et al., 2018); agriculture students obtain higher scores in pro-environmental attitudes than psychology students (Biasutti and Frate, 2017), and those of natural sciences like Zoology have more positive attitude towards sustainability than those of health sciences like Human Nutrition (Shephard et al., 2015). Research often focused on students of educational sciences and pre-service teachers because they will teach environmental values to future generations (e.g. Tuncer et al., 2009; Kukkonen et al., 2018). Tuncer et al. (2009) found that, despite relatively low environmental knowledge, pre-service teachers (students in formation to be school teachers) have positive attitudes towards the environment and high concern about environmental problems. Kukkonen et al. (2018) found that students from educational sciences would support sustainable actions in a larger extent than students from other disciplines like engineering.

A tool widely used to support water resource management decision-making is modeling (e.g. Black et al., 2014). The variety of models used in water management is enormous. They may be built around scenarios—predicted states representing alternative conditions under different assumptions (Mahmoud et al., 2009). Many models integrate biophysical information of hydrological systems and stakeholders' points of view, like those of farmers and managers in CATCHSCAPE model in Thailand (Becu et al., 2003). Opinions of stakeholders have been taken into account to validate models of water demand in Australia (Sarker and Gato-Trinidad, 2017), to choose modeled management options to adapt to climate change in South Europe (Verkerk et al., 2017), or to plan mitigation actions under different scenarios of land use changes in a river of Philippines (Kumar et al., 2020). In Switzerland, expert-based modeling combined with user preferences (determined from user surveys) has been used to map recreation suitability of watercourses (Rabe et al., 2018). Here we will combine biophysical characteristics of rivers evaluated by experts with preferences of potential users in a simple model to explore river conservation priorities.

The main objectives of this study were: 1) To estimate the public value of different elements of river ecosystems, including connectivity; and 2) To model conservation priorities based on public values, applying the estimated relative WTP to objective river features. We focused on lower reaches that are the most affected by river fragmentation (Gavioli et al., 2019), and asked university students of different backgrounds (including students of educational sciences that will influence the environmental values of future generations) for the monetary quantities they would pay to improve five river features that provide important river services. Two river services are related to the habitat and overall environmental quality (river connectivity and habitat quality) and three related to the fish community (quantity of fish, number of native fish species and total fish diversity). We focused on fish because fish fauna is highly appreciated in Europe (e.g. Kochalski et al., 2019). Regarding river habitat, barriers disrupt the connectivity for fish, canoeing and kayaking, but environmental quality is not only aesthetic but is important for ecosystem health and determines ecosystem services related to watering, bathing and other uses. We expected that students would pay more to improve habitat quality than river connectivity (Hypothesis 1). The study region was Asturias (North Spain), where main public uses of lowland river zones are sport fishing (principally of salmonids) and recreational activities like canoeing, kayaking and other sports. Strict ban periods and quotas of sport catch are determined each year, based on population size of fishable species (see the normative for 2021 in the Official Bulletin of Asturias Principality https://sede.asturias.es/bopa/2020/10/29/2020-08730.pdf). Therefore we expected that students will prefer to pay for more fish in the river and native species than to pay for general fish diversity (Hypothesis 2). From the expectations in hypotheses 1 and 2, the least polluted river that contains more fish will be the most appreciated thus prioritized for conservation (Hypothesis 3).

The value that people give to ecosystem services may depend on their educational background, and students of educational sciences have generally a high environmental sensitivity (Tuncer et al., 2009; Kukkonen et al., 2018). Since ecologically oriented people prefer connected rivers (Schulz et al., 2019), we expected that students of educational sciences give more value to all ecosystem services, in general, than students of other disciplines (Hypothesis 4).

MATERIALS AND METHODS

Ethics Statement

Volunteers agreed to participate in the study and signed the informed consent for the use of their answers in research. The study was approved by the competent Ethics Committee of Asturias Principality with the permits of reference number 99/16 for the ecological analysis and 101/16 for the social study.

Willingness-to-Pay Survey

Willingness-to-Pay Questionnaire

The five river features considered were introduced in a simple WTP questionnaire addressed to non-specialists, thus avoiding too technical words like population size or river connectivity. The questions were:

How many euros, up to 100, would you allow to be added to your annual taxes (or donate annually if you are not a tax-payer) for each of the following actions?

1) Build migration passages to facilitate fish movements along the river (= *river connectivity*).
2) Conserve native fish (= *number of native species*)
3) Enhance fish populations for angling (for example with stocking = supportive breeding) (= *population size*)
4) Conserve all fish species in the river (= *fish diversity*)
5) Improve river environment (like restoring damaged areas) (= *habitat quality*).

The questionnaire was previously validated by a group of 20 experts in the subject: PhD students in Environmental Sciences and Biology participating in a workshop about river connectivity. The content reliability was assessed asking them if the questions were relevant for the research purpose. The Lawshe test was employed to assess content validity ratio (CVR) from the following formula:

$$CVR = [(ne - N) - N/2] \quad (1)$$

where ne was the number of experts that answered "yes, relevant", and N = total number of experts.

Survey Procedure

The validated questionnaire was submitted, in writing and in Spanish language, to students of different disciplines in the University of Oviedo (Asturias, Spain). Disciplines were: educational sciences (Degree in Pedagogy with total number of students $N = 363$), natural sciences (Degree in Biology $N = 480$), engineering (Forestry & Environmental Engineering $N = 121$). The total number of students in each degree can be consulted in the Transparency Portal of the University of Oviedo (https://transparencia.uniovi.es/informacion-academica, accessed in March 2021). We aimed at reaching approx. 20% of the students in each degree. Groups of students were chosen as it follows: after consulting Faculty Boards, teachers/instructors were randomly selected from the staff, contacted, and asked to allow a time for this research in one (or several of the same course, in case

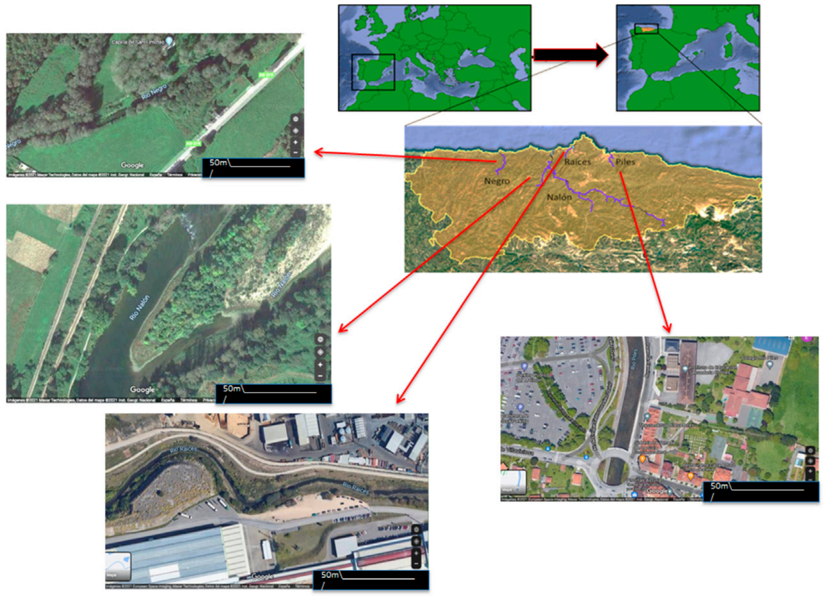

FIGURE 1 | Map showing the studied rivers. Arrows show screenshots on river lowlands; bottom bars at right in each image represent 50 m (source: Google Maps, Google ©2021).

of small class groups) of their regular classes. The date of the survey was May 2019.

Before distributing the questionnaire a brief presentation was given about the rivers in the region, with the visual support of a few pictures of pristine rivers of Asturias (southwest Bay of Biscay, North Iberia): well preserved habitat with surrounding vegetation, clean transparent water permitting the view of natural gravel, boulders and rocks in the bottom, different river fish including Atlantic salmon, brown trout and European eel. Students were informed about the objective of the study, to know their opinion about actions aimed at river conservation.

Samples were: Degree in Pedagogy, $n = 60$; Degree in Biology, $n = 98$; Engineering (within an intensive program of Aquatic Engineering), $n = 28$. Mean age was 20.4 (SD 3.2) and gender ratio 69.8% females, 29.6% males, 0.6% non-binary. Students were told the answers were anonymous and confidentiality was respected.

Prioritization Model Development

Watershed Case Studies

The case studies were four coastal rivers located in Asturias. This region is characterized by a temperate Atlantic climate and an ecosystem of caduceus forests in systems of valleys and mountains up to 2,900 m over sea level. The rivers studied were, from east to west, River Piles (16 km length), River Raíces (15 km), River Nalón (140 km) and River Negro (20 km) (**Figure 1**). The river area considered in this study was the lower reach: the last 10 km upstream from the river mouth, except in River Nalón, where it was 15 km because electrofishing was not possible closer to the coast due to high depth and water flow.

Typical uses of these rivers include water and energy supply, sport fishing (angling), canoeing and other recreational activities. In the lower reach of the rivers, where the study took place, predominant uses are sport fishing, principally of salmonids, and recreational activities like canoeing, bath, bird watching and others.

Native species like Atlantic salmon, highly appreciated for sport fishing, have declined in Asturias due to climate change and habitat loss caused by damming (e.g. Valiente et al., 2011; Juanes et al., 2012). Sport catch quota are set every year after assessment of population sizes (see Alvarez et al., 2010). Following legal regulation, in Asturias only native species can be fished (Spanish Law 6/202 of 18 of June on the protection of aquatic ecosystems and fishing regulation in continental waters, available online at https://www.boe.es/eli/es-as/l/2002/06/18/6/dof/spa/pdf, accessed in November 2020).

River Features and Ecosystem Services

Native Fish Species, Fish Abundance, Fish Diversity

The fish abundance and the number of autochthonous species were taken from the last official inventory of Asturias region that was published in 2014 (De la Hoz, 2014). In addition, new fish surveys were conducted in 2016 and 2017 to check if new species appeared in the rivers since 2014. Standard electrofishing procedure approved by the Spanish Ministry of Agriculture, Fisheries and Environment to implement the EU Water Framework Directive 2000/60/CE was employed: Protocol ML-R-FI-2015 (NIPO: 280-15-122-6). Surveys were carried out by Taxus S.L., a company authorized to conduct aquatic biodiversity surveys in the Principality of Asturias that performs official fish inventories using the named protocol. Fish abundance index was estimated for each river dividing the total of fish caught by electrofishing in the lower reach of each river by the number of fish of the river with higher abundance.

In the study region fishing depends on the abundance of native fish, thus the abundance and the number of native species characterize this ES while the total fish diversity does not necessarily. Rivers were ranked 1-4 (1 worst, 4 best) for each of these features (fish abundance, number of native species, fish diversity). Two independent measures of fish diversity were considered: species richness (= total number of species), and functional diversity. Functional diversity was measured from Shannon index calculated on the number of species in each functional group (herbivores, omnivores, carnivores). Diet of the fish species was consulted from FishBase (Froese and Pauly, 2021) and relevant literature. The native or exotic status of the fish species was determined as in Clusa et al. (2018).

Habitat Quality and Connectivity

The habitat quality was assessed taking into account the following factors: bank vegetation coverage and river canopy (in % of riverbed or river surface covered by vegetation or shaded; the higher the better); artificial riverbed (in % of river bottom; the lower the better); visible level of pollution, in terms of the number of visible sewage/industrial discharges in the river sector examined (the fewer the better). Rivers were ranked 1–4 for each factor, being 1 the worst and 4 the best. Rank scores were summed and the final river rank for habitat quality was allocated from that sum.

Connectivity was assessed from the number of river barriers occurring in the lower reach considered. River barriers occurring in the last 10 km of the river, including the estuary, were counted using Google Earth. The barriers were categorized as <1 m, 1–10 m, >10 m high. The rivers were ranked from the number of river barriers (1 for the river with most and 4 for that with least barriers, considering barrier height as 1, 2, and 3 points for <1 m, 1–10 m and >10 m high barriers, respectively, summing the points and inverting the order in the rank).

Conservation Prioritization From Willingness-to-Pay Results

For application of the WTP results to the rivers considered in this model, we combined the results of the field study with students' declared WTP to model river appreciation by each group. The departure point was the rank scores of each river obtained from field surveys and published fish inventories. They were multiplied to obtain the final value because biotic and abiotic features are interrelated: improving the quality of the environment can increase fish populations or their diversity. This measure was the basis to build the WTP model. Then the five river features (separately with each of the two different measures of fish diversity) were ranked based on relative preference for each group of students. For this, the most valued feature (that with the highest mean will amount) was scored 1 (100%), then the mean will amount of the other features was divided by the will amount of the preferred one thus the scores were proportional to the preferred one. These were the preference coefficients of each group of students.

Rivers were then scored in the model multiplying the direct rank scores of the population features by the preference coefficient assigned to them by a group of students. We did the same for the three groups of students. Corrected rank scores for the five features were multiplied to obtain the value assigned by each group of students to a river.

Statistical Analysis

Differences among groups for will amount means were tested using two-way ANOVA after checking normality of dataset distributions was checked using Shapiro-Wilk test and homoscedasticity with Breusch-Pagan tests. *Post-hoc* pairwise t-tests were carried out when the global comparison was significant. Pearson's r was used to estimate the correlation between the number of barriers in the river sectors examined and exotic fish.

$p < 0.05$ significance level was employed. Statistical analyses were performed using PAST software (Hammer et al., 2001).

RESULTS

Willingness to Pay for River Features

The results of the questionnaire revealed differences amongst the groups of participants and the type of interventions in the WTP for river improvements. Social sciences students valued higher all the interventions proposed than the students of natural sciences and those specializing in aquatic engineering. The declared amount that would be paid to enhance all the river features together (sum of the will amounts for the five ES) was in average 263.5 (SD 137.5), 94.3 (SD 68.7), and 139.8 (SD 148.6) €/year for educational sciences, natural sciences and engineering students, respectively. The difference between them was highly significant (ANOVA with $F(2,183) = 45.32$, $p < 0.001$). Post-hoc *t*-test showed that the students of engineering and natural sciences did not differ significantly from each other ($t = 1.57$ with $p = 0.126$), thus the difference was due to the students of educational sciences that declared to be willing to pay higher for improving all the considered river features than the students of other backgrounds ($t = 8.88$ and $t = 3.83$, both with $p < 0.001$, for the differences between educational sciences and natural sciences and engineering respectively).

Each group of students had different preferences regarding the improvement of river features. The three groups valued environmental quality the most. Second in the list was the total number of fish species for educational and natural sciences students, and native species for those of aquatic engineering (**Figure 2**). Connectivity was the least appreciated ES for the educational and natural sciences, while it was the third for aquatic engineering students, before fish diversity and fish abundance. The observed differences between groups of students were statistically significant (**Table 1**) with $F(2, 915) = 169.1$, $p < 0.001$. The differences among river features were statistically different too ($F(4, 915) = 8.1$, $p < 0.001$). The interaction was marginally significant ($p \approx 0.05$), according to different order of preferences in the different groups of students.

In post-hoc tests (t-values not shown), for engineering students created two overlapping groups of river features where only environmental quality and fish diversity were significantly different (**Figure 3**), that is, the most and least

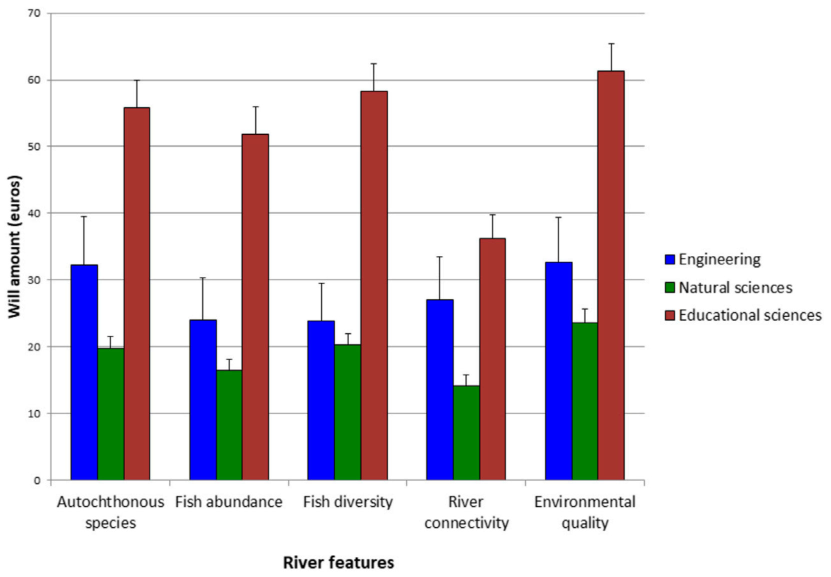

FIGURE 2 | Willingness to pay for conservation of river ecosystem services. Data are presented as the mean number of euros (vertical bars for standard deviation) each group of participants would accept as an increase in their annual taxes for an intervention in river ecosystems.

TABLE 1 | Two-way ANOVA showing the weight of student's background and the river feature in the willingness to pay for river ecosystem improvement.

Factor	Sum of squares	d.f	Mean square	F	P
Student background	214,966	2	107,483	169.1	3.23×10^{-63}
River feature	20,731.2	4	5,182.81	8.15	1.84×10^{-6}
Interaction	9,749.69	8	1,218.71	1.92	0.05
Within	581,622	915	635.653		
Total	8.27×10^{5}	929			

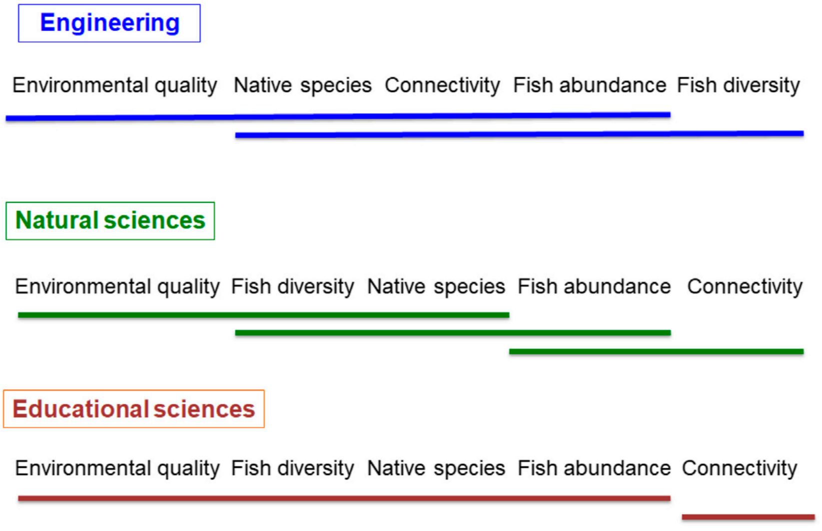

FIGURE 3 | Post-hoc analysis of public appreciation of river features. Groups of river features not significantly different for willingness to pay (from pairwise tests) are underlined.

TABLE 2 | River features. Connectivity measured from the number of barriers. Rank scores of river features.

	Piles	Raices	Nalón	Negro
Number of barriers				
>10 m	0	0	0	0
Between 1 and 10 m	1	1	3	0
<1 m	3	2	10	1
Connectivity rank	***2***	***3***	***1***	***4***

Connectivity is clearly different in the lowlands of the four rivers. The four rivers have different number of barriers of different height (**Table 2**). River Nalón and River Negro record respectively the highest (three medium and ten low-head) and the lowest (one low-head) number of barriers. For the environmental status, River Negro has the highest water quality cleanest and is the best preserved while River Piles is the worst regarding vegetation and artificiality, although not for pollution (**Table 3**).

TABLE 3 | River features. Environmental quality, including canopy, pollution, artificial riverbed, bank vegetation coverage. Rank scores of river features.

% River canopy	2% (*1*)	60% (*3*)	5% (*2*)	90% (*4*)
River pollution	Agriculture, urban (*3*)	Industrial, urban (*1*)	Mining (*2*)	Agriculture (*4*)
Artificial riverbed	90% (*1*)	60% (*2*)	5% (*3.5*)	5% (*3.5*)
Bank vegetation	5% (*1*)	100% (*3.5*)	100% (*3.5*)	70% (*2*)
Environmental quality	***1***	***2***	***3***	***4***

TABLE 4 | River features. Fish species inventoried in the four rivers and their trophic level, relative fish abundance, fish diversity as number of species, and % of exotic fish species. Rank scores of river features are given in bold italics.

Species	Piles	Raices	Nalón	Negro		
Common name	**Scientific name**	**Trophic level**				
European eel	*Anguilla*	3.6 (±0.3) C	X	X	X	X
Atlantic salmon	*Salmo salar*	4.5 (±0.3) C	0	0	X	(X)
Goldfish	*Carassius auratus* *	2.0 (±0.0) H	X	0	0	0
European sea bass	*Dicentrarchus labrax*	3.5 (±0.5) C	X	0	X	X
Iberian gudgeon	*Gobio lozanoi* *	3.2 (±0.44) O	0	0	X	0
Flathead grey mullet	*Mugil cephalus*	2.5 (±0.17) H	X	X	X	X
Adour minnow	*Phoxinus bigerri* *	3.2 (±0.4) O	X	X	X	X
Flounder	*Platichthys flesus*	3.3 (±0.2) C	X	0	0	0
Brown trout	*Salmo trutta*	3.4 (±0.1) C	X	X	X	X
Iberian chub	*Squalius carolitertii* *	3.4 (±0.38) O	0	0	X	0
	Relative fish abundance	0.13	0.16	1	0.28	
	% Exotic species	0.29	0.25	0.375	0.2	
	Shannon's functional diversity	0.956	1.04	0.974	0.868	
	Fish abundance rank	***1***	***2***	***4***	***3***	
	Native fish rank	***3.5***	***1***	***3.5***	***2***	
	Functional diversity rank	***2***	***4***	***3***	***1***	
	Species richness rank	***3***	***1***	***4***	***2***	

*C, carnivore; H, herbivore; O, omnivore; X present, 0 absent, (X) occasional, *non-native species*

valued features. For natural sciences students three groups of features not different from each other were found in the post-hoc analysis; from this grouping, environmental quality was significantly more valued than fish abundance and connectivity. Finally, for educational sciences students significant difference in will amount occurred between the least valued connectivity and the rest of river features that were grouped together (**Figure 3**).

River Features Characterization and Prioritization Model Developed

The four rivers studied were clearly different for the fish species held and the environmental features considered (**Table 2**).

In total ten species were inventoried from these rivers (**Table 4**). Two native marine species enter occasionally the estuaries and lower river reaches: European sea bass (*Dicentrarchus labrax*) and grey mullet (*Mugil cephalus*). Four diadromous species very appreciated in fisheries are European eel *Anguilla anguilla*, flounder *Platichthys flexus*, brown trout *Salmo trutta* and Atlantic salmon *Salmo salar*, the last one established only in River Nalon. A few individuals may enter occasionally River Negro but do not breed there, thus that river has not Atlantic salmon population. Finally, the exotic goldfish *Carassius auratus*, Iberian gudgeon *Gobio lozanoi*, Adour minnow *Phoxinus bigerri* and Iberian chub *Squalius carolitertii* also

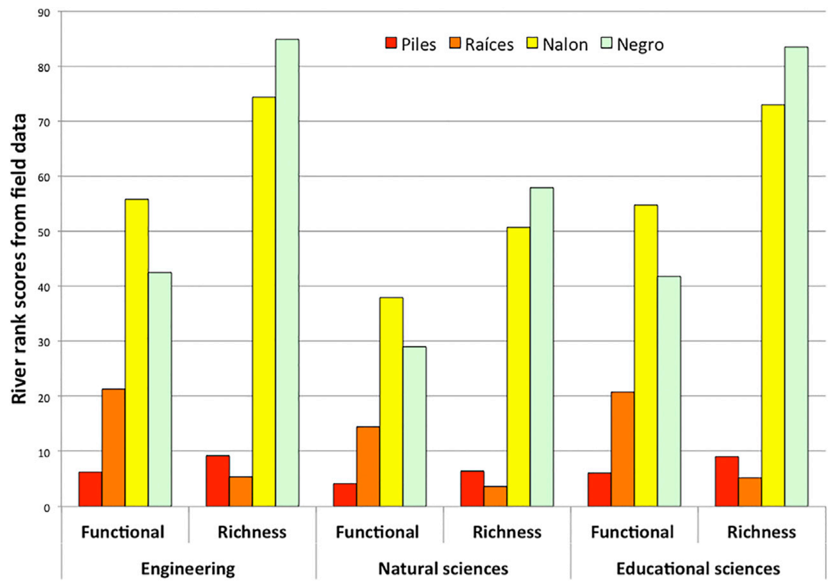

FIGURE 4 | Relative value of the four rivers analyzed in the model, estimated from the features considered. Products of multiplication of the ranks allocated to river features, weighted by the preference coefficients calculated from students' willingness to pay. Two values are given for each river, using functional diversity "Functional" (influenced by non-native species) or species richness "Richness" as estimators of fish diversity. The other features are the same in the two estimated values of each river: connectivity, environmental quality, fish abundance, and number of native fish species.

occur in these rivers. Adour minnow happens in all of them while Iberian chub is found in River Nalon only (**Table 4**).

In **Table 4** we can see that Rivers Nalon and Piles have the same number of native species (5), River Negro 4 and River Raices 3 (Nalon = Piles > Negro > Raices). For fish abundance the lowest corresponds to River Piles according to fish inventories (Nalon > Negro > Raices > Piles), The different measures of fish diversity provide different river ranks in this study (**Table 4**). Species richness is highest in the largest River Nalon and lowest in River Raices (Nalon > Piles > Negro > Raices). The highest proportion of exotic species occurs in River Nalon and the lowest in River Negro. The proportion of non-native species is significantly and positively correlated with the number of barriers (see **Table 2**) (r = 0.959, 2 days. f., $p = 0.04 < 0.05$). Functional diversity, affected by non-native species in temperate rivers (Su et al., 2021), exhibits the following pattern: Raices > Nalon > Piles > Negro (**Table 4**).

From the product of the multiplication of ranks of the five features considered, the order of conservation status (basis of the model) would be Nalon > Negro >> Raices > Piles (**Supplementary Table S1**) using functional diversity to measure fish diversity. The order is Negro > Nalon >> Piles > Raices when species richness is employed.

From the monetary values assigned to river features by student groups and the scores of the different features from field data, the prioritization of the four rivers for conservation would be similar but not identical for the three groups of students (**Figure 4**). The calculations step by step are presented in **Supplementary Table S1**. The three groups of students gave the same order of river preference as the order of river conservation status estimated from field data. The preferences of engineering and educational sciences students would create a very similar ranking of the four rivers using any of the two estimates of fish diversity, with more pronounced gaps between the two most and the two least preferred rivers in comparison with the gaps that appear in the valuation of natural sciences students (**Figure 4**). For example, using functional diversity to estimate diversity the valuation made by engineering and social sciences students was Nalon > Negro >> Raices > Piles, while for the valuation of natural sciences students it was Nalon > Negro > Raices > Piles (**Figure 4**). Estimating diversity from species richness the river total rank based on engineering and social sciences students' valuation was Negro > Nalon >>> Piles > Raices. The gap between River Nalon and River Piles was much smaller using natural sciences students' valuation. This model suggests that river priorities for conservation or improvement actions would be different depending on the diversity measures employed and the group consulted.

DISCUSSION

The results of this study supported the expectation of a higher appreciation for environmental quality than connectivity (Hypothesis 1). Participants valued environmental quality the most, demonstrating that they are conscious of the importance of its conservation for providing a variety of ES. In contrast, river fragmentation was the least valued of the five river features considered, except for the group of engineering students who are expected being more aware of the impacts of large infrastructures. Although the negative impacts of dams and reservoirs, such as biodiversity changes, water quality reductions, sedimentation increase (Malmqvist and Rundle, 2002) are widely described, the river changes caused by them seemed to be overlooked in our study. Connectivity is very important for maintaining a good quality of river ecosystems (Crook et al., 2015), but surely this is not sufficiently known by the wide public. Interestingly, although there are many public views opposed to new damming (e.g. Kirchherr et al., 2016; Schulz et al., 2019), there are also voices against dam demolition even when they are obsolete (Lejon et al., 2009), when they have cultural and historical values. Our results would suggest that spending public money to recover connectivity should be better accepted if the consequences of river fragmentation were better explained to the population.

Despite its importance for sport fishing, fish abundance was not preferred over native species and fish diversity, thus Hypothesis 2 cannot be accepted from our data. Instead it was one of the least valued features. Perhaps students are not aware of sport fishing regulations, recreational fishing being commonly practiced by more aged sectors in Spain (Gordoa et al., 2019).

Hypothesis 4 about the differences between students' willingness to pay for the improvement of river ecological status according to their background was fully supported from our results. According to expectations (Kukkonen et al., 2018), students of educational sciences were those who would pay the most for improving river ecological status in terms of all the considered aspects. This is confirmed by the different importance attributed to fish diversity. It was the second valued feature for natural sciences and educational sciences students, being the least valued for engineering students. This suggests that some students would be aware of the importance of biodiversity, at least those more informed about it from their background (natural sciences) or awareness about sustainability issues (educational sciences).

Hypothesis 3 was as well supported from our model results. Indeed the two rivers in a better ecological status and with more fish ranked higher than the other two, whatever preference coefficient was applied (i.e. engineering vs. natural sciences vs. educational sciences student preferences). However, there was a small difference in the gap between the two most and the two least valued rivers, which was smaller for natural sciences students than for students of the other disciplines. This difference at such small scale is interesting and supports the idea that participatory processes involving multiple sectors are determinant in the public acceptance of interventions in rivers (Kellner, 2019). Our result illustrates the importance of involving different populations sectors when making environmental decisions about river uses.

On the other hand, we observed a clear difference in river conservation status when applying coefficients according to different measures of fish diversity. Using species richness the first priority would be River Negro and the last River Raices, not River Nalon and River Piles respectively like when we used functional diversity. The latter diversity measure is highly influenced by non-native species (Su et al., 2021), which varying between rivers could explain the different river ranks obtained. Different diversity measures (taxonomic, phylogenetic, functional) are changing differentially with the introduction of non-native species in temperate rivers, as seen at a global scale (Su et al., 2021), and we have seen here such differences at small scale with only four rivers.

The model applied in this study has some limits. The first limit is reduced number of rivers employed in the case study that, although being enough to see clear differences in conservation status, impedes a deeper data analysis. Another is the equal treatment given to the five biophysical river features measured in the evaluation of conservation status that is the basis of our WTP model. Actually we could have chosen other features that provide–or threaten- ES, like invasive invertebrate species or degree of urbanization of riverine areas, and could give differential values to each feature. However, it is difficult to assign an objective value to a river feature because it may depend on the circumstances, and on the perspective of the expert or stakeholder. In a very poor region where fishing resources are essential for protein supply, like some African countries (e.g. Golden et al., 2016), fish abundance would be an objective priority if the population wellbeing counts. In rivers where biodiversity is severely depleted by damming or pollution, these features would be more important than the amount of native fish; and so on. Different coefficients could be given to river features depending on the particular case.

Another limit is a possible sampling bias due to the sample composition (students), that might be not representative of all the river users. In Spain few studies reported profiles of users of water and watershed resources. In these studies, the majority of users are studying or have studied at the University: from more than 50% of users of Mar Menor watershed (Mediterranean basin; Velasco et al., 2018) and Valencian beaches (Cabezas-Rabadán et al., 2019), up to 80.8% of water users participating in a study in NW Spain (Andrade et al., 2021). Thus current university students like those included in our study, although not fully representative of all the users of water resources, would be–at least in the future- the majority of water users in Spain. Finally, another bias of our study could be due to the introduction of the study, where different photos of pristine rivers and their natural biota were presented. Our intention showing these pictures was to elicit the issue of conservation status based on multiple aspects, not only lack of pollution but also to recall the rich biodiversity and the water flowing free. However we did not show any picture of a river transformed by human uses (polluted, dammed, devoid of natural vegetation), thus respondents had no recent images of modified rivers. This may have influenced their perceptions and values.

Despite methodological limits of our model, the results suggesting that environmental quality is a priority for (potential) river users could be used for management. For example, knowing that clean rivers are publicly demanded, managers would make more efforts to control pollution. Indeed the results of this small survey and simple model cannot replace participatory approaches in environmental actions for river conservation, where stakeholders participate actively in the evaluation of different scenarios and the choice of mitigation or conservation options (e.g. Verkerk et al., 2017; Kumar et al., 2020).

Barriers transform the fish community in rivers and this has implications for conservation (Han et al., 2008; Horreo and Garcia-Vazquez, 2011; Nislow et al., 2011; Branco et al., 2017). In the four river lowlands examined here, the proportion of exotic fish species was significantly correlated with the number of barriers. At least in the rivers studied here, small barriers seem to affect fish diversity contributing to increase the exotics that would in turn influence functional diversity (Su et al., 2021). River connectivity prevents the establishment of exotics in different ways. On one hand, dams and reservoirs act like reservoirs of exotics (Clavero et al., 2004; Letnic et al., 2014; Santos et al., 2017); on the other, the disturbance caused by barriers promotes the establishment of exotic species (Clavero et al., 2004), probably due to alterations in water flow and temperature (Dudgeon et al., 2006). Our results are in line with this. In contrast, native fish species would prefer more favorable habitat conditions in areas not affected by dams (Fernandez et al., 2018). Since the native biodiversity is crucial to avoid ecological invasions (Kennedy et al., 2002), perhaps its decrease in the river sectors altered by small barriers also contributes to the increase of exotics.

Other implications for conservation derived from this study are related to management. We know the importance of connectivity for biodiversity and the impacts that river barriers cause on the river communities; however, if our results were extrapolated to the general population, public appreciation of this precious ecological feature would be not very high in the studied region. We could expect low public demand for river connectivity restoration there, thus managers would not put connectivity first in the list of priorities. This is consistent with Magilligan et al. (2016) results showing that making river barriers passable is not a priority for restoration actions. Biodiversity valuation depends on cultural and ethical principles, but also on the education as we have seen here. The message should be passed to the general public, for connectivity restoration to be publicly demanded in river conservation programs. Outreach of scientific knowledge and public campaigns to raise environmental awareness about the rivers would be recommended.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Ethics Committee of Asturias Principality. The patients/participants provided their written informed consent to participate in this study. The animal study was reviewed and approved by the Ethics Committee of Asturias Principality.

AUTHOR CONTRIBUTIONS

EG-V planned and directed the research. ED and EA conducted the social study. SF and LC carried out the part of natural sciences research. All the authors contributed to data analysis and article writing.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2021.643820/full#supplementary-material

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