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The economic value of ecosystem conservation: a discrete-choice experiment at the Taravo Wild River in Corsica, France

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Abstract – This article contributes to the literature on non-market evaluation methods, applied to ecosystem services. The ecological status of the Taravo River is currently under threat by human activities. In this context, we value some of the ecosystem services provided at the Taravo River Basin using a stated-preference approach. Four different econometric estimations were considered for this discrete-choice experiment. On average, respondents are willing to pay 128 euros per year for the enhancement of the ecosystem services selected. This result is in line with those obtained in recent contributions that have applied similar approaches. Beyond this average, this article conducts a spatial analysis to confirm the different willingness to pay on the territory (upper versus lower Taravo).

Keywords: Discrete-choice experiment / ecosystem services / non-market valuation / spatial econometrics / stated-preferences methods

1 Introduction

In February 2017, the Taravo River became the first river to obtain the Wild Rivers Label (*Site Rivière Sauvage* in French) in the island of Corsica in France. This label is granted by the Non-Governmental Organization (NGO) of the European Rivers Network (ERN), the French Biodiversity Agency (AFB) and the French Standardization Association (AFNOR) to rivers whose ecological conditions are judged to be excellent (Charais *et al.*, 2014).

In this context, we carried out an economic valuation of some of the ecosystem services provided at the Taravo River Basin, using a stated-preference approach. In particular, the population's Willingness To Pay (WTP) for increased recreational opportunities and water quality was estimated via a Discrete-Choice Experiment (DCE). In addition, the conservation of architectural heritage and the eradication of invasive species were included in the experimental attributes, even though their classification as ecosystem services *per se* is debatable (*cf.* the Common International Classification of Ecosystem Services - CICES: https://cices.eu).

A number of econometric specifications were tested, and the best results come from a Random Parameter Logit Model that allows us to relax the Independence of Irrelevant Alternatives (IIA) assumption. On average, respondents were willing to pay up to 128 euros per year for the maximum proposed enhancement of the attributes selected in this DCE. As we will show in this article, this result is in line with those obtained in related work[1].

1.1 The concept of ecosystem services

The concept of ecosystem services was implicitly a topic of interest as early as the 1970s when the conservation science community began focusing on ecosystem degradation (Ehrlich and Mooney, 1983; Gómez-Baggethun *et al.*, 2010; Barnaud *et al.*, 2011), but it came into mainstream consciousness with the Millennium Ecosystem Assessment (MEA: https://www.millenniumassessment.org). This United Nations program was created in response to the call for the global scientific assessment of ecosystems at the conclusion of some of the Multilateral Environmental Treaties of the 1990 s, notably the Convention on Biological Diversity (CBD) and the Convention to Combat Desertification.

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[1] This DCE is part of more comprehensive assessment, funded by the South Corsica Département, which expands the analysis to other ecosystem services, including their biophysical aspects. The economic valuation of those additional services was carried out using alternative methods, which are not described here.

The results from the MEA, and subsequent work, show that biodiversity and ecosystems are rapidly being depleted and degraded, faster than at any point in human history. In order to act on this pressing issue, the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) was created following the 2010 Nagoya Protocol to the CBD, with the goal of assisting the implementation of the Convention. This panel provides policymakers with objective scientific assessments, coming from across the disciplines and knowledge communities, of the planet's biodiversity, ecosystems, and their positive impacts on human welfare (IPBES, 2008).

In short, ecosystem services are the benefits that humans obtain from ecosystems. For ease of comprehension, these have been divided into four broad categories: provisioning (of food, water and other natural resources), regulating (water purification, climate, and disease control), supporting (nutrient cycles and crop pollination, which support the provision of other services), and cultural services (spiritual and recreational benefits). However, there is still a considerable degree of interdependence between these services, according to the CICES.

As the concept spread throughout the scientific community, efforts have been made by public and private institutions worldwide to include ecosystem services in decision-making and policy planning, with the goal of finding a balance between economic development, a rational use of natural resources, and social well-being (Ruckelshaus *et al.*, 2015). Note that the identification and assessment of the contribution of ecosystems to the satisfaction of socio-economic needs is a complex task, requiring extensive research and a multidisciplinary approach (TEEB, 2010).

1.2 Stated-preference methods for environmental valuation

Despite the clear benefits that are obtained from ecosystem services, their economic value remains difficult to quantify, mainly because they are a special type of good in the sense that they are not traded on a market. This means that it is not possible to infer the marginal impact of changes in their provision and relative prices on utility from individuals' behavior as consumers, which is the common practice in economic analyses (Hanley *et al.*, 1998; Johnston *et al.*, 2017). As such, the survey-based approach of stated-preference methods may be a practical alternative, enabling the elicitation of both use and non-use values. These methods can in addition be adapted to many different contexts, and used to estimate the WTP for either current or future services[2].

Two main stated-preference methods can be found in the literature. These follow the same principle: a hypothetical market is created and presented to a representative sample of the population of interest, in the form of a carefully-designed questionnaire. The first stated-preference studies used the Contingent-Valuation (CV) method, where people are simply asked whether they would support – financially and, in the case of public goods, politically – a proposed change in the provision of a set of goods or services (Hanley and Barbier, 2009). The second method, known as DCE, began to be applied in the early Eighties, with the work of Louviere and Hensher (1983), and Louviere and Woodworth (1983). In contrast to CV, a number of attributes (with increasing levels of provision) of the proposed good or service to be improved are selected during the design phase of the DCE. Individuals are then asked to indicate their preferred scenario from multiple alternatives with respect to a baseline, with these alternatives differing in the attributes' provision levels. A hypothetical cost is part of the attributes that the respondents choose between in each scenario.

One of the virtues of this method is to simplify to a great extent respondents' effort, as it would be hard for them to state their preferences over good attributes if they were asked directly. In addition, a properly-designed DCE allows several choice tasks of this type to be presented to respondents (Hanley *et al.*, 1998), thus increasing the sample size. In the context of ecosystem services, the valuations obtained from stated-preference methods can be used to carry out comprehensive policy analyses and environmental-damage assessments, which in turn can help decision making by public- or private-sector entities, court sentencing regarding environmental damage litigation and advocacy by NGOs.

Nonetheless, the validity of the results obtained from these methods continues to be debated. It is possible that respondents give higher figures than their actual WTP as a result of the hypothetical nature of the survey, which is known as hypothetical bias. Clarity in the presentation of realistic baseline conditions, hypothetical changes and their working mechanisms is essential to overcome this issue. This information must be clearly understood, accepted and seen as credible by respondents (Johnston *et al.*, 2017).

1.3 The project at the Taravo river basin

The project at the Taravo River Basin took place between May and November 2017, and was part of a multi-stakeholder partnership, which included the NGO ERN (whose objective is the preservation of the rivers characterized as having the most intact ecological status in the countries concerned), and the Environment Division of the South Corsica *Département* Council. The analysis was requested by the latter, as an ecosystem-services assessment was deemed relevant in the context of the ongoing efforts aimed at the ecological preservation of the Taravo watershed.

The ecosystem services, or the multiple benefits that the local population obtains from the Taravo River Basin, were the main subject of this analysis. For the purpose of this assessment, the most relevant ecosystem services provided at the Taravo River Basin were identified in June 2017 by a committee of technical experts from different public entities and private associations at the local and regional levels. The results from this technical committee were later confirmed by a steering committee, whose members were public- and private-sector stakeholders (these included the mayors of some of the municipalities concerned, and representatives of public entities that deal with environmental and rural-development issues).

[2] As a result of these advantages, the use of this method is not limited to ecosystem services: they have been applied in many different fields, including health, transportation and marketing (Hanley and Barbier, 2009; Johnston *et al.*, 2017).

This latter committee provided an important opportunity to uncover the public's perception of the selected ecosystem services and the main issues affecting the Taravo River's ecological status.

The selected ecosystem services come from the regulating, provisioning and cultural categories, according to the CICES scheme. The regulating services included flow control, water purification, water streaming, erosion control, climate regulation and pest control. The provisioning services consisted of water, both for drinking and irrigation purposes, wood and biodiversity, as this ecosystem is rich in flora and fauna, including endemic species such as the macrostigma trout. Last, the cultural services consisted of emblematic landscapes and recreational activities, such as fishing and hunting.

This ecosystem-services assessment follows other initiatives, going back to 2013, the results of which suggested that the Taravo River is in excellent ecological condition. These efforts include a comprehensive diagnostic study (Lindenia, 2013) and the granting of the Wild Rivers Label[3]. It should be noted that ecological preservation in Corsica is helped by the island's relatively-low population density compared to the rest of the country, leading to less stress on natural resources. Moreover, Corsica is an island environment with a strong rural identity, and its inhabitants share a strong attachment to their natural flora, fauna and features (Casula, 2006).

Despite these generally good results, critical water-pollution issues in some municipalities needed to be addressed. At the opposite end from the above mentioned initiatives, the National Sanitation Authorities have banned swimming in 23 km of the river since 2008, as a consequence of the poor results from the routine environmental inspections of water quality. These sanitation issues have moreover influenced the perception of many local residents who, during the survey for this study, frequently used the words "sewage" and "trash can" to describe the Taravo when asked their opinions on the current state of the river. Last but not least, a project to build a large hydroelectric dam in the village of Olivèse – located in the middle of the River Basin – has been discussed over the past 30 years. If carried out, this project would imply a drastic change in both the conservation and development strategies of the River Basin due to its significant environmental impact.

1.4 The question to be addressed

The main objective of this assessment is to provide useful and robust information for stakeholders evaluating the benefits resulting from the ecological conservation of the river. The whole project, beyond the research described in this article, asked the four following questions:

- What are the main ecosystem services provided by the Taravo River?
- What are the biophysical mechanisms involved in the provision of those services?
- What is the economic value of those services?
- Based on the results obtained, how would a development strategy based on environmental conservation compare to the hydroelectric-dam project?

The current article will mainly address the third question. A clear response to the first question was given in the results from the meetings with the technical and steering committees, while the answers to the remaining questions were set out in the comprehensive assessment presented to the South Corsica *Département* Council, which included a Benefit-Cost Analysis of the development strategies of either ecological conservation or the hydroelectric-dam project.

Given the nature of the ecosystem services, which can contribute to human well-being either directly or indirectly, a number of approaches to economic valuation can be tested[4]. We will here discuss one of those approaches, the application of a stated-preference method (namely a DCE). The attributes of this DCE are directly linked to two ecosystem services, water quality and outdoor recreation, and indirectly to the service of scenic landscapes. In addition, even though they are not part of the CICES, architectural-heritage conservation and invasive-species eradication were included in the DCE attributes.

The remainder of the article is organized as follows. In Section 2, the literature on the economic valuation of the ecosystem services provided by rivers and other watersheds will be reviewed. Section 3 will then describe the method, design and execution of the DCE, while Section 4 presents and discusses the main findings. Last, Section 5 concludes.

2 Literature review

Given the importance of the ecosystem services provided by bodies of water, their economic value should be taken into account for water-policy planning in general, and river restoration and preservation in particular. Extensive research has been carried out worldwide in recent decades, using the whole spectrum of environmental-valuation methods, including revealed and stated preferences (Brower, 2017; Bergstrom and Loomis, 2017).

Bagstad *et al.* (2013) propose spatial tools to model ecosystem services, such as Artificial Intelligence for Ecosystem Services (ARIES) and Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST), which they then apply to the San Pedro river watershed, which is shared by Mexico and the United States of America (USA). These tools were used to model the services of carbon storage, water provision, and scenic views. Ecosystem-services changes were quantified through the construction of a number of scenarios of urban growth and native-vegetation management. The results from this study allow the comparison of modeling-tool characteristics in order to assess their potential for resource-management evaluation.

[3] At this time, only 12 French rivers had received this label. A "Wild River" is a living, reference, preserved river that flows freely and contains exceptional biodiversity in its quality waters and along its banks (Charais et?al., 2014).

[4] Among the services included in the economic valuation were recreational fishing (estimated from expenditures on fishing licences and equipment), soil quality for agricultural productivity (using the European Agricultural Standard Gross Production as the relevant indicator) and the provision of drinking water (based on drinking-water prices).

The replacement-cost approach was applied by Honey-Rosés *et al.* (2013) to value the positive effect of stream restoration for drinking-water treatment in the Llobregat river in Spain. This approach was complemented with the use of another modeling tool: the Stream Network Temperature Model (SNTEMP). In addition, hedonic pricing was used to estimate the effect of the removal of a small dam on property prices in the USA. Provencher *et al.* (2008) used this approach in south-central Wisconsin, while Lewis *et al.* (2008) took the same approach for properties along the Kennebec river in Maine.

Regarding stated preferences, the Contingent Valuation method has been extensively applied over the years. Biro (1998) carried out an economic valuation of the environmental impacts associated with the Karyaktepe dam in Turkey. These included the losses of agricultural income, value from natural forests and non-use values. Reynaud *et al.* (2017) estimated households' WTP for different infrastructure projects, which were presented in the form of attribute-differentiated scenarios to be valued using the CV method. Lazaridou and Michailidis (2020) used a contingent valuation survey on farmers in the Nestos Delta river basin in Greece and found a high rejection rate (64.57% zero response), prompting them to re-estimate farmers' WTP for water quality in accordance with the European Water Framework Directive. Finally, Jones *et al.* (2016) used a CV study to value both the social and environmental impacts of the Glen Canyon dam on the Colorado river.

For the specific method we use here, Bliem *et al.* (2012) applied two identical DCEs, one year apart, to test the temporal stability of environmental preferences regarding the Austrian sector of the Danube River. Flood frequency and water quality were the river attributes, and the results suggest that preferences and WTP estimates are stable over a short period of time in the absence of extreme events. Lizin *et al.* (2016) tested spatial heterogeneity using a labeled-choice experiment on the Oude Kale and Leie rivers in Belgium. Their results suggest that efforts to restore the latter should be prioritized. In addition to the river-specific coefficients generated by the labelled design, the authors also considered distance from the rivers and past visit behavior as respondents' spatial variables. The chosen attributes were the extent of the restoration, its length in kilometres, water quality, species richness and accessibility.

Spatial-preference heterogeneity was also tested in Asefaw *et al.* (2016) regarding the Shiyang River Basin in China. Eight attributes were chosen for this DCE, a substantially larger number than in most of the work in Europe, but in line with other analyses in China (Shi *et al.*, 2016) and the USA (Zhao *et al.*, 2013). These included tourist amenities and water quality and quantity. Using advanced econometric techniques and tests (such as the Poe independent empirical distribution equality test), there was evidence of preference heterogeneity by residential location, as the socioeconomic context and ecological status of the river differ in the river's three main sub-basins (the upper, middle and lower).

The application of these methods is neither limited to high-income countries nor to natural-water bodies. Brouwer *et al.* (2016) used DCE in order to assess a spatial analysis of the non-market benefits of ecological river restoration in three Danube River Basin countries: Austria, Hungary and Romania. Kahn *et al.* (2017) use choice modeling to estimate the population WTP for restoring the Rio Paraiba do Sul in Brazil. The extent of the restoration and the time this would take were the chosen attributes. Equally, Perni and Martinez-Paz (2017) apply this method to value the ecosystem services provided by the artificially-created El Hondo wetland in Spain. They selected biodiversity, water provision and the areas available for fishing, hunting and public access as the wetland attributes.

There is controversy over the construction of a large dam on the Taravo River in Olivèse. Despite the positive aspects of hydropower, being a renewable and reliable energy source with no Greenhouse Gas emissions, there may be considerable environmental impacts through other channels. Decisions regarding the building of hydroelectric facilities therefore require a case-by-case approach. The environmental impact is multi-dimensional, depending to a large extent on site characteristics and the type and size of the hydropower plant. A poorly-chosen site for hydroelectric development would require a whole array of costly monitoring and mitigation measures later on (Botelho *et al.*, 2017). As such, environmental valuation and Benefit-Cost analysis can be valuable tools for decision-makers, to the extent that they translate positive and negative impacts into the same units of measurement. Furthermore, given the case-by-case nature of this issue, DCEs seem to be an apt way of assessing the environmental impacts of large hydropower plants. The impacts on biodiversity, landscape, water resources and historical remains are among the most common identified in the literature (Botelho *et al.*, 2017).

A pioneering contribution to the use of DCE to value the environmental impacts of hydropower is the work of Sundqvist (2002) on Swedish households. He selected the downstream water level (indirectly reflecting the impact on flora and fauna), erosion, vegetation and the impact on fish life as the attributes. Likewise, Han *et al.* (2008) applied this method to the Tong river in South Korea. The selected river attributes were the tree population in a protected forest, the number of protected animal species, the number of protected vegetal species and the protection of historical remains.

For France, the only application of a DCE to help decision-making for river management is Creti and Pontoni (2014). This work was focused on the Aspe river in France, and is related to the discussion of hydroelectric dams, as there were 16 hydropower plants on the River Basin at the moment of the study. In addition, the river's ecological status was severely affected in 2007 by the accidental discharge of 17,000 liters of Potassium Hydroxide. This shock undoubtedly had an impact on individuals' preferences, as water pollution was an issue of concern at the time of the study. The selected attributes were water quality, fish population and hydro-morphology. In their results, the fish population was the most-valued attribute.

A DCE evaluation has also been conducted in France for the economic valuation of the WTP for the services provided by urban green spaces and peri-urban forests in the city of Nancy (Tu *et al.*, 2016). Moreover, the French National Research Institute of Science and Technology for the Environment and Agriculture (IRSTEA) and the *Commissariat général au développement durable* (CGDD: the National Commission on Sustainable Development) undertook an evaluation of the WTP for biodiversity preservation in urban forests at the national level (CGDD, 2016).

Finally, a recent application of the DCE method to estimate the WTP for reducing the environmental impacts of hydroelectric dams was undertaken in Portugal (Botelho *et al.*, 2015). The impacts on the landscape, fauna and flora, noise emission and heritage destruction were the selected attributes. The authors used a Binary Logit model, without the status-quo alternative. Notably, this study did not consider a specific river in Portugal, but rather addressed electricity production from hydropower in general, with nuanced environmental impacts as the levels.

3 The economic valuation of the taravo river basin's ecosystem services

3.1 The five valuation steps

The main steps in this valuation were as follows:

- *The choice of the preference-elicitation method, between contingent valuation and DCE:* After a thorough review of the existing economic literature and validation from the different parties involved in the project, the DCE method was chosen for this valuation, as the level of detail from the selection of attributes was better-suited for the expected outcomes of this project.
- *The selection of attributes and levels for the DCE:* The attributes were selected following valuable advice from experts in hydrology and environmental engineering who had previously worked at the Taravo River. In most cases, the experts were able to be assembled together, which allowed direct exchange and constructive discussions to select a common set of key attributes. We had to prepare these meetings in advance to provide support material on data related to the Taravo (environmental data, socio-economic data, *etc.*) and ecosystem services in general. The criteria for attribute selection included the ecosystem services provided by the river, the specific characteristics of the local population and data availability. The latter was key for the selection of credible evidence-based levels for each attribute.
- *Survey design and pre-testing:* The first versions of the survey were presented to pilot groups of respondents in order to draft the final version based on their reactions and feedback.
- *Survey administration:* The survey was carried out via in-person interviews by a team of four surveyors.
- *WTP estimation:* Four econometric models were estimated using the data obtained from the survey.

The following section discusses the aspects taken into account in the design of the study, starting with a brief description of the study site.

3.2 The design of the study

3.2.1 The study area

The Taravo River Basin is located on the South West of the French island of Corsica, between Ajaccio and Propriano, covering a surface of 490 km^2 and 31 different municipalities. This is a sparsely-populated area with a population density of 15.44 people/km^2, as compared to 122 in France (*Institut national de la statistique et des études économiques*: INSEE, and the World Bank). The Taravo and its tributary streams make up a hydrographic network of roughly 1500 km. With a length of approximately 65 km, the Taravo River is the third largest watercourse in the island and the largest in South Corsica. Its source is located in the Flasca forest (to the north of Monte Grosso in Palneca) at an altitude of 1580 meters, and its mouth is at the Valinco Gulf, near Olmeto.

3.2.2 The survey design

The survey consisted of three parts. In the first, basic sociodemographic information about the respondents (age, gender, sector of activity, village of residence, distance from their home to the river, etc.) was collected, as well as information on the use that they make of the river (recreational activities, water extraction, frequency of visits, *etc.*), their perception of its current ecological status, and the importance they assign to its ecological preservation and restoration. In addition, people were asked to rank the main services provided by the river, as a training exercise for the DCE questions.

The second part of the survey presented the relevant information regarding the results of recent evaluations of the river's status, the main ecosystem services it provides, and the main challenges for its future management. The main attributes of the DCE were then presented in detail, and respondents were invited to answer a binary-choice set, where one scenario dominated the other, in order to illustrate the type of questions to be asked. Visual aids were also used in this part of the survey.

Last, nine choice sets were presented to the respondents who were asked to indicate their preferred scenario for each set. Each set comes from multiple alternatives to a baseline, where each alternative differs in terms of attribute provision levels and costs (see Sect. 3.2.4 on the attributes and provision levels). Nine sets is a relatively large number and could lead to fatigue bias. However, this number was deemed necessary in order to compensate for the small number of expected participants, given the short timeframe available for the survey. Note that these choice sets are by nature hypothetical scenarios, but they were thoroughly constructed with input from the experts to make them realistic in terms of the induced costs of each proposal in relation to the attribute level (sanitation costs, for example). Note too that in parallel, we also conducted a poll to record individuals' opinions regarding the construction of a large hydroelectric dam in the Taravo River, at the request of South Corsica *Département*.

3.2.3 Sample selection and descriptive statistics

The survey was conducted on a sample of 106 people living along the Taravo River Basin, out of a population of about 11,000 inhabitants in 2014 (INSEE). This sample is admittedly rather small in absolute terms, compared to what is found in the literature (the smallest sample in Creti and Pontoni (2014) is 200 people). This limitation was known from the beginning of the study and was taken into account in order to minimize the risk of losing statistical power. Interviews were conducted face-to-face over a wide and sparsely-populated geographical area, making data collection difficult and time-consuming. For this reason, every day we checked that the respondents were a representative sample of the whole population, both in terms of socio-economic and geographic profile (socio-professional categories, ages, *etc.*, for each village). Statistically, 106 respondents corresponds to a reasonably standard Confidence Level of 90% and a Margin

Table 1. Descriptive statistics.

	Min	Max	Mean	SD
Age	19	82	49.7	17.7
Distance from the river (meters)	2	15,000	3770	3583
	Daily	Once a week	Once a month	Less frequently
Visit frequency	12%	37%	23%	28%
	Very bad	Bad	Acceptable	Good
Opinion about the current state of the river	31%	28%	26%	15%
	Yes		No	
Direct user	50%		50%	
Recreational user	77%		23%	
Priority of river preservation	87%		13%	
	Male		Female	
Gender	71%		29%	
Sample size	106			

of Error (the percentage that the populations responses deviate from the sample) of 8%, which is higher than the normal 5% but still a reasonable number. The econometric regression results, despite this issue, appear to be robust, as the main coefficients of interest are statistically significant.

The respondents were aged between 19 and 82, with an average age of 49.7. The average distance from their home to the river was 3.8 km. The respondents seem to have a strong sense of belonging to the river, as river preservation was a priority for 87% of them. In addition, 77% stated that they carried out a recreational activity on the river. Finally, the bad reputation of the river was also evident, as over half of the respondents considered that it was in a bad ecological condition. These (and other) results are set out in Table 1.

The distribution of the population in the upper, middle and lower sectors of the River Basin was the baseline for the geographical distribution of the sample. Before carrying out the analysis, we expected to find a higher WTP from respondents in the lower sector, as they have relatively higher incomes (INSEE). This could reflect greater affluence of tourists, due to this sector's seaside location.

The respondents were moreover asked about their sector of activity. In the statistical analysis, activity sectors were regrouped into three broad categories, according to their expected WTP for the Taravo River's ecosystem services. The first is business owners in the Agriculture and Tourism sectors, as they have both relatively high revenues and a direct economic interest in the ecological preservation of the river. Given their sense of public service and general interest and their ties to the local territorial community, civil servants were also expected to have a higher WTP, and appear in the second category. The third group consists of all the other respondents, covering mostly students and retired people. Unlike most stated-preference work, individual incomes were not recorded directly. Our local partners in Corsica advised against doing so during the survey-design phase, as this question might be considered as disrespectful in the island's culture. The geographical and activity sector groups described above helped to compensate for this lack.

Table 2 presents the descriptive statistics by these two groups, together with the total WTP estimated in the proxy CV question. The results seem to confirm our preliminary hypothesis.

3.2.4 The selection of attributes and provision levels

Both the underlying ecological processes and the links between humans and ecosystems vary across sites, population and temporal scales. As such, it was essential to understand the particular context of the study site in order to adequately select the attributes for the DCE. In general, the context is key for the choice of attributes, which is for example central for the identification of general guidelines for ecological monitoring, modeling and mapping (Boyd *et al.*, 2016).

We had a number of consultations with technical experts in hydrology and ecology during the DCE design phase, whose knowledge of the Taravo River Basin was vital in describing the local context. The goal of these focus groups was to define the DCE attributes, taking into account the recommendations from the literature (Boyd *et al.*, 2016). The meetings with the technical and steering committees served as the first of these focus groups. These meetings produced the list of the main ecosystem services provided by the study site, which was a key input in attribute selection. A second consultation was made with the hydrology experts who had carried out the diagnostic study on the ecological condition of the Taravo in 2013. Finally, the third focus group was made with environmental experts from the South Corsica *Département*.

Given the complexity involved in linking biophysical and economic analyses, the selection of the DCE attributes shares some of the same challenges as the selection of relevant ecosystem services indicators in general. As such, some of the guidelines and recommendations for the selection of ecosystem-service indicators were taken into account at this stage. For instance, evidence suggests that indicators that are more proximate to human welfare within an ecological-production framework may improve accuracy and reduce bias, including cognitive errors, confusion, speculation and scenario rejection (Boyd *et al.*, 2016).

Regarding the discussion over the use of aggregated or disaggregated indicators for behavioral modeling and valuation, findings suggest that disaggregated detailed indicators

Table 2. Descriptive statistics and WTP by geographical distribution and activity sector.

	Upper taravo	Middle taravo	Lower taravo	Entire basin
Official population distribution	31%	25%	44%	100%
Sample distribution	35%	26%	39%	100%
Activity sector				
Business owners	30.5%	29.5%	22.5%	27%
Civil servants	30.5%	18.5%	35%	29%
Other sectors	39%	52%	42.5%	44%
Mean WTP (SD) in Euros				
Total	57.22	47.04	74.3	61.18
	(28.24)	(20.72)	(43.06)	(34.9)
Business owners	70	42.5	100	71.79
	(35.77)	(29.64)	(61.85)	(48.54)
	50	52	75.86	62.4
Civil servants	(20.98)	(19.24)	(42.37)	(34.23)
	52.86	47.86	59.41	53.47
Other sectors	(24.94)	(15.78)	(23.24)	(21.7)

are more relevant for scientific experts, users and those with more extensive experience of the resource in question. Conversely, generalized aggregate indicators work better for the general public, non-users and those with little or no experience of the resource. In addition, the identification of attributes is a more open-ended process in a non-use than a use value context. There are certainly fewer clear guidelines, with no insight in this respect from Revealed Preference analyses. However, the fundamental properties of attributes remain similar regardless of their use context. Last, the units of account have to satisfy two main conditions: they must have unambiguous interpretations and should allow the indicators to be understood in the same way by laypeople and experts (Boyd *et al.*, 2016).

Taking all of these considerations into account, we selected three river attributes. We then carried out pilot studies on small groups to test the clarity and relevance of the attributes, the acceptance of the payment vehicle, the amounts of the bids, and reactions to the method proposed. We also tested the number of choice sets presented in order to minimize fatigue bias. The feedback from these pilot studies was taken into account in the final experimental design.

In particular, the first attribute is linked to the ecosystem services of water quality and outdoor recreation. To this end, the swimming ban on 23 km of the river was used to determine the provision of this attribute. The number of kilometers where swimming is banned is an excellent linking indicator of water pollution, as it is easily understood, has a direct impact on human welfare, and is particular to the context of the Taravo River Basin.

The provision levels were determined based on the two main sanitation challenges affecting water pollution in the Taravo River, and a realistic program addressing these issues and lifting the swimming ban was proposed in this DCE. The first issue is the treatment of waste from pig breeding in the upper part of the basin, as this does not comply with basic sanitation standards. In consultation with hydrology experts who have worked on the Taravo River, it was estimated that the correct treatment of this waste (through centralized collection and incineration) would reduce the swimming ban to 10 km (corresponding to the distance between the Pinu and Trinité bridges). This was called the intermediate provision level. The second issue concerns the lack or malfunction of the water-sanitation facilities in various municipalities.

The second attribute was the maintenance and restoration activities on the river. This had three provision levels: basic, intermediate and comprehensive. The highest provision level included interventions to preserve the correct hydrological functioning of the river, and the treatment of riparian vegetation and *Fallopia japonica* (an invasive vegetal species). The third attribute corresponded to the enhancement of cultural (through the restoration of historic remains and buildings) and natural heritage (through the development of infrastructure for outdoor sports and activities).

Last, local taxes over the next five years were chosen as the payment vehicle to reflect costs. These took four values: 15, 25, 37 and 52 euros. A five-year period was chosen, as this was the time frame for a comprehensive sanitation plan in accordance with the highest level of the water-quality attribute. All of the attributes and provision levels are summarized in Table 3.

3.2.5 The experimental design

Given the number of attributes and provision levels selected, there are 144 possible combinations of scenarios $\left(4^2 \times 3^2\right)$. Excluding repeated scenarios and repeated questions which only differ in the order of the scenarios, there are 10,296 unique dichotomous choice questions that could be presented to respondents. The obvious impracticality of asking all the possible questions justifies the use of statistical software to identify an optimal design. The final design had to be efficient both in terms of orthogonality, in order to obtain significant coefficients, and respondent comfort, so as to avoid fatigue bias (Johnson *et al.*, 2007).

In addition, the experimental design helped address some of the issues particular to this study, namely the time

Table 3. Attributes and provision levels.

Attribute	Levels
Water quality (swimming-ban length)	– 23 km – 10 km – 0 km
River-restoration activities	– Basic – Intermediate – Comprehensive
Heritage-enhancement actions	– No action – Cultural heritage only – Natural heritage only – For both cultural and natural heritage
Investment through local taxes	– 15 EUR – 25 EUR – 37 EUR – 52 EUR

Table 4. Choice-Set Example.

Attribute	Choice A (baseline)	Choice B	Choice C
Water quality (swimming-ban length)	23 km	0 km	0 km
River-restoration activities	No action taken	Intermediate level	Comprehensive level
Heritage-enhancement actions	No action taken	No action taken	No action taken
Local tax	0 EUR	15 EUR	25 EUR

constraints, limited resources to conduct the survey, and the low population density in the Taravo basin, from which a relatively small sample size was foreseen. As in Perni and Martinez-Paz (2017), the experimental design was generated using the *support.CEs* package in R software, which is based on orthogonal main-effects arrays. In particular, the rotational method was used to select and randomize the questions into blocks (Aizaki, 2012).

The final design consisted of 36 questions, split into four blocks of nine questions each. Each question consisted of two alternative improvements to the river's current condition, implying a hypothetical increase in municipal taxes over the next five years, and the opt-out alternative. Table 4 presents one example of the 36 choice sets in the experiment.

3.3 Econometric analysis

The idea that the value of a good or service reflects its specific attributes, rather than the good itself, follows the characteristics theory of value in Lancaster (1966). DCE are based on Random Utility Theory (RUT), which is consistent with choice-behavior theory. In RUT, the latent utility implied by the choice of an alternative is explained by a deterministic component and a stochastic error. The utility of individual $i\,(i = 1, \ldots, I)$ from alternative $j(j = 1, \ldots, J)$ in choice set $m(m = 1, \ldots, M)$ is given by:

$$U_{ijm} = b_{ijm}s_{ijm} + \gamma_i z_i + v_{ijm} \quad (1)$$

$$d_{ijm} = \begin{cases} 1, if & U_{ijm} \geq U_{ikm} \forall j, k \in c_m \\ 0, & otherwise \end{cases} \quad (2)$$

where, for each respondent i, s_{ijm}, is the $(s \times 1)$ attribute vector of alternative j, z_i is a $(g \times 1)$ vector of observable respondent socio-demographic characteristics, b_{ijm} and γ_i are respectively $(1 \times s)$ and $(1 \times g)$ row vectors of marginal-utility coefficients and v_{ijm} is an error term. From equation (2), an alternative j from choice set m is selected if and only if it yields the greatest utility for the respondent.

Once the survey responses are available, a first approach would be to estimate equation (1) directly, either from a Conditional (based on the attributes) or a Multinomial (based on the respondents' characteristics) Logit regression, or a combination of the two. However these approaches have been criticized, notably for the IIA assumption, which is likely to be violated in practice. Under the IIA, the error terms v_{ijm} are distributed independently of each other and the parameters are distributed identically across the population, without any respondent-specific variation in preferences. Thus, either all respondents have the same preferences or these are only determined by observable characteristics. This in addition implies that changes in the choice set do not affect the choice-probability ratio between two alternatives in the choice set.

The IIA can be relaxed via the use of other econometric models that yield more accurate results than the Conditional Logit. One example is the Random Parameters Logit (RPL), also called the Mixed Logit Model (MXL), which accounts for unobserved preference heterogeneity (Bliem *et al.*, 2012; Lizin *et al.*, 2016; Asefaw *et al.*, 2016). In other words, the RPL allows the parameters associated with alternative-specific attributes to vary randomly across individuals within a population, so that different respondents can have different preferences. Formally, this can be written as:

$$b_{ijm} = \beta_{jm} + \omega_i \quad (3)$$

Thus, from equations (1) and (3):

$$U_{ijm} = \left(\beta_{jm} + \omega_i\right) s_{ijm} + \gamma_i z_i + v_{ijm}$$
$$= \beta_{jm} s_{ijm} + \gamma_i z_i + \omega_i s_{ijm} + v_{ijm}. \quad (4)$$

Here β_{jm} is a vector of population-mean coefficients and ω_i is the stochastic deviation representing individual tastes relative to β_{jm}. It follows from $\omega_i s_{ijm}$ in equation (4) that the error term is correlated with the alternative attributes.

Both Conditional Logit and Random Parameter models were used to estimate respondents' indirect utilities from their choices[5].

4 Results and discussion

Table 5 presents the main estimation results, using either the Conditional or Mixed Logit model (the latter known as the RPL). The coefficients for the attribute variables are of the expected sign and are all significant, regardless of the econometric model and the explanatory variables used in the estimation. For each model, the first specification includes the attribute variables only, while the second adds their interactions with the socioeconomic variables.

The interactions were significant in two cases under RPL estimation: first, the interaction of water quality with a dummy for the respondent working in the Agriculture and Commercial sectors; and second, the interaction between ecological restoration and a dummy for the respondent living in the upper sector of the basin. The WTP was found to be above average for the former and below average for the latter. In addition, according to the results from the conditional logit model, having a bad perception of the current status of the Taravo was found to have a positive impact on the WTP for improving water quality. However, this result did not hold when relaxing the IIA assumption.

The differences in the WTP for certain attributes can be partly explained by income, as those with higher-than-average WTP to reduce water pollution are mainly farmers and business owners, while those in the upper sector have lower incomes than individuals in the rest of the basin. Moreover, these results may reflect some of the specific incentives faced by each group of respondents. Respondents in the first group may well have economic incentives to improve water quality: this may increase agricultural productivity for farmers, and make the area more appealing for tourists in the case of business owners. On the contrary, maintenance and restoration activities may be less appealing for residents in the upper sector of the basin, as there is less need for restoration and maintenance activities, and the invasive *Fallopia Japonica* is not present there.

Using the coefficients from the RPL estimation, the WTP per attribute appears in Table 6. The calculation of point estimates, standard errors and significance levels was based on the "delta method" approximation. The population has a WTP of 48.65 euros for the maximum provision of water quality, 45.54 euros for full maintenance and restoration activities, and 33.89 euros for the enhancement of both cultural and natural heritage and landscape.

The results are in line with those in the literature. Bliem *et al.* (2012) found that people were willing to pay 68.21 euros per year to improve water quality from moderate to very good. Moreover, individuals were willing to pay up to 68.47 euros per year for the same attribute and levels according to the results in Lizin *et al.* (2016), who also found that people were willing to pay 43.45 euros for a major river restoration. In Botelho *et al.* (2015), people were willing to pay 50.12 euros per year to avoid the loss of cultural heritage from the construction of hydroelectric dams in Portugal. Regarding the WTP for all the attributes, the results from this DCE are close to the 144 euros per year figure for the Aspe River in the South of France (Creti and Pontoni, 2014). Moving away from Europe, it is interesting to see how changes in purchasing power seem to affect the WTP for ecosystem services. For instance, Asefaw *et al.* (2016) found that respondents were willing to pay 19.69 euros to obtain the greatest possible water-quality improvement in the Shiyang river in China, which is in line with the 17 euros in Shi *et al.* (2016) for the Wei River in China. Finally, in Brazil Kahn *et al.* (2017) found that people were willing to pay 32.68 Reais (8.80 euros) per year for the full restoration of Rio Paraiba do Sul. A summary of this work appears in Table 7.

5 Conclusions

The results from this DCE provide the first ever indicators of the economic value of ecosystem services for the Taravo River Basin, on the issues of water quality, restoration activities, enhancement of cultural and natural heritage and landscape. Four econometric estimations were considered (two Conditional Logit, two Mixed Logit), and we found that, on

[5] The particular model estimated is: $V_{ij} = ASC_{sq} + \beta_w WQ + \beta_m MR + \beta_{ch} CH + \beta_{nh} NH + \beta_{cnh} CNH + \beta_{tax} TAX$ where ASC_{sq} is the Alternative Specific Coefficient, a dichotomous variable: zero for observations corresponding to the opt-out alternative in each question, and one for those corresponding to the choice alternatives. The ASC_{sq} can be interpreted as the utility of switching from the status quo. The marginal utilities of river ecosystem services (water quality, ecological maintenance and restoration, and cultural- and natural-heritage enhancement) and the payment mechanism are estimated by the remaining coefficients (β_w, β_m, β_{ch}, β_{nh}, β_{cnh} and β_{tax}). Based on Kahneman, and as is common practice in stated-preference analysis, the ratio of marginal substitution (RMS), dividing each river attribute coefficient by the monetary attribute, approximates the WTP for each attribute $k : RMS = WTP_k = -\frac{\beta_k}{\beta_{tax}}$. Likewise, the welfare gains from a particular Ecosystem-Service scenario can be estimated via the Compensating Surplus (CS) with respect to the status quo; CS is: $CS = -\frac{1}{\beta_{tax}}(U_{sq} - U_{sn})$ where the indirect utilities associated with the status quo U_{sq} and the alternative scenario U_{sn} are estimated using the coefficients from the econometric regression.

Table 5. Econometric Estimations

	Conditional Logit		Mixed Logit	
	(1)	(2)	(3)	(4)
Mean				
ASC	16.99	17.59	21.33	22.23
	(0.03)	(0.02)	(0.01)	(0.00)
Water Quality	0.140***	0.0891***	0.216***	0.169***
	(11.37)	(5.54)	(8.03)	(7.23)
Cultural Heritage	1.290***	1.298***	1.416***	1.363***
	(4.36)	(4.25)	(4.06)	(3.94)
Natural Heritage	1.952***	1.920***	2.074***	1.994***
	(5.78)	(5.52)	(5.24)	(5.12)
Cultural and Natural Heritage	2.678***	2.592***	2.877***	2.714***
	(6.93)	(6.56)	(6.25)	(6.08)
Ecological Restoration	0.849***	1.013***	1.123***	1.216***
	(11.23)	(10.49)	(9.62)	(9.86)
Tax	–0.0680***	–0.0705***	–0.0821***	–0.0801***
	(–8.97)	(–9.02)	(–8.16)	(–8.70)
Water Quality X Private Sector		0.134***		0.144***
		(4.82)		(3.46)
Ecological Restoration X Upper Basin		–0.331*		–0.366*
		(–2.37)		(–2.27)
Water Quality X Negative Perception		0.0497*		
		(2.55)		
SD				
Water Quality			0.137***	0.117***
			(5.85)	(5.43)
Cultural Heritage			–0.00243	0.0216
			(–0.01)	(0.04)
Natural Heritage			–0.114	–0.131
			(–0.09)	(–0.12)
Cultural and Natural Heritage			0.00108	–0.0294
			(0.00)	(–0.05)
Ecological Restoration			0.204	0.00698
			(0.77)	(0.01)
Observations	2754	2679	2754	2679

t-statistics in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

average, respondents are willing to pay 128 euros per year for the enhancement of the three services selected. This result is in line with findings from recent contributions. Beyond this average, a spatial analysis confirms the different WTPs on the river basin (upper, middle and lower Taravo), for socio-economic and environmental issues, human-nature interactions, *etc*., that differ between the areas of this territory.

This article is obviously open to improvement and future research. First, future research could concern sample size (the Margin of Error of this study was 8%). Indeed, optimal sample size calculation should be executed, as an under-powered study may lead to poor insights and weak decisions by policymakers. Given the size of the population in this study, the optimal sample size would be about 300 respondents. However, we can assume the specific attachment of this island population to its natural ecosystems (Casula, 2006) (and further confirmed here) makes our results especially stable over time.

Second, future research could compare these WTPs for conservation to known alternative local projects, typically land-use planning projects. The construction of a hydroelectric dam on this river would have significant ecological consequences in the long term, affecting biodiversity and the provision of ecosystem services (Botelho *et al.*, 2017). Indeed, the European Commission (EC) identifies hydroelectricity as a renewable energy but not a sustainable one as it undermines the functioning of ecosystems (EC, 2021). For the specific services evaluated in this DCE, a dam would severely impact landscape quality, and reduce opportunities for outdoor recreation, especially swimming and fishing.

Table 6. WTP per Attribute (RPL)

Attribute	Sample group	WTP
Water quality (swimming-ban removal)	Entire sample	EUR 2.12*** / km (0.31) EUR 48.65*** to completely lift the 23km ban (7.12)
	Business owners	EUR 3.92** / km (0.58) EUR 89.99*** to completely lift the 23km ban (13.45)
River-restoration activities (comprehensive level)	Entire sample	EUR 45.54*** (5.64)
	Upper Taravo	EUR 31.83*** (5.64)
Cultural-heritage enhancement	Entire sample	EUR 17.02*** (4.19)
Natural-heritage enhancement		EUR 24.90*** (4.19)
Cultural- and natural-heritage enhancement		EUR 33.89*** (4.84)

t-statistics in parentheses.
* $p < 0{:}05$, ** $p < 0{:}01$, *** $p < 0{:}001$.

Table 7. Benchmark Analysis Results.

Author	Year	Country	Attribute	WTP (Euros)
Bliem *et al.*	2012	Austria	Water Quality	68.21
Lizin *et al.*	2016	Belgium	Water Quality	68.47
Lizin *et al.*	2016	Belgium	River Restoration	43.45
Asefaw *et al.*	2016	China	Water Quality	19.69
Shi *et al.*	2016	China	Water Quality	17
Kahn *et al.*	2017	Brazil	River Restoration	8.8
Botelho *et al.*	2015	Portugal	Cultural Heritage	50.12
Créti and Pontoni	2014	France	All the Attributes	144

Third, from a technical point of view, our evaluation contributes to the expansion of non-market evaluation methods but only a few ecosystem services. A river basin is a complex ecosystem that may encompass a variety of landforms, coastlines, forests, agricultural areas, cities, *etc*., which means it can shape a huge variety of ecosystem services. Note that the application of DCEs is not limited to any one type of ecosystem and that significant progress has also been made in other areas. Apart from rivers and other watersheds, DCEs have already been applied to forests (Tu *et al.*, 2016; CGDD, 2016) and marine areas (Wattage *et al.*, 2011), amongst others. Future research could better embrace the number and complexity of intricately-linked attributes.

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