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Heterogeneity in citizens' valuation of ecosystem services from a Mediterranean Sea-connected lagoon restoration: Evidence from Tunisia

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Abstract

The North African region's lagoon ecosystems face numerous challenges, including urbanization, wastewater pollution, and overexploitation. The negative impact of these challenges on the ecological health of lagoons is evident, leading to socioeconomic consequences that have proven to be detrimental. Therefore, we conducted a choice experiment to assess citizens' preferences for Mediterranean Sea-Connected lagoon restoration in Tunisia, as a case study and their willingness to support the EcoPact endeavor to enhance the prevailing circumstances and halter environmental degradation. This research devised two improvement scenarios and utilized a Latent Class Model to gauge citizens' utility in a lagoon restoration. The results revealed two citizen classes, "Pro-restoration" and "Reluctant to Restore". The majority are pro-restoration citizens willing to voluntarily pay (WTP) up to $165.58 for one-year contribution for a high-impact scenario. The other class, Reluctant to Restore, appear to recognize the value of the project's attributes, as evidenced by their significant WTP for high-level attributes. However, they still prefer to maintain the current situation for other reasons, resulting in an insignificant WTP for the overall high or medium scenario. The results showed that the aggregated benefits is very close to the required project cost for the high-impact scenario, suggesting that the project is almost viable only if the improvement is highly significant. Hence, further evaluation is required to validate these results.

Keywords: *Bizerte citizens' preferences, Latent heterogeneity, Choice experiment, Lagoon restoration, Developing countries.*

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1. Introduction

Lagoons are among the most productive and ecologically significant ecosystems, offering many goods and services vital to local communities' well-being (El Zrelli *et al.*, 2021). These dynamic environments serve as crucial food sources, supporting fisheries and contributing to local economies and food security. Beyond their direct provisioning of resources, lagoons also offer recreational opportunities, including water sports, bird watching, and scenic spaces that enhance community leisure and tourism activities (Conde *et al.*, 2015; Jorge *et al.*, 2023). Moreover, lagoons are essential in supporting various industrial processes, such as salt production and aquaculture, which provide employment and stimulate economic growth in coastal regions. They deliver critical ecosystem services, including water purification, climate regulation through carbon sequestration, and protection against storm surges, thereby mitigating the impacts of climate change. Additionally, lagoons possess rich cultural legacies, deeply embedded in the history and traditions of local communities, fostering a sense of identity and heritage (Lopes and Videira, 2013; Newton *et al.*, 2018). Their unique biodiversity (Tonin, 2018), also makes them prime sites for ecotourism, attracting visitors interested in experiencing the natural beauty and diverse wildlife of these Mediterranean coastal landscapes (Newton *et al.*, 2018). However, despite their immense value, lagoons face significant vulnerability and threats, primarily from pollution caused by human activities, including industrialization, agriculture, and climate change, which profoundly affect water bodies. This susceptibility manifests by introducing various organic, inorganic, and nutrient pollutants (Newton *et al.*, 2018). Excessive amounts of pollutants, particularly nitrate and phosphate, can lead to the eutrophication of marine ecosystems (Elizabeth and Joy, 2018; Owa, 2013).

Globally, the adverse impacts of marine pollution and freshwater contamination on human health and their contribution to the loss of local sense of place and cultural identity have been extensively documented (Mechler *et al.*, 2019). For example, recent research by McNamara *et al.* (2021)and will continue to experience, extensive non-economic loss and damage (NELD investigated stakeholder perceptions of non-economic loss and damage in Pacific island contexts, aligning with prior studies and elucidating anticipated risks and impacts such as escalating temperatures, fish protein shortages, and substantial biodiversity threats. Consequently, ecological restoration is essential for preserving marine ecosystem services, fostering conservation efforts, and enhancing human welfare (Stainback *et al.*, 2020; Paramana *et al.*, 2023).

The body of literature highlights the necessity of lagoon restoration (Tuan *et al.*, 2014; Clara, 2018; Beharry-Borg and Scarpa, 2010; Smyth *et al.*, 2009; Eggert and Olsson, 2009; Beharry-Borg and Scarpa, 2010; Wang *et al.*, 2013; Newton *et al.*, 2018; Pacifico *et al.*, 2025) prompting policymakers to enact directives to protect ecological well-being, animal welfare, and water standards by aiming for sustainability. However, restoration has financial costs to society. While pollution is a pressing issue in developing and developed countries, its significance is particularly pronounced in developing nations due to the wide use of unsustainable industrial waste management systems. Tunisia is a pertinent example of a developing country grappling with pollution challenges.

Croitoru and Sarraf (2010) documented the order of magnitude of marine pollution externalities in Tunisia. They conducted a study to measure the cost of water degradation in Tunisia due to inappropriate agricultural practices, transport, industry, and power generation. The estimated total cost was approximately $165.8 million[1] in 2004.

At a regional level, Bizerte Lagoon, located in northern Tunisia, represents one of the most productive marine ecosystems. It contributes to the country's GDP through fishery products,[2]

[1] 0.6% of the GDP in 2004 (INSTM, 2004).
[2] The total annual fishery production in 2020 was 62417 kg ≅ 62 tons (INSTM, 2020).

aquaculture, shellfish farming, and industrial activities. However, the region is suffering the consequences of misusing the lagoon. Untreated water sewage, lack of treatment plants, wastewater discharges, and gas emissions from factories installed around the lagoon represent the major causes of environmental degradation, making the lagoon unsuitable for reaction activities and commercial fishing. Moreover, the fish and seafood caught in the lagoon are unsafe for human consumption (El Zrelli *et al.*, 2021).

Because of these concerns, the EcoPact[3] project was implemented to enhance the socioeconomic and environmental situation in the Bizerte Lagoon. In particular, the project aimed at (1) reducing industrial pollution (i.e., atmospheric emission, liquid effluents, solid waste, and wastewater collection and treatment), (2) extending the artisanal port[4] of Manzel Abderrahmèn to reduce exposure to storms and increase its boat accommodation capacity, and (3) developing an esplanade to the east of Manzel Abderrahmèn port to improve the lagoon frontage of the region. Throughout an initial 5-year period, the project plans to significantly reduce indirect pollution impacting the Mediterranean Sea through an integrated and concerted approach.

The existing literature indicates that citizens in developed countries are generally willing to pay for ecosystem restoration (Anaya-Romero *et al.*, 2016; Birol *et al.*, 2006; Blasi *et al.*, 2023; Martínez-Paz *et al.*, 2013; Perni *et al.*, 2011; Xu *et al.*, 2020). This study contributes to the limited body of research on estimating the economic values of lagoons in developing countries (Ahmed *et al.*, 2005; Ali *et al.*, 2014; Diop *et al.*, 2016; Ghermandi & Nunes, 2013; Kairo *et al.*, 2008; Lal *et al.*, 2024; Rönnbäck *et al.*, 2007). It aims to enhance our understanding of how local communities perceive and prioritize various ecosystem attributes. Focusing on Tunisia, this study expands the geographic scope of discrete choice experiment (DCE) applications in environmental valuation, an area that remains underexplored in North Africa. It is the first lagoon valuation study conducted in Tunisia. It provides insights into the trade-offs people are willing to make for improved lagoon management, better water quality, and biodiversity conservation.

To our knowledge, no previous study has evaluated the benefits of restoring lagoons in Tunisia, particularly in Bizerte. This gap can be attributed to two main factors: first, there is a lack of economic information on lagoon restoration; second, few valuation studies have assessed the benefits or non-use values of lagoon restoration, especially in developing countries.

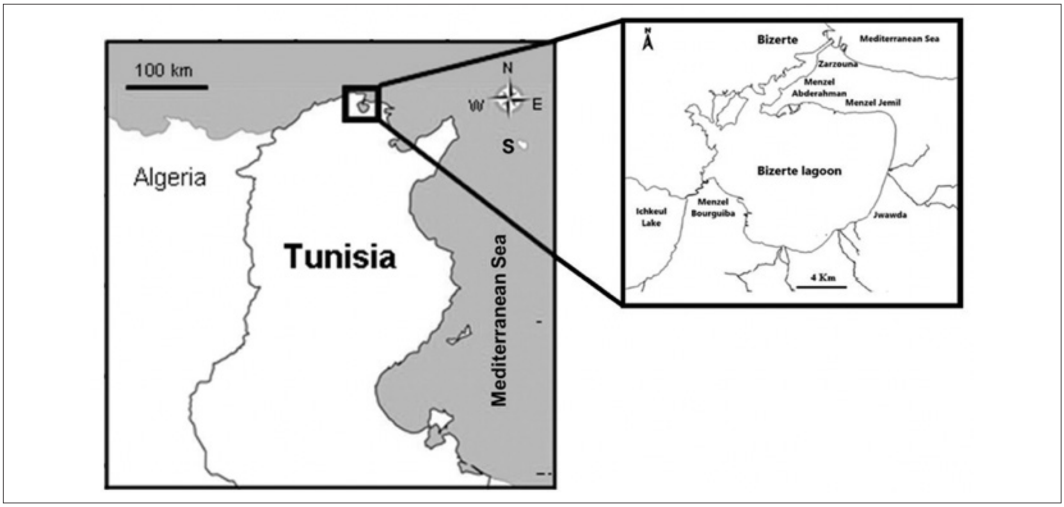
Additionally, using traffic light indicators as a communication tool enhances accessibility for non-expert respondents, ensuring that valuation outcomes reflect broader societal preferences. This study examines preference heterogeneity, offering deeper insights into variations in public attitudes toward lagoon conservation. These findings are particularly relevant for policymakers in developing countries, where financial and institutional constraints often limit effective environmental management. They highlight the support of Bizerte citizens for lagoon restoration, providing concrete evidence of the project's feasibility. The insights gained can help secure further backing and ensure a thorough evaluation of the project's potential viability. By offering valuable support to policymakers and illuminating social demand in Tunisia, this study may also guide future investments from international organizations, such as the Food and Agriculture Organization (FAO) and the World Bank (WB), fostering opportunities for development and investment in Tunisia.

The article is structured as follows. The next section overviews the Bizerte Lagoon, followed by a description of the design and the survey's conduction. Subsequently, the results are presented in Section 3, while the discussion and conclusions are offered in Section 4.

[3] Details of the project are available at http://ecopact.tn.

[4] The port is situated inside the Bizerte lagoon, approximately 5 km from Manzel Jemil and 4 km from Bizerte.

Figure 1 - Bizerte Lagoon, Main Industrial Agglomeration.



Source: Nasri et al. (2022).

2. Methods

2.1. *Study Area*

The Bizerte Lagoon is located on the northern coast of Tunisia. It has an area of 150 km² and an average depth of 7 m (Figure 1). The lagoon is connected to the Mediterranean Sea by a 7-km-long channel and Lake Ichkeul by the Tinja River, which supplies it with irregular fresh water. According to the National Institute of Statistics (INS,[5] 2023) census, approximately 300,000[6] people live around it (90% are in the city of Bizerte).

Bizerte is recognized for its industrial heritage, tourism, agriculture, fishing, and a significant commercial port, supported by free trade zones that encourage investment with tax exemptions (Ministry of Environment[7], 2016). The city is home to around 274 industrial companies, including 172 exporters, with 33.6% in textiles.

The region's agriculture produces 67,280 tons of fodder, 238,409 tons of cereals, and significant quantities of market gardening products, red meat, milk, white meat, and eggs. Additionally, it generates 6,229 tons of fishery products from five ports and 1,280 fishing fleets (Tunisian National Institute of Statistics[8], 2015).

The lagoon has an urbanized and industrialized shoreline. Moreover, it features 10 industrial zones spanning 250 hectares, with notable industrial activities are readily present, including heavy industries like SOTULUB and Bizerte Cement Factories employing over 45,858 people (located in the vicinity of Bizerte), dye works, and metallurgy (located in Menzel Jemil), making it one of the most threatened lagoons in Tunisia (Alves Martins *et al.*, 2015).

The Bizerte Lagoon has been used as the principal dumping place for water discharge directly or after primary treatment for several decades. However, it does not meet the standards set by the central government for used water treatment. The three wastewater treatment plants built in 1997 to treat the water before being dumped in the lagoon have decayed. Previous studies conducted in Bizerte (Barhoumi, 2014; Boukef *et*

[5] For more information, see: https://www.ins.tn/sites/default/files/publication/pdf/Estimation%20de%20%20la%20population%201er%20Janvier%202023.pdf.

[6] Represents approximately 187,000 in Bizerte center, almost 66,000 in Manzel Bourguiba, 31,000 in Manzel Jmil, and 21,000 in Manzel Abderrahmen. The total population of Bizerte was 600,012 inhabitants in 2023.

[7] https://www.ins.tn/en/statistiques/45.

[8] https://www.ins.tn/en/statistiques/45.

al., 2010; Toumi *et al.*, 2019) showed that the level of water treatment is low and the quality of treated water is non-compliant with discharge standards, particularly in terms of the levels of nitrate, phosphorus, polycyclic aromatic hydrocarbons, and heavy metals. These pollutants can be present in the atmosphere or the soil or especially dissolved in aquatic environments that are much more contaminated than others (Barhoumi, 2014). Moreover, the city of Bizerte has experienced atmospheric pollution due to industrial emissions in the region (Barhoumi, 2014), along with human population growth around the lagoon and maritime traffic that have increased wastewater discharge into the lagoon.

The lagoon is historically known for artisanal fishing activities, aquaculture, and, specifically, shellfish farming. The production from shellfish farming in the lagoon has decreased for over a decade (General Direction of Fishery Products and Aquaculture [DGPA] 2018) due to the rise in water temperature and the decrease in the level of dissolved O_2 (Bousbih[9], 2015).

2.2. *Data Collection: Choice Experiment-Based Survey*

This study used a DCE to investigate citizens' valuation of the benefits and the costs of restoration plans that EcoPact is considering implementing in the Bizerte Lagoon. A DCE is a quantitative research technique that presents individuals with alternative scenarios and asks them to state their preferred scenario (Hensher *et al.*, 2015). Several attribute levels describe each alternative scenario. Individuals' responses are then used to determine whether their preferences are significantly influenced by the attribute levels considered in the DCE. The responses are also used to determine the relative importance of the attributes. Individuals' WTP for the attribute levels of the alternative scenarios can also be estimated if a monetary attribute (e.g., the price or cost of each alternative) is considered in the choice experiment.

An initial and exhaustive list of attributes was prepared based on an extensive literature review on economic values of lagoons and wetlands (Hanley *et al.*, 1998; Brouwer *et al.*, 1999; Brander and Schuyt, 2004; Birol *et al.*, 2006; Christie *et al.*, 2006; Campbell *et al.*, 2008; Meyerhoff *et al.*, 2009; Barhoumi, 2014; Dang *et al.*, 2022; Pacifico *et al.*, 2024, 2025) to identify the most relevant attributes to consider in the choice experiment. The literature-based list of attributes and their levels was then refined using three focus groups (totaling 30 persons) of residents, experts, and scientists where the main objective is scoring the most relevant attributes according to the context, the urgent public intervention, and local priorities. This attribute selection and refinement process by focus groups is crucial for our choice experiment design, as it ensures that the attributes chosen are both relevant to the specific wetland or lagoon context and meaningful to the local population. Moreover, this participatory approach also helps to capture any unique local factors that might not be apparent from the literature review alone.

The attributes typically considered in such studies include environmental factors such as biodiversity and water quality and socio-economic aspects like fisheries production and recreational opportunities (Birol *et al.*, 2006; Tsegaw, 2012; Dixon *et al.*, 2021; Pacifico *et al.*, 2024).

After the focus group discussions, the attributes are typically scored and ranked based on their perceived importance and relevance. This process helps narrow the list to a manageable number of attributes for the choice experiment, usually between 4 to 6 attributes (Bliemer & Collins, 2016). The final selection of attributes considered in this study were water quality, biodiversity, recreational facilities, reduced gas emissions, and the cost of improvement which represent a one-payment cost to be voluntary paid. A description of the attributes and their corresponding levels is displayed in Table 1 below.

Water quality, biodiversity, reduced gas emissions, and recreational facilities were defined as categorical attributes with three levels each.

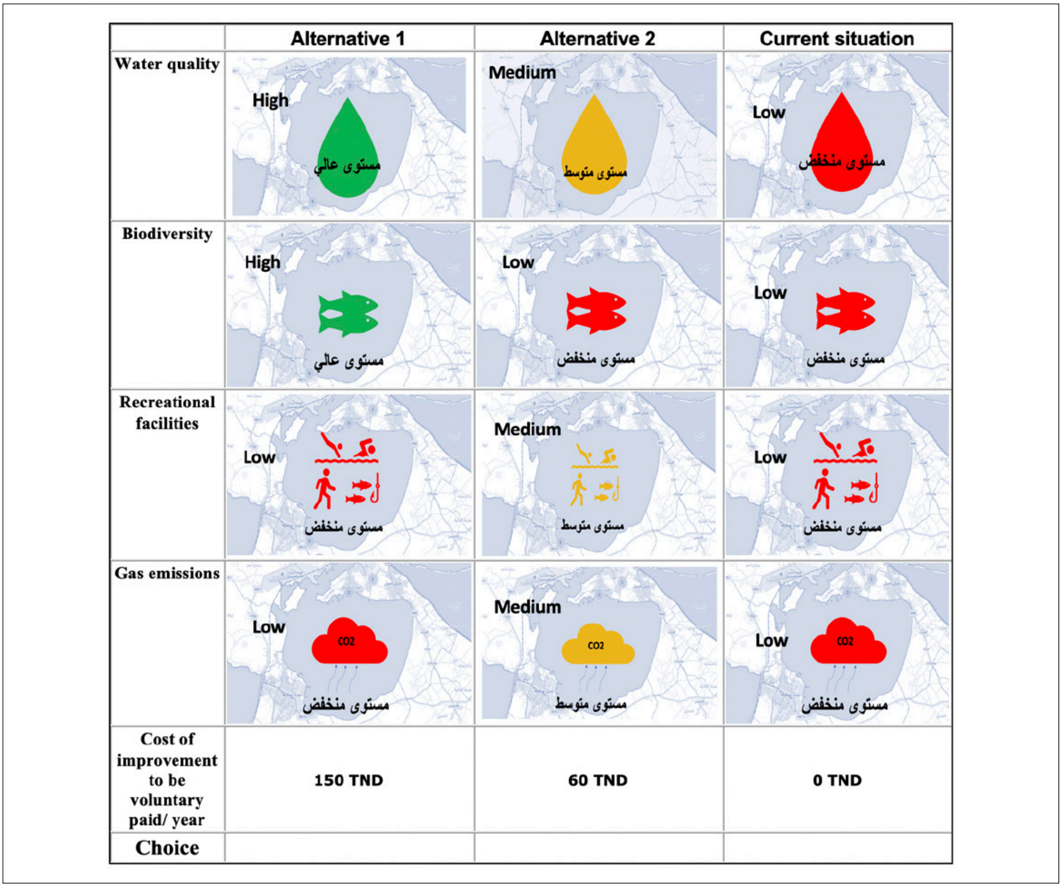
[9] Press at: https://inkyfada.com/fr/2015/07/27/bizerte-pollution-lac-peche-tunisie/.

Table 1 - Description of Attribute used in the DCE and Their Levels.

Attributes	*Attribute Levels*	*Variable Description in Model Estimation (Effect Coding)*
Water Quality	High (Green)	It refers to a high improvement level where water quality and clarity respond to the standards without a nasty smell and rehabilitated sanitation networks (1 = high water quality [green color], 0 otherwise).
	Medium (Amber)	It refers to a medium level of improvement where water quality, clarity, and smell improved compared to the current situation (1 = medium water quality [amber color], 0 otherwise).
	Low (Red)	It refers to poor water quality and clarity, with a nasty smell (–1 = low water quality [red color]).
Biodiversity	High (Green)	It refers to a high level of improvement where fauna (well-diversified species) and marine flora (nutritive algae) are diversified, valorisation of invasive species (1 = high biodiversity [green color], 0 otherwise).
	Medium (Amber)	It refers to a medium level of improvement where marine fauna and flora are more diversified compared to the current situation (1 = medium biodiversity level [amber color], 0 otherwise).
	Low (Red)	It refers to a situation where some species have disappeared while invasive species have appeared (–1 = low biodiversity [red color]).
Recreational Facilities	High (Green)	It refers to a high level of improvement where all activities are accessible (i.e., fishing, swimming, and walking) due to the development of the coastal infrastructure (1 = high recreational facilities [green color], 0 otherwise).
	Medium (Amber)	It refers to a medium improvement level where coastal infrastructure is moderately developed and at least one activity is possible (1 = medium recreational facilities [amber color], 0 otherwise).
	Low (Red)	It refers to a situation where the coastal infrastructure is not developed, and accessibility to activities is almost limited (–1 = low recreational facilities [red color]).
Decreased Gas Emissions	High (Green)	It refers to a high improvement level where air quality is good (filters installed), good visibility (i.e., almost clear emissions, decreased CO_2 emissions), and no smell (1 = high decreased gas emissions [green color], 0 otherwise).
	Medium (Amber)	It refers to a medium improvement level where average air quality (average CO_2 level in the atmosphere), average visibility (less gray emissions than before), and less smell compared to the current situation (1 = medium decreased gas emissions level [amber color], 0 otherwise).
	Low (Red)	It refers a situation with poor air quality is poor (significant CO_2 in the atmosphere does not meet discharge standards), poor visibility (gray emissions), and bad smell (–1 = low decreased gas emissions [red color]).
Voluntary Improvement Cost		TND[1] 0 (no payment), TND 30, TND 60, TND 90, TND 120 (40 EUR), TND 150 (continuous variable).

[1] *TND: Tunisian dinar.*

Figure 2 - Choice Example Cards.



Each was color-coded:[10] red for no improvement (i.e., the status quo), amber for moderate improvement, and green for high improvement. To further ease the understanding of the attribute levels and avoid confusion (Osman and Thornton, 2019), qualitative terms (i.e., low, medium, and high) were used to describe the traffic light color-coded levels (Fig. 2). Many studies supported the use of visual saliency instead of only including texts or values to avoid the hypothetical bias (Shr *et al.*, 2019; Delong *et al.*, 2021).

Respondents were invited to contribute voluntarily to support a five-year project through a one-time payment. We based our assumption on the belief that the improvement cost would be covered through voluntary payments. These contributions are likely more effective in Tunisia due to cultural norms and a social familiarity with charitable giving. Additionally, the proposed cost levels were informed by feedback from three focus groups, which helped refine the list of attributes considered for the questionnaire.

The combination of the five attributes and their levels resulted in 405 possible combinations (i.e., $3^{\wedge 4} * 5$). Ngene software was used to generate a Bayesian D-optimal (i.e., fractional) design that allowed robust estimation of all main effects (ChoiceMetrics, 2018). The priors for the

[10] This study adopted the concept of visual saliency, where both images and text were presented to respondents. This approach aimed to mitigate hypothetical bias and prevent confusion by providing a clear and tangible representation of the attributes evaluated. Recent research by Netusil *et al.* (2023) and Shr *et al.* (2019) showed that the respondents strongly preferred attributes represented by both image and text.

fractional design were obtained from a pilot of 30 respondents. The final experimental design (D-error = 0.07) consisted of 18 choice cards, each comprising three alternatives – two pairs of hypothetical options of improvements and the status quo (SQ). The final design had three blocks (i.e., each respondent was presented with only six of 18 choice sets). An example of one of the choice example cards used in this study is shown in Figure 2.

The survey was designed with a structured approach, divided into four sections to ensure comprehensive data collection and accuracy. The first section introduced the study's framework, outlining its objectives and methodology while emphasizing the voluntary nature of participation. Participants were required to review and sign an informed consent form, which assured them of anonymity and clarified that the research had no commercial purposes. The second section focused on the choice task and began with a detailed explanation of the survey's context, objectives, and the importance of providing unbiased responses. To minimize hypothetical bias, reminders and "cheap talk" techniques were included. Respondents were then presented with randomly assigned choice cards, designed to enhance realism and reduce potential bias. Each choice question included three alternatives: two hypothetical improvement scenarios and a status quo (SQ) option. The first two alternatives were described using five key attributes detailed in Table 1, with variations across different choice questions, while the SQ option remained unchanged, reflecting the actual condition of the lagoon at the time of data collection. The final section gathered socioeconomic information from respondents to provide context for the findings.

The survey was conducted face-to-face in Bizerte between February and April 2023, engaging 371 citizens. However, 10 respondents were identified as zero protestors and were excluded from the final dataset based on the criteria[11] stated by De Jong *et al.* (2023) and Xu *et al.* (2020). As a result, the final data used in the analysis was based on the responses of 361 respondents.

2.3. *Econometric Modeling of DCE Data*

According to Hensher *et al.* (2015), the total utility derived by an individual n from choosing an alternative j is equal to the sum of two components, a deterministic component and an indeterministic component ε_{nj} assumed to be independent and identically distributed:

$$U_{jn} = V_{jn} + \varepsilon_{nj} \quad (1)$$

Assuming that the deterministic component of the utility is linear-in-parameter, equation (1) can be written as follows:

$$U_{njt} = \beta X_{njt} + \varepsilon_{njt} \quad (2)$$

where β denotes the K × 1 vector of unknown utility parameters and, X_{njt} represents the attribute levels.

Average respondents' preferences and WTP were estimated using the conditional logit model (CLM).

A Hausman test was performed to evaluate whether the IIA assumption holds; our test results indicated that this assumption does not hold, suggesting that the choices among alternatives are interdependent and necessitating alternative models that can account for this interdependence (See Table 2).

However, to investigate respondents' preferences and WTP heterogeneity[12] a latent class

[11] They choose the SQ in all the choice sets.

[12] The estimation of the Random Parameter Logit (RPL) model showed a non-significant price coefficient, likely due to the exponential function amplifying the standard deviation and leading to a low z-value. Using the "logitr" R package, we found that treating price as a random parameter complicated model convergence in willingness to pay (WTP) space. To assess the price parameter's impact, we tested several distributions, including normal and lognormal. We fixed the scale parameter and treated other parameters as normally distributed. However, assuming a constant price implies uniform sensitivity across individuals, which may bias WTP estimates by ignoring variations in price sensitivity.

model (LCM) was also estimated. In the LCM, respondents were grouped in a finite number of identifiable classes, allowing the respondents' preferences to be heterogeneous across classes but homogeneous within each class (Greene and Hensher, 2003; Sinha *et al.*, 2021).

In the LCM, the probability of individual *n* in class *c* choosing alternative *i* from a particular set of alternatives *J* was as follows:

$$P_{ns|c} = \frac{\exp(\beta'_c X n_i)}{\sum_{j=1}^{J} \exp(\beta'_c X n_{nj})} \quad (3)$$

where βs is the parameter vector of class *s* associated with the vector of explanatory choice attributes X_{ni}. Additionally, the analyst considered a classification model as a function of some individual-specific characteristics to determine the allocation of individuals to the *c* classes.

According to Greene and Hensher (2003), the probability that an individual *n* belongs to latent class *c* is given by

$$P_{n\epsilon c} = \frac{\exp(\theta'_c Z_n)}{\sum_{C=1}^{C} \exp(\theta'_c Z_n)} \quad (4)$$

where z_{in} is the vector of respondents' socioeconomic characteristics, and θ is a set of parameters to be estimated. Moreover, the log-likelihood of the LCM can be expressed as follows:

$$\ln L = \sum_{n=1}^{N} \ln\left[\sum_{c=1}^{c} P_{n\epsilon c}\left(\prod_{s=1}^{n} P_{ns/c}(j)\right)\right] \quad (5)$$

The WTP of an individual *n* who belongs to a latent class *c* for a given attribute *A* can be computed by dividing the estimated parameter ($\widehat{\beta_{A/c}}$) for *A* by the coefficient of the monetary attribute "Price" ($\widehat{\beta_{p/c}}$):

$$WTP = -2\left(\frac{\widehat{\beta_{A/c}}}{\widehat{\beta_{p/c}}}\right) \quad (6)$$

The ratio of the parameters is multiplied by 2 because all the non-price attributes are effect-coded (Rahmani & Loureiro, 2019).

Previous studies (Boxall *et al.*, 2002; Rahmani & Loureiro, 2019; Schaak *et al.*, 2020; Weller *et al.*, 2020) have used several criteria to guide the selection of the number of classes, but no consensus exists about the best criteria. The selection process used in this study considered multiple metrics, including the Akaike information criterion (AIC), the Bayesian information criterion (BIC), and the share of respondents in each class. Furthermore, the results' theoretical interpretability should be considered when choosing a solution. This study estimated LCM models with two, three, and four classes, while the LCM model with five classes did not converge. Therefore, we chose to present and discuss the results from the two-class LCM because, even though the three-class and four-class models had the lowest BIC values, all parameters for one of the classes in the latter two models were insignificant and had high standard errors, which made the computation of the WTP impossible (see Table 3).

Table 2 - Hausman Test to Test for IIA Assumption.

Hausman Test of Independence of Irrelevant Alternatives for sample			
Dropped Alternatives	X^2	*Degree of freedom*	*Probability*
Alternative 1	66.19	10	0.00
Alternative 2	48.31	10	0.00
Alternative 3 (SQ)	ND[1]	10	Could not carry out Hausman test for the IIA

[1] *Undefined.*

Table 3 - Metrics on the converged latent segment model.

Number of Classes	*Pseudo R-squared*[1]	*AIC*	*BIC*[2]
2	*0.43*	*2725.2*	*2862.1*
3	0.47	2584.6	2800.5
4	0.49	2506.4	2801.8

[1] *PseudoMcFadden R-square for both RPL models is >= 0.40. According to Bu* et al. *(2006) and McFadden (1973), in logistic regression, where the outcome variable is categorical, the Pseudo R-squared values help evaluate the proportion of variance explained by the model. They range from 0 to 1, with higher values indicating a better fit. A value of 0.2 to > 0.4 is generally considered a good fit for logistic regression models.*
[2] *BIC is calculated using the likelihood function of the model and penalizes models for having more parameters, thus favoring simpler models that explain the data well (De Jong* et al.*, 2023). AIC and BIC are always lower for higher number of classes.*

The final utility equation is presented as follows:

$$U_{in} = ASC_{SQ} + \beta_{1in} * \text{Biodiversity} + \beta_{2in} * \text{Recreational facilities} + \beta_{3in} * \text{Water Quality} + \beta_{4in} * \text{Gas emissions} + \beta_{5in} * \text{Cost} \quad (7)$$

where i = 1, 2, 3[13] for the three scenario alternatives, and n refers to the individual.

3. Results

3.1. *Respondents' Characteristics*

In Table 4 we show the comparison between the sample and population characteristics, revealing that the sample is representative of the Bizerte general population in terms of gender, secondary education[14] level and population aged >60. Approximately 60% of respondents have a monthly income of less than 1,500 Tunisian dinars (approximately less than USD 400[15]), which is considered low according to the National Institute of Statistics (INS, 2023).

3.2. *LCM Results*

Results from the LCM's estimation are displayed in Table 5. The LCM model splits respondent into two groups with distinct preferences based on their attitudes toward the status quo. Both groups support the lagoon's environmental restoration, but Class 1 prefers change (indicated by a negative sign), valuing the project's attributes and additional unmentioned benefits. In contrast, Class 2 supports the attributes while still favoring the status quo for other reasons.

Class 1, comprising 84.5% of respondents, strongly endorsed a restoration of the Bizerte Lagoon with a tangible improvement in water quality, the availability of recreation facilities, biodiversity, and a significant reduction in gas emissions from the factories near the Bizerte lagoon. This endorsement was evidenced by the negative and significant value of the preferences for the SQ, suggesting an inclination among members of this class to move away from the current situation. The results showed that Class 1 members preferred the restoration alternatives that provided a high level of improvement in all non-monetary attributes. Moderate improvement

Table 4 - Respondents' socioeconomic Characteristics.

Bizerte					
	Sample		*Population*		*p-value*
Female	184	0.51	298,200	0.50	<u>0.63</u>
Male	178	0.49	301,800	0.50	<u>0.7</u>
Age > 60	29	0.08	70,340	0.12	<u>0.012</u>
Age 18–59	333	0.92	319,260	0.53	<0.01
Primary educational level	147	0.40	187,512	0.33	<0.01
Secondary Studies Level	179	0.49	297,690	0.49	<u>0.34</u>
High educational level	23	0.06	68,186	0.12	<0.01
Income	361	1397.36[1] [mean] (SD = 867.88)	433,286[2]	< 1500[3] (400 $)	-

[1] 1397.36 TND = 450.76 $. [2] Active population in Bizerte. [3] According to the INS.

[13] It refers to the status quo (current situation).

[14] Some of the respondents did not declare their educational level.

[15] Where the average of personal annual expenditure estimated 5468 TND per year (1760$) without rent. a family of four estimated monthly costs are 7040$ according to the Tunisian National Institute of Statistics (March, 2021 and the average number persons per households is 5) https://www.ins.tn/en/statistiques/104.

Table 5 - Respondents' Estimated Preferences from the CLM and LCM.

	Conditional Logit Model		Latent Class Model			
Parameters	*All Respondents*		*Class 1*		*Class 2*	
Status Quo	-1.781 [(-1.931) _ (-1.631)]	***	-2.786 [(-3.006) _ (-2.566)]	***	1.548 [0.495_2.601]	***
Biodiversity Improvement						
Medium	0.309 [0.205__0.414]	***	0.277 [0.156_0.399]	***	0.128 [(-0.436) _0.693]	
High	0.388 [0.270_0.506]	***	0.644 [0.490_0.798]	***	0.598 [(-0.036) _1.232]	*
Recreation Improvement						
Medium	0.027 [-0.082_0.136]		0.100 [(-0.02) _0.228]		0.483 [(-0.116) _1.083]	
High	0.580 [0.473_0.686]	***	0.671 [0.538_0.805]	***	1.038 [0.423_1.654]	***
Water Quality						
Medium	0.219 [0.110_0.327]	***	0.227 [0.100_0.355]	***	0.935 [0.351_1.520]	***
High	0.736 [0.631_0.841]	***	0.984 [0.849_1.118]	***	0.756 [(-1.650) _0.137]	*
Gas Emission Reduction						
Medium	0.337 [0.229_0.446]	***	0.284 [0.156_0.411]	***	0.614 [(-0.317) _1.546]	
High	0.732 [0.623_0.841]	***	1.027 [0.874_1.180]	***	1.363 [0.585_2.142]	***
Cost of improvement	-0.020 [(-0.022) _ (-0.019)]	***	-0.023 [(-0.024) _ (-0.021)]	***	-0.026 [(-0.039) _(-0.013)]	***
Class Assignment Parameter						
Constant	NA		1.113 [0.534_1.691]	***	-	Fixed parameter
Gender: Female	NA		0.832 [0.052_1.613]	**	-	Fixed parameter
Age: Young adults	NA		0.951 [0.150_1.752]	**	-	Fixed parameter
Education: Primary	NA		-1.274 [(-2.20) _ (-0.342)]	***	-	Fixed parameter
Log-likelihood value	-1,599.3		-1,338.5			
Class share	100%		84.5%		15.5%	

****, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.*
[1] The values in brackets represent the confidence intervals of the estimated coefficients.

in biodiversity and water quality and a moderate reduction of gas emissions were also positively valued but much less than high improvement. This class was labeled "Pro-restoration."

Class 2 comprised 15.5% of respondents and exhibits a significant and positive preference for the high level of the attributes (save for water quality). However, the positive and significant coefficient for the status quo suggests that the members of this class prefer the current situation over a restoration for other reasons not explained by the attributes (to be discussed in the discussion part). Therefore, this class was labeled "Reluctant to Restore." The results also showed that Class 2 members were willing to support a restoration of the lagoon, especially if it resulted in highly improved biodiversity, water quality, and recreation facilities, with a high reduction in gas emissions.

Table 6 - WTP[1] of Bizerte Citizens for Lagoon Restoration in TND.

Parameters TND [Confidence Interval]	*Class 1: Pro-restoration (84.5%)*	*Class 2: Reluctant to Restore (15.5%)*	*Weighted Average[2]*
Biodiversity_Medium	24.07 (8.02) *** [13.55_34.59]	9.84 (3.28) [-33.13_52.82]	21.86 (6.83) *** [10.94_32.78]
Biodiversity_High	55.82 (18.60) *** [42.54_69.10]	45.75 (15.25) [-10.23_101.74]	54.26 (16.95) *** [40.06_68.46]
REC_Medium	8.68 [-2.36_19.73]	36.99 [-10.05_84.04]	13. 07 (4.08) [1.27_24.87]
REC_High	58.20 (19.40) *** [46.78_69.62]	79.46 (26.48) *** [31.21_127.70]	61.49 (19.21) *** [49.56_73.43]
WQ_Meduim	19.74 (6.58) *** [8.69_30.79]	71.58 (23.86) *** [19.42_123.74]	27.78 (8.68) *** [15.38_40.17]
WQ_High	85.26 (28.42) *** [73.94_96.58]	-57.86 [-132.93_17.20]	63.08 (19.71) *** [47.72_78.43]
GAS_Medium Reduction	24.60 (8.20) *** [13.49_35.71]	47.00 (15.66) * [-34.07_128.08]	28.07 (8.86) *** [12.84_43.30]
GAS_High Reduction	89.01 (29.67) *** [75.61_102.40]	104.31 (34.77) *** [37.52_171.10]	91.38 (28.55) *** [76.20_106.55]
Total WTP_High[3]	529.70 (165.58) *** [488.70_570.69]	53.20 [-45.86_152.27]	455.84 (142.45) [421.61_499.60]
Total WTP_Medium[4]	318.50 (99.53) *** [292.26_344.73]	46.96 [-18.42_112.34]	276.41 (86.37) [79.42_95.03]

****, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.*
[1] The values in parenthesis represent the converted value from TND to dollar while the values in brackets represent the confidence intervals of the estimated coefficients.
*[2] Weighted WTP average for an attribute level = (WTP of the concerned significant attribute level of Class 1 * 0.845 + WTP of the concerned significant attribute level of Class 2 * 0.155).*
[3] Corresponding to WTP for high levels of restoration, adding the ASC.
[4] Corresponding to WTP for medium levels of restoration, adding the ASC.

Interestingly, both classes exhibit similar sensitivity to the attribute cost, with values of (-0.023) and (-0.026). This suggests that differences in Willingness to Pay (WTP) are likely due to variations in preferences for non-monetary attributes and other factors not included in the model. In other words, respondents may favor the project because they anticipate benefits not explicitly mentioned among the attributes (Class 1), or they may recognize the value of the project's attributes but still prefer to maintain the current situation for other reasons (Class 2).

The WTP results (Table 6) further confirmed the findings. All WTP values were originally calculated in TND and subsequently converted to USD[16].The results show that members of Class 1 are willing to pay between TND 318.50 ($99.53) and TND 529.70 ($165.58) per year for respectively medium and high-impact scenarios. In contrast, members of Class 2 are unwilling to pay for both scenarios, with insignificant WTP for both medium and high-impact scenarios. To represent a representative average willingness to pay for both classes, a weighted average of WTP was calculated by combining their willingness to pay values with their respective frequencies or weights. The weighted average WTP for the high-impact scenario is TND 455.58 ($142.45) per year, while for the medium-impact scenario, it is TND 276.41 ($86.37) per year (see Table 4).

Regarding the profile of each class member, the results in Table 3 show that Class 1 members were more likely to be female and young respondents with higher education than those in

[16] 1 USD = 3.2 TND (current conversion, up to October 2024).

Table 7 - Total present Benefits values per Bizerte's Active Population.

	Class 1 (84.5%)		*Class 2 (15.5%)*		*Weighted*	
Active Population (No. of Citizens)	*Medium impact scenario (WTP/ Citizen)*	*High impact scenario (WTP/ Citizen)*	*Medium impact scenario (WTP/ Citizen)*	*High impact scenario (WTP/ Citizen)*	*Medium impact scenario (WTP/ Citizen)*	*High impact scenario (WTP/ Citizen)*
433,289[1]	318.50 ($99.53)	529.70 ($165.58)	NS	NS	276.41 ($86.37)	455.84 ($142.45)
WTP of Active Population per Year TND (USD)	138 million ($43.13 million)	229.5 million ($71.74 million)	NS	NS	119.7 million ($37.42 million)	197.5 million ($61.72 million)
NS: Insignificant						

[1] *See https://www.ins.tn/en/statistiques/111.*

Class 2. This finding was in line with previous studies on the profiles of sustainability-minded individuals. For instance, Plavsic (2013) and Ramstetter and Habersack (2020) found that female respondents were more likely to have pro-environmental attitudes and were more inclined to support "green" actions compared to male respondents. Meyer (2015) and Tianyu and Meng (2020) found that the surveyed adults' educational levels correlated with a greater awareness and understanding of environment-related issues and the importance of conservation efforts. Hence, individuals with higher education levels may have a deeper understanding of the benefits of project restoration and its impact on the environment, leading to a higher willingness to contribute financially. Elahi *et al.* (2022) found that young adults exhibited higher pro-environmental attitudes than older respondents.

This study serves, also, as a crucial opportunity to assess the economic viability of the Eco-Pact project by conducting a viability[17] analysis (Table 6)[18]. A comprehensive viability analysis allowed us to scrutinize the project's potential by comparing its costs to expected benefits (Birol *et al.*, 2006). The total cost of providing the project implementation is estimated at $67 million, equivalent to TND 214.74[19] million.

The weighted average WTP between the two classes was determined, as mentioned before, to allow for a comparison between the costs and expected benefits. Benefits were estimated by multiplying the weighted average WTP per Bizerte active population (433,286[20] active[21] inhabitants). Based on Table 7, Bizerte's active population's willingness to pay (WTP) was analyzed across different impact scenarios. For Class 1, which represents 84.5% of the population, the medium impact scenario results in a total WTP of $43.13 million per year, while the high impact scenario results in $71.74 million per year. In contrast, Class 2 (15.5% of the population) does not show significant WTP in either scenario. Considering the weighted average of both classes, the medium impact scenario produces a WTP of USD 37.42 million, and the high impact scenario produces USD 61.72 million per year.

In the high-impact scenario, the weighted

[17] The goal was to compare costs and estimated benefits to ensure the project can realistically achieve its objectives within the given constraints and conditions. With a viability analysis, decision-makers can make informed judgments about whether to modify the project.

[18] Bizerte statistics are available on Tunisian National Institute of Statistics (https://www.ins.tn/en/statistiques/111).

[19] According to 2025 current currency.

[20] We assume that only the population of Bizerte will benefit from the restoration. We are aware that Bizerte has many visitors during summer who can certainly contribute to the pollution while also benefiting from the restoration, so they also should pay. However, no statistics on the number of visitors was identified.

[21] According to the INS, active population refers to all the adults who work and pay taxes.

WTP (USD 61.72 million) is very close to the required project cost of USD 67 million.

As all study, this has also some limitations that must be considered when interpreting results. While we obtained positive WTP results, this exercise might have only captured some of the benefits stemming from lagoon restoration. Therefore, the voluntary nature of the payment commitment could lead individuals to show higher support or generosity, potentially inflating the WTP valuations. Moreover, free-rider engagements could further impact the accuracy of the estimations. Therefore, it is prudent to approach these estimations cautiously and adopt a conservative perspective. A sensitivity analysis for the viability study should consider both present and future values for a more realistic assessment to ensure its replicability.

3.3. *Discussion and Conclusions*

The study provides valuable insights into the heterogeneity of Bizerte residents' willingness to support the restoration of the Bizerte Lagoon and bear the expected cost (i.e., WTP). Two classes with distinct preferences were identified: "Pro-restoration" and "Reluctant to Restore," which underscores an interesting point. Both classes appreciated the presented attributes.

However, respondents in Class 1 are drawn to the project because they support both lagoon's environmental restoration and other benefits that are not explicitly included in the attributes. In contrast, respondents from Class 2 recognize the value of the project's attributes, as evidenced by their significant WTP for high-level attributes (e.g., TND 79.46 ($26) for REC_High and TND 104.31 ($34) for Gas_High reduction). Yet, they still prefer to maintain the SQ for other reasons, resulting in an insignificant WTP for the overall high or medium scenario.

The study presents also a contribution in a way that the the constant ASC_SQ emerged as the greatest contributor to the TEV. Moreover, it is a key driver of the high WTP observed in Class 1. Including ASC_SQ significantly elevates the value of WTP, indicating a strong desire to move from the status quo. In contrast, in Class 2, the influence of ASC_SQ, which must be deducted from the utility of the other attributes, on WTP significantly results in insignificant WTP values in both high and medium scenarios. In other words, while Class 2 respondents appreciate the benefits of the project's attributes, they are ultimately unwilling to pay for the overall high or medium-impact scenarios, likely due to factors not explicitly captured in the model. This suggests that their preferences are influenced by a combination of the project's attributes and other unobserved considerations. This may be because, despite they value the project they prefer to allocate additional resources to other priorities such as education and food, which are perceived as pathways to increasing their income, as observed by Whittington (2010). In a way that understanding citizens' social commitment and priorities is crucial when assessing ecosystem services, as it directly influences the effectiveness and sustainability of conservation efforts.

Despite facing economic challenges exacerbated by the global financial crisis, the sampling citizens' commitment to environmental conservation highlights the sense of shared purpose and collective action. This high WTP may be explained in several ways. First, the strong association between citizens and the lagoon produces a reasonable answer about both the expected WTP of Bizerte citizens. A recent study by Missaoui *et al.* (2023) revealed that in the context of the Bizerte Lagoon, fishermen are eager to contribute to its restoration to safeguard the cultural legacies of their port. Second, the level of awareness about environmental issues can significantly impact the citizens' willingness to contribute to the restoration of the lagoon, mainly when the lagoon plays a vital role in their livelihoods, such as fishermen and owners of tourist-related businesses. As part of the survey, a question was included to gauge respondents' awareness of the threats to the lagoon and their causes and consequences. The results revealed that 89% of respondents from Bizerte were aware of the irreplaceable nature of the lagoon within Tunisia's arid ecosystem, where water bodies are scarce and precious. The lagoon's ecological functions are not easily replicable by artificial means, making its preservation vital for environmental sustainability. This finding aligns with a study conducted by Nahar *et al.*

(2023) in Dhaka, Bangladesh, which emphasized that respondents with high environmental awareness exhibited a greater understanding of environmental laws and regulations, indicating a positive relationship between awareness and environmental concerns. Third, this finding may also be justified by the importance that respondents assign to recreational facilities where citizens are willing to contribute TND 58.20 ($19.40) (Class 1) to TND 79.46 ($26.48) (Class 2) for a high-impact scenario, representing the most preferred attribute. Hence, enhancing coastal infrastructure could serve as an asset for the citizens of Bizerte by allowing them to reclaim the values and activities they have lost due to pollution over time. Reviving activities such as swimming, artisanal fishing, and walking through improved coastal infrastructure would enhance the residents' quality of life while helping restore cultural and recreational practices that hold significance for the community. Moreover, the study highlighted the importance that citizens assigned to reducing gas emissions. They were willing to pay TND 89.01 ($29.67) (Class 1) to TND 104.31 ($34.77) (Class 2) to reduce the maximum of gas emissions.

The WTP results for Class 1, where members were willing to pay up to TND 55.82 ($18) to enhance biodiversity, align with comparative WTP analysis results from similar studies (Owuor *et al.*, 2019; Chen & Ting Cho, 2019) where citizens were willing to pay TND 73.6 ($23) to improve biodiversity. However, the findings regarding biodiversity in Class 2 were unexpected and differed from the existing literature. Specifically, biodiversity was not deemed important at the medium and high levels. People may be more focused on short-term, tangible results that they can see and touch immediately (O'Donoghue and Rabin 2000). Furthermore, drawing from López *et al.* (2007), non-economic motives for biodiversity WTP, such as familiarity and biophilia, may play a significant role. Individuals may be less inclined to contribute to biodiversity conservation efforts if they lack a personal connection or appreciation for nature. Thus, it may reflect how to increase in biodiversity awareness among citizens.

Results from the viability study, in the present value, suggest that voluntary payments could almost fully fund the project, assuming the population perceives a high benefit from the intervention, suggesting that the EcoPact project is almost viable only if the improvement is highly significant, which may be because respondents are willing to pay much more for the high-improvement scenario since it entails more substantial changes and interventions than the medium-improvement scenario. These interventions will likely result in more significant environmental, social, and economic benefits, such as improved water quality, enhanced biodiversity, and increased recreational opportunities.

The difference between the medium and high-impact scenarios is significant. For the medium impact scenario, the weighted WTP is only USD 37.42 million, far below the project cost. This highlights the sensitivity of the population to contribute based on their perception of the benefits. Suppose the perceived impact of the project is low or moderate. In that case, the funding gap will be much larger, affecting the project's viability or requiring additional funding sources such as government subsidies. Otherwise, governmental efforts will be needed to reduce project implementation costs and cover the required average investment and operational expenses so that aggregated WTP for medium level can cover the costs because medium improvements are more attainable and less costly than a high-impact scenario. Consequently, the medium-impact scenario may not recover its total costs without a government subsidy.

The article adds to the existing literature by providing new insights into the increasing public concern over the degradation of the Bizerte Lagoon's ecosystem, indicating a social demand for restoration. The results emphasize the substantial net benefits derived from both ecological and social aspects of restoring the Bizerte Lagoon in a way that by providing the economic values of ecosystem services, this study can serve as a baseline that policy-makers are based on to conduct the benefit transfer method and assess the TEV or precisely ecosystem services values in other similar locations. It can serve also as an input to assess the ongoing projects or research aiming to set best management for marine ecosystems such lagoons.

Successful implementation relies on harmonious collaboration between institutions and effective government involvement.

Research indicates that individuals place significant value on public goods and often demonstrate a willingness to contribute financially to their preservation. This finding suggests a strong potential for community support for public policies aimed at the conservation or restoration of natural spaces that provide essential ecosystem services. Moreover, citizens can play a pivotal role in financing these initiatives, which addresses a major challenge – financial constraints – often encountered in the implementation of public policies. These insights can be instrumental in designing effective programs; by ensuring they achieve a meaningful impact; we can enhance public support and engagement. For public authorities aiming to promote the protection of public goods, such as lagoons, it is crucial to understand how to effectively engage different segments of the population. Tailoring approaches for Class 1 and Class 2 citizens will be key to raising awareness and fostering a collaborative environment for conservation efforts. In this way, policies should emphasize the organization of campaigns to effectively raise awareness about environmental issues among older individuals using spoken local dialects to ensure accessibility and the ability to understand the technical terms for those with limited literacy skills and strengthen collaboration with non-governmental organizations to facilitate information-sharing and dissemination of environmental knowledge, as emphasized through the results obtained from Class 2. It is also crucial to maintain a solid foundation in environmental education for young students to ensure similar results in WTP for Class 1 and to achieve better outcomes for Class 2. Disseminating environmental education in schools can also be a solution. Furthermore, by teaching kids the environmental importance of the lagoon, they can grow up with greater awareness, which will make it easier to influence their behavior positively when they become adults. Tunisian government must supplement existing environmental legislation with regular monitoring of wastewater treatment plants and gas filtration to ensure that factories surrounding the lagoon comply with standard norms. Deviations from these norms must be met with appropriate penalties to deter non-compliance.

In conclusion, this enchanting lagoon holds immense significance not just for the residents of Bizerte but for the entire Mediterranean region. Its intricate connection to the sea underscores the importance of its restoration; by rejuvenating this vital ecosystem, we actively contribute to the preservation of the Mediterranean – a lifeblood for countless communities surrounding its shores. "This lagoon is more than a body of water; it is a sanctuary of ecological diversity and a source of cultural heritage, deeply intertwined with the lives of those who inhabit this beautiful coastal landscape".

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