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1 Spatial preferences for invasion management: a
2 choice experiment on controlling *Ludwigia*
3 *grandiflora* in a French regional park

4 Douadia Bougherara*, Pierre Courtois†, Maia David‡, Joakim Weill§

5 October 29, 2021

6 **Abstract**

7 If individuals have spatially differentiated preferences for sites or areas im-
8 pacted by an invasive alien species, effective management must take this
9 heterogeneity into account and target sites or areas accordingly. In this
10 paper, we estimate spatially differentiated preferences for the management
11 of primrose willow (*Ludwigia grandiflora*), an invasive weed spreading in a
12 French regional park. We use an original spatially explicit discrete choice
13 experiment to evaluate individuals' willingness to pay (WTP) to control the
14 invasion in different areas of the regional park. Our results indicate that
15 WTP for management highly depends on the area considered, with areas
16 where it is three times higher than others. We analyze the main factors
17 explaining the heterogeneity of preferences and show that the closer respon-
18 dents live to the park, the more they visit and/or practice activities in it, the
19 higher their WTP and spatial preferences. Park residents and regular users
20 have high WTP and unambiguous preferences for targeting control to specific
21 areas. Non-residents and occasional users have much lower WTP and more
22 homogeneous spatial preferences. These results suggest that implementing
23 management strategies that spatially target invasion control according to
24 public preferences is likely to produce significant utility gains. These gains
25 are all the more important as the preferences taken into account are those

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26 of the stakeholders directly concerned by the invasion, the residents and reg-
27 ular park users. Ignoring these spatial preferences will lead to sub-optimal
28 invasion management.

29 Keywords: Discrete choice experiments, Spatial heterogeneity, Cost assess-
30 ment, Primrose willow, Invasive weed, Public preferences.

1 Introduction

Invasive alien species are tremendously impacting ecosystems, economic activities, and human welfare (Paini et al., 2016; Bradshaw et al., 2016; Diagne et al., 2020). Limited public funds (Scalera, 2010) make *where* and *how* to control a given invasive alien species a major management challenge (Potapov and Lewis, 2008; Epanchin-Niell and Wilen, 2012; McGeoch et al., 2016). To prioritize management efforts spatially, the bioeconomic literature has principally analyzed cost-effective allocations targeting efforts to minimize or slow the spatial spread of invasions (see Epanchin-Niell, 2017; Büyüктаhtakin and Haight, 2018, for an extensive review of the literature). A few studies have analyzed the spatial allocation problem by maximizing net benefits through considering spatially heterogeneous management costs and/or benefits (Burnett et al., 2007; Epanchin-Niell et al., 2012; Jardine and Sanchirico, 2018). However, none of these studies used economic valuation methods based on individual preferences. Yet, these methods are relevant for estimating the value people place on the spatial benefits of management and, more generally, for prioritizing sites according to public preferences.

Invasive alien species often cause multiple losses of use and non-use values, making accounting approaches difficult to apply. Stated and revealed preference methods have been developed in economics to assess individual preferences through their willingness to pay (WTP). Among the stated preference approaches, which have the advantage of accounting for non-use values, discrete choice experiments (DCEs) provide an especially suitable framework to support decision-making. The method is based on assessing individual preferences for a discrete set of alternative options that differ by their *attributes* (see Hoyos, 2010, for a review). Analyzing respondents' choices enables scholars to estimate the implicit WTP for each attribute. When these attributes relate to spatial characteristics, the ranking of WTP allows spatial preferences for management to be ordered.

To our knowledge, six DCEs have been applied to invasive alien species management (Adams et al., 2011; Rolfe and Windle, 2014; Chakir et al., 2016; Sheremet et al., 2017; Subroy et al., 2018; Japelj et al., 2019), of which only two have a spatial dimension. Rolfe and Windle (2014) analyzed spatial preferences for the control of imported red fire ants in Brisbane, Australia, and assessed WTP for eradication versus containment strategies in public, private, and protected areas. They showed unambiguous preferences for eradication in public areas, such as schools and parks. Japelj et al. (2019) elicited WTP for different removal strategies over a set of invasive alien species impacting Slovenian forests. Considering three control methods in two distinct locations (urban and forest), they analyzed the heterogeneity of public preferences using a latent class model.

Although not applied to invasive alien species management, several studies introduced spatial considerations into DCEs. They focused foremost on two as-

71 pects: (1) the spatial characteristics of the respondents, in particular their location
72 in relation to the area of interest, and (2) the identification of spatially explicit
73 preferences. Concu (2007) and more recently Glenk et al. (2020) reviewed the
74 extensive literature on the theoretical and empirical foundations of distance decay
75 (i.e., the decrease in WTP due to the distance of respondents from the area of
76 interest). Their reviews showed that the decay is mainly explained by travel and
77 accessibility costs, information and search costs, availability of substitute sites,
78 and moral obligations and motivations. The second aspect received less atten-
79 tion from the literature. Several studies assessed spatial preferences using DCE
80 based on geographical maps. Johnston et al. (2002) were the first to synthesize
81 management options in stylized maps to analyze alternative plans to develop rural
82 lands in four towns in southern New England (U.S.). Applying a related method
83 using cartographic attributes, Brouwer et al. (2010) assessed preferences for water
84 quality improvements in different parts of a river basin in Spain. They showed
85 that even though respondents are willing to pay for water quality throughout the
86 entire river basin, they are willing to pay more to reach a condition better than
87 "good" only in some sub-basins (see also Martin-Ortega et al., 2012).

88 In this paper, we conduct a DCE to obtain the public's spatial preferences
89 for the management of primrose willow (*Ludwigia grandiflora*), an invasive weed
90 with a negative impact on biodiversity and activities in an emblematic marsh of
91 a French regional park. The marsh is publicly owned, and local taxes fund the
92 management of the invasion. The management strategy is entirely in the custody
93 of the park office, which selects the areas of the marsh to prioritize. This strategy,
94 however, concerns also the inhabitants and the main users of the park who suffer
95 the effects of the invasion and finance its management.

96 We aim to analyze primrose willow management from a public preferences
97 perspective. We ask how much residents and non-residents of the park are willing
98 to pay for invasion control in five different areas of the marshland. As in Johnston
99 et al. (2002) or Brouwer et al. (2010), we synthesize choice options in the form of
100 stylized maps and define a DCE setting in which attributes correspond to different
101 geographical areas of the marshland. We assess WTP for invasion control in the
102 different areas considered and estimate how this WTP varies between residents
103 and non-residents, regular and occasional users of the park, and people living
104 further away. Our spatial analysis is twofold: (1) highlight the heterogeneity of
105 preferences for the management of primrose willow in different spatial areas of the
106 marshland (by allowing respondents to choose between different *maps*), and (2)
107 take into account the spatial characteristics of the population surveyed, analyzing
108 how spatial preferences vary according to the location of the respondents (distance-
109 decay effect).

110 The principal results are to provide estimates of WTP to inform spatial man-

111 agement of primrose willow based on individual preferences and to investigate the
112 drivers of public preferences. We find that WTP is significant but highly heteroge-
113 neous across the areas considered. Respondents are willing to pay annually from
114 5 € for the lowest-valued area to 17 € for the highest-valued area to reduce the
115 invasive alien species from a medium to a low invasion level. They are willing to
116 pay 17 € for the lowest-valued area and 28 € for the highest-valued area annually
117 to reduce the invasive alien species from a high to a medium invasion level. Three
118 categories of area can be distinguished based on public preferences: two priority
119 areas, two intermediate areas, and one secondary area. In intermediate areas,
120 management is valued twice as much as in the secondary area. Management in
121 priority areas is valued three times as much. We also find in the study that WTP
122 is very heterogeneous among respondents. We show that the closer respondents
123 live to the regional park, the more they visit or practice activities in it and the
124 more they value it. We also show that the closer respondents live to the regional
125 park, the more heterogeneous their spatial management preferences are (i.e., the
126 more they prefer to target management efforts in priority areas).

127 The main policy implication of these results is that (1) management in priority
128 areas of the regional park would produce greater utility gains, and (2) this is all
129 the more true as the preferences assessed are those of frequent users and/or of
130 people living in the park.

131 2 Material and methods

132 2.1 Case study

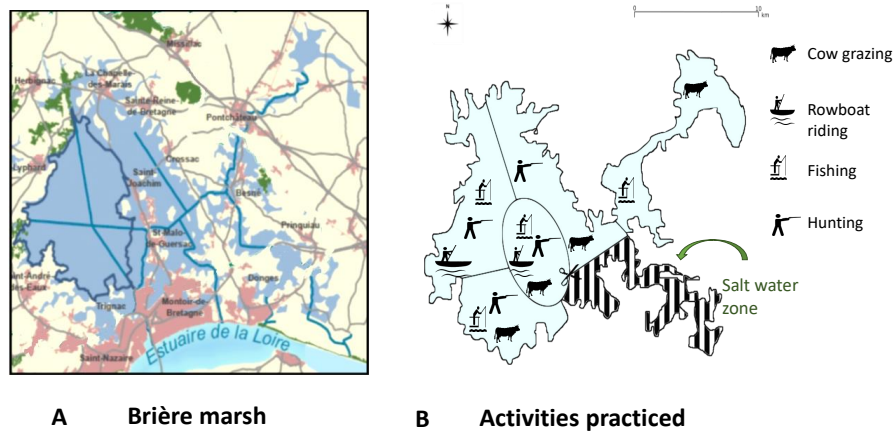
133 The regional park of *Brière* is located on the West coast of France, in *Loire-*
134 *Atlantique*, a subregion with a population of 1.42 million inhabitants¹, at the
135 extreme north of the *Pays de la Loire* region. The regional park covers more than
136 50,000 hectares (500 square kilometers) and includes several villages and pastures.
137 The special feature of the park is its 1,700 hectares of wetlands, a marshland
138 consisting of a network of navigable canals, and water bodies (see Figure 1A).

139 The marsh offers multiple recreational and tourist activities, such as hiking,
140 fishing, waterfowl hunting, and rowboat rides.² Pasture lands scattered between

¹In the Nomenclature of Territorial Units for Statistics (NUTS) (<https://ec.europa.eu/eurostat/web/nuts/background>), this subregion is NUTS3. In France, NUTS2 is the "région" level, NUTS3 is the "département" level, and LAU (Local Administrative Unit) is municipalities or groups of municipalities. There are 18 NUTS2 regions in France divided into 101 NUTS3 regions, which are administrative entities similar to U.S. counties.

²The regional tourism turnover in 2019 is estimated at 3.2 billion € with 16,000 direct tourist jobs (source <https://www.paysdelaloire.fr/>). Although tourism activity is mainly concentrated on the coast, the park has many visitors, with 284 accommodation facilities, 95 restaurants, 30

Figure 1: The marsh and the activities practiced



141 canals provide grazing areas for cows, a breeding activity associated with a local
 142 production label (the "*Valeurs Parc Naturel Régional*" label). Located south of
 143 the regional park is the international harbor of *Saint-Nazaire*, one of France's most
 144 important trade hubs. The proximity to globalized markets has put the park under
 145 tremendous pressure from invasive alien species.

146 The most worrisome invasion by far is that of the primrose willow, *Ludwigia*
 147 *grandiflora*, an amphibious plant first reported in the park in 1994.³ The plant
 148 initially spread from the southwest to the center of the marsh and is denser in
 149 these areas. It is now present throughout the marsh, except for the southeastern
 150 area, which is too saline for primrose willow. If left uncontrolled, primrose willow
 151 has such an explosive proliferation that canals become inoperable, halting rowboat
 152 rides and fishing, two recreational activities crucial to the economy of the wetland.

153 Furthermore, when canals and waterbeds are highly invaded, the plant spreads
 154 along the banks and edges of the surrounding pastures. The result is a series of
 155 economic losses for farms that use the marsh as grazing land for their herds. First,
 156 primrose willow is toxic to livestock and makes grazing impossible in the invaded
 157 areas. The obstruction of the canals also makes it difficult to access pastures.
 158 Second, the loss of grazing land could threaten cattle ranchers' ability to use the
 159 regional production label, which requires that breeding and grazing of cows occur

heritage sites, and 7 main natural sites, all located in the wetland.

³Primrose willow is one of the 37 key preoccupying invasive alien species reported in EU regulation list 2016/1141 adopted on July 13, 2016.

160 in the marsh. Finally, if farmers do not graze their herds in the marshland, they
161 eventually lose the subsidies from the European Common Agricultural Policy's
162 agri-environmental schemes.⁴

163 In addition to the impacts on recreational, tourism, and agricultural activities,
164 the invasion reduces the local biodiversity of the wetland, impacts the landscape,
165 and increases the risk of flooding. In particular, several endangered and critically
166 endangered species (e.g., pike perch, chub, lamprey) are directly threatened by
167 primrose willow. These negative impacts on use and non-use values make this
168 invasion a public bad that requires a management strategy to limit its extent.

169 An important feature of the marsh is that it is not privately owned but be-
170 longs to the 21 municipalities that make up the park.⁵ The marshland pastures
171 also belong to the 21 municipalities but can still be used free of charge by local
172 ranchers. Local taxes fund the management of the primrose willow⁶. Management
173 is delegated to the park management office, which is fully accountable for man-
174 agement strategy and operations. The annual budget allocated to management
175 is approximately 110,000 €. The invasion can only be addressed in part because
176 control is costly. Management is based on manual or mechanical removal and
177 takes place each year during the flowering periods of primrose willow. Because
178 of its deep roots and ability to reproduce, eradicating the invasion is impossible
179 unless resorting to salinization, which would completely disrupt the environment
180 and be disastrous for local biodiversity. The management strategy of the park of-
181 fice, particularly the site prioritization strategy, is poorly documented and, in the
182 opinion of the managers, geared towards adopting partial but extensive control of
183 all areas, with a particular focus on the navigability of canals. Public preferences
184 are not currently taken into consideration in this strategy.

185 Yet, the population and especially the residents are relevant stakeholders, and
186 their preferences should be taken into account. Individuals living in the park are
187 not uniformly distributed in space and may have spatial preferences for control
188 in their vicinity. In particular, the population density is higher in the south and
189 center of the marsh. Agricultural and recreational activities are also area-specific
190 (see Figure 1 B), and users of the park may have spatial preferences based on
191 habits or ease. The central and western areas of the marsh are more frequented

⁴The payment received for agri-environment-climate commitments pertains to the class of incentives for grazing practices, sub-measures Herb1-2-3-4 now entitled 10.1.4 Grassland GS1-17. In 2015, for example, 20 landowners received 235,507 € for their commitment to using 1,193 hectares of grazing land, of which 38,588 € had to be repaid due to the invasion of 195 hectares by primrose willow, which made grazing impossible.

⁵This idiosyncrasy is due to a decision by Francois II, Duke of Brittany, in 1461 (François II, 1461).

⁶Namely, housing and employment taxes of Saint Nazaire Metropolis, a Local Administrative Unit of approximately 127,000 fiscal households (INSEE, 2017).

192 and popular than other areas.

193 Hunting is practiced mostly on water bodies and is therefore concentrated in
194 the western and central parts of the marsh. Fishing can be practiced anywhere,
195 although fishers poorly use the northeastern part of the marsh. Cow grazing
196 cannot be practiced in the northern part of the marsh, and major agricultural
197 activities occur in the central and southern parts. Finally, rowboat-riding activities
198 are located in the central and northwestern parts. As these last two activities
199 generate significant economic output for the park, one may expect a preference
200 for preserving those areas. Non-use values, particularly biodiversity, are uniformly
201 impacted by the invasion because the marsh as a whole constitutes a biodiversity
202 hotspot. Therefore, it is not preferable to control the invasion in one area rather
203 than another in this respect except to avoid very high invasion densities, which
204 would harm the biodiversity due to the covering capacity of the primrose willow.

205 **2.2 The choice experiment**

206 DCEs involve presenting a set of choice tasks to respondents. Each task consists of
207 several alternatives, usually limited to three (see Louviere et al., 2000, for a review).
208 Respondents are asked to pick their favorite alternative within each choice task.
209 Alternatives comprise different attributes, and each attribute can take different
210 levels of provision. When one of the attributes is either a price or a cost, the method
211 allows for eliciting the WTP for changes in the levels of the other attributes.
212 This feature makes DCEs an attractive method to estimate preferences for goods
213 or amenities that do not have a market price, such as environmental amenities
214 (Adamowicz et al., 1994).

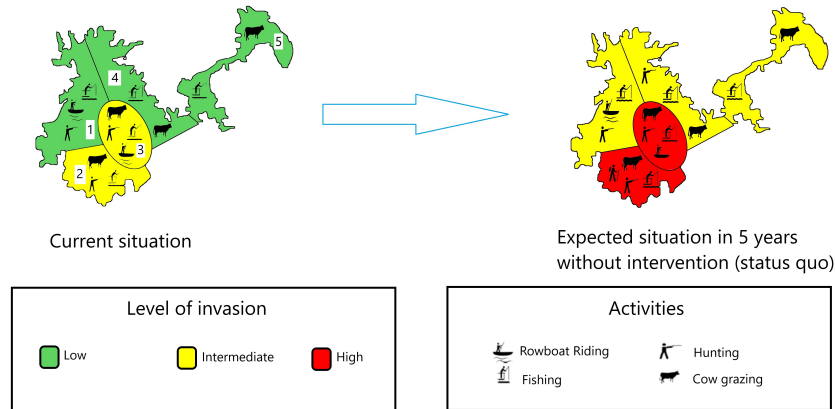
215 **2.2.1 Attributes and their levels**

216 The first components of a DCE are the attributes that compose each alternative
217 and their possible values (levels). As Hanley et al. (2002) explained, the number
218 of attributes must be small to limit the cognitive burden imposed on respondents.
219 Because the objective of our DCE is to assess respondents' WTP for spatial control
220 of primrose willow in the marsh, we assume two categories of attributes: (1) spatial
221 attributes delineating areas of interest for management and (2) a cost attribute to
222 evaluate the WTP for each alternative.

223 To define our spatial attributes, we relied on expert advice from park managers
224 and a pilot study. We divided the marsh into five main areas of interest for invasion
225 management, resulting in five spatial attributes numbered 1–5 (see Figure 2, left-
226 hand side).⁷ To avoid preferences being influenced by size effects, we set the
227 areas to be of equal size, which was explicitly made clear to respondents at the

⁷Note that these five areas have no physical existence as such and are defined only for the

Figure 2: Actual and predicted invasion with area numbers and activities associated with each area



228 beginning of the survey. Area boundaries were defined by the experts to best
 229 distinguish between uses, levels of invasion prevalence, and the location of major
 230 villages that might impact respondents' preferences. The resulting areas are five
 231 cohesive units that can be managed independently of each other.

232 For each spatial attribute, we set three possible values corresponding to the
 233 level of primrose willow prevalence and its impact on use and non-use values.
 234 Levels are presented to respondents with traffic-light colors (see Figure 2)⁸. The
 235 color green is used to represent *Low* levels of primrose willow involving almost no
 236 impact on activities and biodiversity. The color yellow is used to represent *Medium*
 237 levels of invasion. Some canals are clogged; their banks and some water bodies are
 238 partially invaded. The users of the park can practice activities but are likely to
 239 be disturbed by the primrose willow and must modify their habits. Biodiversity is
 240 impacted without the ecosystem being radically modified. The color red is used to
 241 represent *High* levels of invasion. The invasion clogs all canals and largely covers
 242 water bodies. The banks are colonized. Accessibility is compromised, and human
 243 activities become impossible. Biodiversity is also greatly impacted. We carefully
 244 explained the meaning of these different prevalence levels at the beginning of the
 245 survey and highlighted the current level of invasion and the level expected in five
 246 years if no action is taken (the so-called *status quo* scenario) (see Figure 2, right-
 247 hand side).

248 The sixth attribute is monetary in the form of a yearly tax increase, which

purposes of the study. No physical barriers or property rights define those areas. The sum of these five areas constitutes the entire area of the marsh where primrose willow is susceptible to management by the park management office.

⁸For the black and white version, red is dark grey, yellow is light grey, and green is the intermediate grey.

249 allows us to estimate WTP for different levels and spatial patterns of invasion. This
250 attribute can take 5 different levels: 0 €/year, 5 €/year, 15 €/year, 30 €/year,
251 and 60 €/year. These levels were also chosen based on expert opinions and our
252 pilot study.

253 As a result, the different management alternatives, distinguished by the loca-
254 tion and extent of the control of the invasion, take the form of different maps, each
255 associated with a cost.⁹ Each choice task consists of selecting a preferred man-
256 agement option from three alternatives. For each task, one of the three available
257 alternatives is to do nothing (with a zero cost) and let the invasion spread, the
258 so-called "status quo" option represented by the alternative on the right-hand side
259 of each card. Figure 3 presents three different examples of a choice task.

260 2.2.2 The experimental design

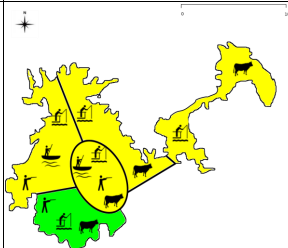
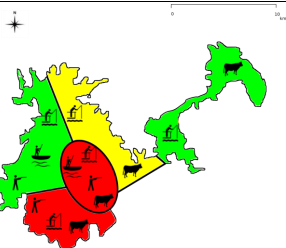
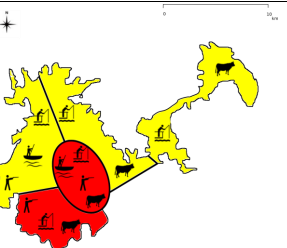
261 With three levels associated with the five spatial attributes and five levels associ-
262 ated with the cost attribute, the full factorial range of combinations is too wide
263 to collect respondents' opinions on all of them. We selected a statistically optimal
264 subset of these combinations using a Bayesian D-optimal design (see experimen-
265 tal design techniques in Louviere et al., 2000; Street et al., 2005) using the *NGene*
266 software, which is standard in the literature. We used a fractional factorial efficient
267 design¹⁰ adapted for a random parameter logit model with parameters following
268 a normal distribution. The design further accounted for two constraints: (1) in
269 each area, the alternatives cannot present a worse invasion level than the *status*
270 *quo* situation, and (2) the tax levels in the non *status quo* alternatives are strictly
271 positive, implying that improving over the *status quo* has a cost.

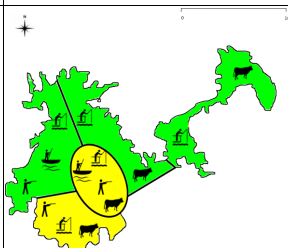
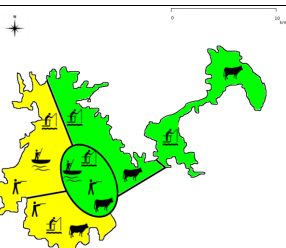
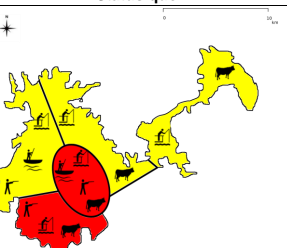
272 This experimental design led to 16 different choice sets. As is usual (see Choice-
273 Metrics, 2018), these were blocked into two groups to reduce the cognitive load,
274 so the final questionnaire presented 8 choice sets to each respondent. Respondents
275 were randomly assigned to one of the two groups. The order of the choice sets was
276 randomized to avoid declining attention systematically impacting the responses
277 to specific choice sets. The program used for the experimental design and the 16
278 associated choice sets are available upon request.

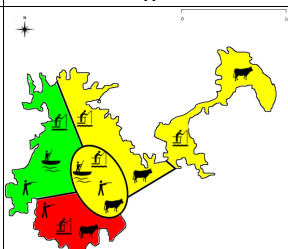
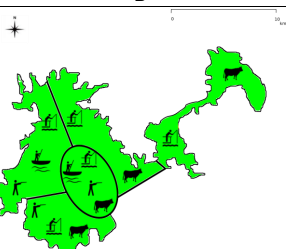
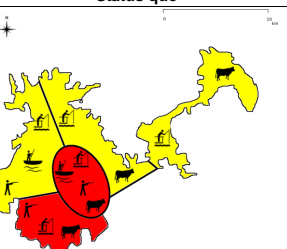
⁹Note that our pilot study showed that using five different areas was tractable to respondents. Compared with a classical DCE with six attributes, our spatial DCE generates less cognitive bias (i.e., requires less concentration from respondents) because five of the attributes are visually synthesized through a map, making the information easier to process.

¹⁰Efficient designs have been empirically shown to lead to smaller standard errors in model estimation compared with orthogonal designs (Greiner et al., 2014; Bliemer and Rose, 2010, 2011).

Figure 3: Examples of choice sets

Options	A	B	Status quo
Situation in 5 years			
Yearly cost	Tax + 15 €	Tax + 5 €	Tax + 0 €
Your choice	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Options	A	B	Status quo
Situation in 5 years			
Yearly cost	Tax + 60 €	Tax + 60 €	Tax + 0 €
Your choice	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Options	A	B	Status quo
Situation in 5 years			
Yearly cost	Tax + 5 €	Tax + 60 €	Tax + 0 €
Your choice	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

279 **2.2.3 Econometric background**

280 The econometric analysis of choice experiments is based on random utility theory
 281 (McFadden, 1973; Manski, 1977), which posits that the indirect utility an individ-
 282 ual n obtains from choosing an alternative i , U_{ni} , is made of both an observed com-
 283 ponent V_{ni} and a random (unobserved) component ε_{ni} , such that $U_{ni} = V_{ni} + \varepsilon_{ni}$.
 284 Individual n then chooses alternative i over all other alternatives j if and only if
 285 $U_{ni} > U_{nj} \forall j \neq i$. Because we do not observe ε_{ni} , this component is assumed to be
 286 random. The probability that individual n chooses alternative i can be expressed
 287 as

$$(1) \quad P_{ni} = \text{Prob}(V_{ni} + \varepsilon_{ni} > V_{nj} + \varepsilon_{nj}) \forall j \neq i$$

288 Different assumptions regarding the distribution of the random component
 289 translate into different discrete choice models and estimating procedures. Further-
 290 more, the observed utility component includes individual and alternative-specific
 291 characteristics that influence the indirect utility through a vector of parameters to
 292 be estimated. These parameters are either assumed to be fixed or random (i.e.,
 293 varying in the population according to a certain distribution). The latter assump-
 294 tion is the one we retain because it allows for taste heterogeneity (see Train, 2009,
 295 for an enlightening review).

296 We thus present results obtained with a random parameter logit (RPL) model.
 297 This model allows for preference heterogeneity, flexible substitution patterns be-
 298 tween alternatives, and dynamic correlation among unobserved factors. As shown
 299 by McFadden and Train (2000), this model can approximate any random utility
 300 model arbitrarily closely.¹¹

301 We follow the literature and choose a standard linear specification for the de-
 302 terministic part V_{ni} of the utility function. The utility V_{ni} is derived from the levels
 303 of the K attributes of the alternative i , denoted by $\mathbf{X}_i = (x_{i1}, \dots, x_{ik}, \dots, x_{iK})$. In
 304 our case, $K = 6$ with five spatial attributes (5 areas) and one monetary attribute
 305 (tax). In addition, V_{ni} depends on a set of A economic and attitudinal charac-
 306 teristics (socioeconomic variables) that characterize the respondent, denoted by
 307 $\mathbf{Z}_n = (z_{n1}, \dots, z_{na}, \dots, z_{nA})$.

308 We also introduce an alternative-specific constant (*ASC*) to value the prefer-
 309 ence for the *status quo*. We define the dummy variable *ASC*, which takes the
 310 value one in the *status quo* alternative and zero otherwise. A statistically signifi-
 311 cant positive coefficient η associated with the *ASC* dummy variable (see equation
 312 (2) below) indicates a preference for the *status quo* alternative.

¹¹The RPL model further relaxes the IIA assumption (independence of irrelevant alternatives) (McFadden and Train, 2000).

313 The model is thus specified so that the utility of individual n in alternative i is
 314 a linear function of the attributes levels \mathbf{X}_i , the socioeconomic characteristics \mathbf{Z}_n ,
 315 and the alternative specific constant (ASC) for the *status quo*:

$$(2) \quad U_{ni} = (\eta + \mathbf{Z}_n \boldsymbol{\alpha}^{ASC}) ASC + \mathbf{X}_i (\boldsymbol{\beta}_n + \boldsymbol{\alpha} \mathbf{Z}_n^\top) + \varepsilon_{ni}.$$

316 The vector $\boldsymbol{\alpha}^{ASC} = (\alpha_1^{ASC}, \dots, \alpha_A^{ASC})^\top$ measures the effect of the socioeconomic
 317 characteristics on the *status quo* utility. The matrix $\boldsymbol{\alpha}$ of size (K, A) is composed
 318 of coefficients α_{ka} , capturing the cross-effect of socioeconomic characteristic a on
 319 attribute k . The coefficients quantifying the influence of the K attributes on
 320 utility are given by the column vector of coefficients $\boldsymbol{\beta}_n = (\beta_{n1}, \dots, \beta_{nK})^\top$, which
 321 are specific to each respondent n .

322 Once coefficients are estimated, WTP can be determined by estimating the
 323 marginal rate of substitution between each non-monetary attribute and the mon-
 324 etary attribute (Louviere et al., 2000). The marginal utility of income is represented
 325 by the monetary attribute coefficient, β_{cost} . The WTP_k^l associated with attribute
 326 k and level l is $WTP_k^l = -\frac{\beta_k^l}{\beta_{cost}}$. This corresponds to the WTP to move from
 327 the *status quo* level of attribute k to level l . As commonly assumed in the liter-
 328 ature (Hensher and Greene, 2003), the coefficient associated with the monetary
 329 attribute (β_{cost}) is considered to be constant. The other RPL parameters (random
 330 parameters β_k^l) are assumed to be normally distributed (500 Halton draws). We
 331 use the mixlogit Stata command (Hole, 2007b) and estimate WTP by bootstrap
 332 (Hole, 2007a). We take into account the panel structure of the data to estimate
 333 standard errors because each individual responds to 8 choice sets.

334 2.3 Sample data and descriptive statistics

335 2.3.1 Data collection

336 We conducted interviews with 540 respondents. We met with individuals on-site
 337 in the park (302 respondents) from July to August in 2016 and 2017 and collected
 338 responses online from August 2016 to July 2017 (238 respondents). For the on-site
 339 interviews, respondents were selected at the four cardinal points of the park, taking
 340 care to ensure that the sample was spatially calibrated. For the online interviews,
 341 a survey was implemented following advertisements in the local newspapers. We
 342 were careful to deliver identical information through both interview modes.¹²

343 The survey was organized into four parts. First, there was a 4-minute video
 344 presentation displaying general information about the study area, the primrose

¹²Previous works find that mixed-mode surveys are an efficient and satisfactory way to increase the sample size and representativeness of a survey (Dillman et al., 2009; de Leeuw and Hox, 2011; Nielsen, 2011; Van der Heide et al., 2008).

345 willow invasion and its impacts, and a detailed explanation of the choice sets with
346 an emphasis on how colors translated into actual invasion densities (the script
347 of this presentation is provided in the Appendix in section C)¹³. Second, there
348 was a set of preliminary questions (e.g., reasons for visiting the park, frequency
349 of the visits, awareness of the invasion). Third, there were the DCE choice sets.
350 Fourth, there was a set of final questions on the socioeconomic characteristics of
351 the respondents, their degree of understanding, their satisfaction regarding the
352 survey, and the rationale for their choices if the *status quo* was chosen in all choice
353 sets (to distinguish protest answers and zero-value answers). Overall, the survey
354 required approximately 15 minutes to complete.

355 Before starting the video presentation, respondents were asked whether they
356 lived in the subregion where the park is located. Respondents living in the area sur-
357 rounding the park (i.e., subregion of *Loire-Atlantique*) were told that the primrose
358 willow would be managed with a budget financed through an increase in residential
359 and labor taxes. People living outside this area were informed that controlling the
360 invasion would increase the tourist tax.¹⁴ In both cases, the payment mode was
361 very similar as it was an increase in a tax rate. The choice of the mode of payment
362 was discussed in focus groups and seemed the most adequate for our case study.

363 During the choice experiment itself, each individual was presented with the 8
364 choice sets obtained from the experimental design (see sub-section 2.2.2).

365 Among the 540 respondents, 124 were excluded for not having answered all the
366 choice sets. Of the remaining 416 respondents, 26 were excluded due to “protest
367 answers”, and 5 others due to lack of understanding. Respondents identified as
368 providing "protest answers" are those who, while answering the *status quo* in
369 all choice sets, explained their unwillingness to reveal their true preferences with
370 specific reasons (e.g., it is not their responsibility to pay, anger against politics,
371 anger against polluters, ...). Those answering the *status quo* in all choice sets but
372 explaining this choice with reasons that show a real zero-WTP (e.g., no interest in
373 preserving this zone) were left in the sample. We identified a lack of understanding
374 based on an open-ended question that asked respondents who stated they were not
375 satisfied with their answers to explain why. We excluded respondents who declared
376 that they had difficulties understanding the study.

377 Some respondents completed the survey much faster than others (less than 2
378 minutes), which could indicate they did not reveal their true preference. Our re-

¹³Note that we were careful to emphasize the consequentiality of our study - that is the fact that respondents believe there is a nonzero probability that their answers actually influence decisions, which improves their incentives to answer truthfully (Johnston et al., 2017) - by specifying that the results would be communicated to the park managers to build their future management strategy.

¹⁴This tax is to be paid by clients at check-out in a hotel, in a campsite, etc. It is not generally included in the reservation quote but is announced in the terms.

379 sults remain unchanged when we exclude the top quartile of the speed-distribution,
380 and we decided to retain these respondents in our preferred sample. Moreover, we
381 tested the interaction of the decision time with the evaluation of the attributes,
382 showing that decision time does not significantly affect respondents' valuation of
383 attributes. Robustness checks were also done when removing 19 respondents who
384 said that the explanations given at the beginning of the survey were not fully clear
385 to them. Because removing these respondents did not impact the results of the
386 model, we kept them in the sample.

387 The final sample used for data analysis comprised 385 respondents (272 face-
388 to-face and 113 web respondents) and 9,240 observations (8 choice sets times 3
389 alternative options per choice set times 385 individuals).

390 **2.3.2 Descriptive statistics**

391 Tables 1 and 2 summarize the variability in respondents' general socioeconomic
392 characteristics and their use of, and acquaintance with, the regional park and the
393 marsh in particular. Variables used in the parametric regression are also intro-
394 duced.

Table 1: Summary statistics

Variable	#Obs	Mean	SD	Min	Max
Do you live in <i>Loire-Atlantique</i> ? (<i>LiveInTheRegion</i> : 1=Yes; 0=No)	385	0.69	0.46	0	1
Have you visited the park before? (<i>VisitBefore</i> : 1=Yes; 0=No)	374	0.83	0.37	0	1
I have visited the park before:					
because I live in the park (<i>LiveInThePark</i> : 1=Yes; 0=No)	385	0.37	0.48	0	1
because I work in the park (<i>Work</i> : 1=Yes; 0=No)	385	0.15	0.36	0	1
for hiking (<i>Hike</i> : 1=Yes; 0=No)	385	0.45	0.50	0	1
for boat rides (<i>Boat</i> : 1=Yes; 0=No)	385	0.27	0.45	0	1
for hunting (<i>Hunt</i> : 1=Yes; 0=No)	385	0.06	0.23	0	1
for fishing (<i>Fish</i> : 1=Yes; 0=No)	385	0.14	0.34	0	1
Did you know before that the primrose willow was an invasive alien species? (<i>KnowInvasive</i> : 1=Yes; 0=No)	385	0.65	0.48	0	1
Household size? (<i>Householdsize</i>)	361	2.4	1.2	0	7
Age (<i>Age</i>)	365	51.22	16.19	16	85
Do you visit the park at least once a year? (<i>HowOften</i> : 1=Yes; 0=No)	385	0.68	0.47	0	1

Table 2: Summary statistics (continued)

Variable	Freq.	%	Cumul.
How often do you visit the park? (<i>323 non-missing responses</i>)			
1=At least once a week	119	36.84	36.84
2=Every month	46	14.24	51.08
3=At least once a year	94	29.10	80.19
4=Less than once a year	62	19.20	99.38
5=Never	2	0.62	100.00
Household yearly income (<i>302 non-missing responses</i>)			
1=Less than 15,000 €	48	15.89	15.89
2=Between 15,001 and 25,000 €	98	32.45	48.34
3=Between 25,001 and 45,000 €	113	37.42	85.76
4=More than 45,001 €	43	14.24	100.00
Education			
0=Strictly less than high school + 2 years	201	52.21	52.21
1=High school + 2 years or more	184	47.79	100.00
Gender (<i>374 non-missing responses</i>)			
0=Male	229	61.23	61.23
1=Female	145	38.77	100.00

395 Note that 69% of the interviewed population lives in the *Loire-Atlantique* sub-
396 region, and 83% had visited the park before. Only 65% of respondents were aware
397 of the primrose willow invasion even though more than 80% of respondents visit
398 the park at least once a year.

399 Tables 3 and 4 compare some socioeconomic characteristics of the sample re-
400 spondents (as defined in Tables 1 and 2) with the French population and the
401 population that lives in the subregion of *Loire-Atlantique*.¹⁵

Table 3: Representativeness of the sample with respect to socioeconomic characteristics

	Our sample	France ^a		<i>Loire-Atlantique</i> ^b	
	Mean	Mean	p-value ^c	Mean	p-value ^c
Household size	2.4	2.2	0.000	2.2	0.000
Age	51	49	0.009	48	0.000
Higher education	47.8%	30%	0.000	31.8%	0.000
Gender (% of female)	38.8%	48.9%	0.000	51.5%	0.000

^a Data from INSEE (2017, 2018), the French national statistics institute.

^b Data from INSEE (2017), the French national statistics institute.

^c Significance of one-sample t-tests: test of equality of our sample's mean to mean at French and *Loire-Atlantique* levels.

¹⁵As almost 70% of our sample are respondents from *Loire-Atlantique*, we compare our sample not only with the whole French population but also with the population living in this region.

Table 4: Representativeness of the sample with respect to occupation

	Our sample	France ^a		<i>Loire-Atlantique</i> ^b	
	%	%	p-value ^c	%	p-value ^c
Farmer	3.8%	0.8%	0.000	0.7%	0.000
Craftsman, shopkeeper, business owner	12.6%	3.4%	0.000	3.3%	0.000
White collar professions	19%	9.6%	0.000	10.1%	0.000
Middle-level occupation	8.6%	13.8%	0.002	16.1%	0.000
Employee	17.7%	15.3%	0.315	15.9%	0.505
Worker	6.4%	11.8%	0.001	12.7%	0.000
Retiree	26.3%	32.5%	0.003	26.3%	0.706
Other without professional activity	5.6%	12.8%	0.000	14.8%	0.000

^a Data from INSEE (2017, 2018), the French national statistics institute.

^b Data from INSEE (2017), the French national statistics institute.

^c Significance of one-sample proportion tests: test of equality of our sample's proportion to proportion at French and *Loire-Atlantique* levels

402 Our sample differs from the French population except for the proportion of em-
403 ployees and the *Loire-Atlantique* population except for the proportion of employees
404 and retirees. In terms of magnitude, our sample shows a slight over-representation
405 of males and high levels of education (typical of online surveys). Regarding occu-
406 pation, we observe an over-representation of farmers, craftsmen/shopkeepers, and
407 white-collar workers and an under-representation of middle-level professions and
408 workers.

409 3 Results

410 Table 5 presents parameter estimates of the random parameter logit (RPL) models
411 with the ASC. As explained in section 2.2.3, the ASC parameter can be interpreted
412 as the respondents' variation in utility due to staying in the *status quo*. A negative
413 coefficient parameter estimate associated with the *status quo* means respondents
414 reject the no-policy option.

415 Three models are estimated. The first model does not include interaction vari-
416 ables (Model 1 in Table 5). The second model includes interactions with variables
417 that account for the residential location of the respondents (Model 2 in Table 5, see
418 subsection 3.2). The third model takes into account respondents' socioeconomic
419 characteristics and stated recreational and professional use of the park (Table A1
420 in the Appendix, see subsection 3.3).

Table 5: Random Parameter Logit: attributes only (Model 1) and interactions with location of respondents (Model 2)

	Model 1		Model 2					
	Param. Coeff. (SE)	SD Coeff. (SE)	Live in the Park		Live in the subregion		Log(Distance to Park)	
			Param. Coeff. (SE)	SD Coeff. (SE)	Param. Coeff. (SE)	SD Coeff. (SE)	Param. Coeff. (SE)	SD Coeff. (SE)
ASC	-3.403*** (0.005)	5.325*** (0.055)	-3.794*** (0.539)	5.318*** (0.564)	-3.445*** (0.846)	5.276*** (0.485)	-4.148 (2.593)	5.111*** (0.565)
x <i>Local</i>			0.969 (0.680)		-0.071 (0.903)		0.042 (0.229)	
area 1								
<i>Medium</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>
<i>Low</i>	0.687*** (0.096)	0.916*** (0.127)	0.784*** (0.123)	0.913*** (0.127)	0.605*** (0.165)	0.884*** (0.126)	0.671 (0.603)	0.829*** (0.145)
x <i>Local</i>			-0.079 (0.188)		0.132 (0.192)		0.006 (0.058)	
area 2								
<i>High</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>
<i>Medium</i>	1.029*** (0.136)	0.009 (0.127)	0.981*** (0.160)	0.017 (0.187)	0.648*** (0.202)	0.032 (0.191)	2.325** (0.725)	0.003 (0.235)
x <i>Local</i>			0.052 (0.212)		0.522** (0.221)		-0.118* (0.068)	
<i>Low</i>	2.093*** (0.170)	0.552*** (0.136)	2.048*** (0.188)	0.561*** (0.137)	1.810*** (0.221)	0.529*** (0.142)	3.217*** (0.717)	0.490** (0.152)
x <i>Local</i>			0.093 (0.208)		0.384* (0.216)		-0.099 (0.066)	
area 3								
<i>High</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>
<i>Medium</i>	1.738*** (0.104)	0.054 (0.128)	1.580*** (0.118)	0.059 (0.127)	1.520*** (0.153)	0.008 (0.128)	2.395*** (0.555)	0.007 (0.141)
x <i>Local</i>			0.439** (0.170)		0.299* (0.169)		-0.070 (0.052)	
<i>Low</i>	2.722*** (0.176)	1.058*** (0.138)	2.405*** (0.195)	1.044*** (0.138)	2.413*** (0.245)	1.003*** (0.138)	4.382*** (0.820)	0.895*** (0.152)
x <i>Local</i>			0.930*** (0.257)		0.438* (0.255)		-0.172** (0.077)	
area 4								
<i>Medium</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>
<i>Low</i>	0.665*** (0.092)	0.128 (0.345)	0.642*** (0.115)	1.044 (0.138)	0.492*** (0.153)	0.091 (0.487)	1.167* (0.587)	0.319 (0.295)
x <i>Local</i>			0.038 (0.168)		0.230 (0.176)		-0.041 (0.056)	
area 5								
<i>Medium</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>	<i>Ref.</i>
<i>Low</i>	0.332*** (0.087)	0.253 (0.173)	0.385*** (0.100)	0.254 (0.176)	0.396*** (0.127)	0.194 (0.219)	0.359 (0.437)	0.162 (0.239)
x <i>Local</i>			-0.180 (0.142)		-0.088 (0.134)		0.002 (0.041)	
Tax	-0.062*** (0.005)		-0.063*** (0.005)		-0.062*** (0.005)		-0.064*** (0.006)	
Log L	-2238.3***		-2229.4***		-2232.2***		-1,784.8***	
AIC ^a	4510.553		4507.034		4514.205		3619.633	
BIC ^a	4631.785		4685.317		4692.487		3792.255	
#Obs.	9,240		9,240		9,240		7,368	
#Ind.	385		385		385		307	

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; ^a: Akaike's Information Criterion and Bayesian Information Criterion;

3.1 Model without interactions

In the RPL model without interactions (Model 1 in Table 5), the estimated parameters are statistically significant and consistent with what we expected. Several standard deviation parameter estimates are also significant, hinting at preference heterogeneity among the respondents for the *status quo* and areas 1, 2, and 3. The ASC is significantly negative, indicating that respondents have, on average, a disutility associated with the *status quo* and favor implementing management strategies against the primrose willow invasion. However, the large and significant standard deviation parameter for the ASC indicates heterogeneity of preferences regarding the *status quo*: some respondents are strongly willing to pay to manage the invasion, whereas others are indifferent or unwilling to pay to improve the *status quo*.

Unsurprisingly, the parameter associated with the monetary attribute is negative: respondents' utility decreases as the tax increases, all else being equal. Parameters are significant and positive for the five areas, meaning that lowering the level of invasion increases respondents' utility for all five areas. However, comparing the same improvement with respect to invasion prevalence in different areas shows that respondents value some areas more. For instance, improving area 1's level of invasion from *Medium* invasion levels (Yellow) to *Low* invasion levels (Green) increases respondent's utility twice as much as the same improvement in area 5 (parameters 0.687 and 0.332, respectively). These results strongly suggest spatially differentiated preferences.

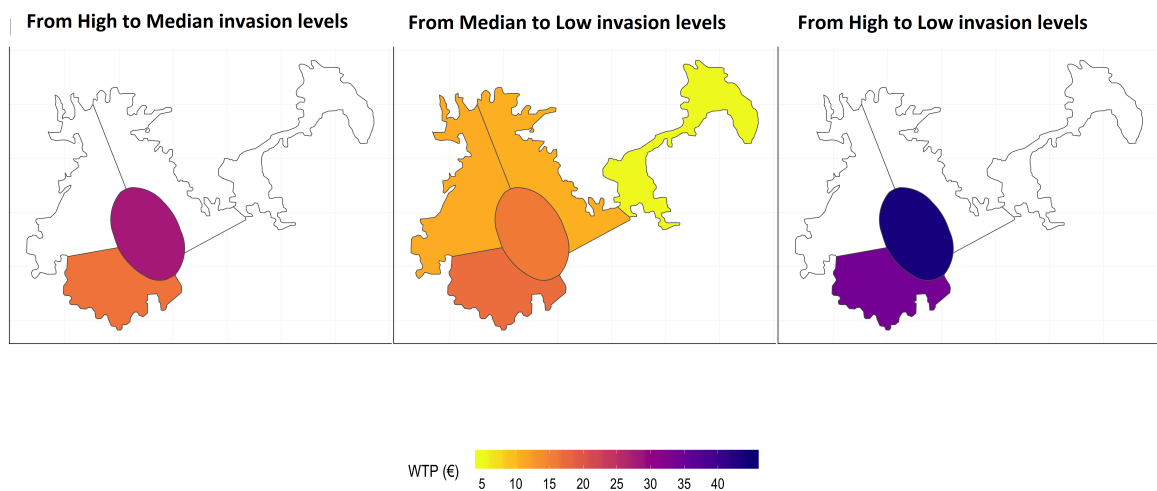
Table 6 presents the WTP derived from the estimates of the RPL without interactions, with confidence intervals computed by bootstrap (Hole, 2007a). As noted earlier, there is significant spatial heterogeneity in preferences. Focusing first on invasion level improvements from *Medium* to *Low* levels of invasion, the WTP is three times higher for areas 2 and 3 than area 5. On average, respondents are willing to pay approximately 5 € to maintain the primrose willow at a *Low* invasion level in area 5. They are willing to pay twice as much for the same objective in areas 1 and 4 (around 10 €) and three times as much in areas 2 and 3 (around 15 €). This heterogeneity of WTPs supports the hypothesis that central and southern areas are more valued, possibly because they are more frequented and important to support the economic and recreational activities of the park. Another explanation is that the central and southern areas (areas 2 and 3) are historically the first areas invaded. The invasion then spread to areas 1 and 4 and finally reached area 5. The central and southern areas are also the only ones likely to reach a *High* invasion levels in five years if no controls are put in place. As *High* invasion levels have critical impacts on use and non-use values, avoiding these impacts may explain the preference for invasion control in these two areas. Figure 4 shows the extent of WTP estimates in the different areas.

Table 6: Willingness to pay (€) and bootstrapped confidence intervals from the RPL without interactions (Model 1 in Table 5)

	WTP for improving the invasion level		
	from <i>High</i> to <i>Medium</i>	from <i>Medium</i> to <i>Low</i>	from <i>High</i> to <i>Low</i>
area 1		11.09 [8.30, 13.87]	
area 2	16.60 [12.69, 21.12]	17.16 ^a	33.76 [30.10, 38.48]
area 3	28.03 [23.12, 32.98]	15.86 ^a	43.89 [37.11, 50.02]
area 4		10.72 [8.04, 13.30]	
area 5		5.35 [3.68, 7.46]	

Note: (a) Difference between WTP for improvement from *High* level of invasion to *Low* level of invasion and WTP for improvement from *High* level of invasion to *Medium* level of invasion.

Figure 4: Average WTP for primrose willow management in different areas



461 As expected, the transition from *High* to *Low* invasion levels is always more
462 valued than a transition from *High* to *Medium* invasion levels. Interestingly, the
463 WTP to avoid *High* invasion levels is much higher for area 3 than it is for area 2.
464 Respondents are reluctant to let the primrose willow reach critical levels, especially
465 in area 3. This may be because area 3 is home to one of the park’s major tourist
466 villages, Saint-Joachim, which is the center of economic and recreational activities
467 in the marsh. This village is home to the park office, multiple rowboat departures,
468 and thatched buildings, typical of the historic houses of the marsh. The remainder
469 of the data analysis focuses on explaining spatial heterogeneity by exploring the
470 impact of respondents’ residential location (section 3.2) and their socioeconomic
471 characteristics and recreational/professional use of the marshland (section 3.3).

472 3.2 Heterogeneity analysis: residential location

473 To explore the role of the respondents’ residential location on their spatial pref-
474 erences, we interact each area (spatial attribute) with three spatial variables: (1)
475 whether the respondent lives in the park, (2) whether the respondent lives in the
476 subregion of *Loire-Atlantique*, and (3) how far from the park the respondent lives¹⁶.
477 These three variables are used as proxies for being a local resident or not (this is
478 why they are associated with the term *Local* in the first column of Table 5). The
479 estimation results are provided on the right side of Table 5 (Model 2), and the
480 WTP for areas in which the coefficient on the interaction variable is significant is
481 presented in Table A2, Appendix B.

482 The principal impact of living in the park on WTP is for area 3. For this area,
483 local residents are willing to pay 30 to 40% more to increase the control of the
484 primrose willow (see Table A2).

485 Hence, a respondent living in the park is willing to pay 53 € (38.22 + 14.78)
486 for the prevalence of invasion in area 3 to decrease from a *High* invasion level to a
487 *Low* invasion level. The average respondent is willing to pay 38 € for the same
488 improvement (see Table A2 in the Appendix). When comparing the preferences of
489 individuals who live inside and outside of the *Loire-Atlantique* subregion, results
490 are similar and indicate a preference of individuals living in the subregion to control
491 the invasion in areas 2 and 3. The WTP estimates for area 2 are 20% to 80% greater
492 for the subregion residents compared with the mean respondent and about 20%
493 greater for area 3 (see Table A2 in the Appendix).

494 Finally, we construct a third variable indicating the log of the distance from
495 the centroid of the park to the centroid of the ZIP code of respondents’ residences.

¹⁶We use a log specification for the distance to the park. There is little theoretical guidance regarding the specification of the distance variables (Concu, 2007), and we empirically explored several. The log specification was found as best performing in terms of AIC (Akaike Information Criterion) and BIC (Bayesian Information Criterion).

496 The city of *Saint-Joachim* is coded as the center of the park¹⁷. Goodness of fit
497 parameters show that the model using this third proxy is the best-fitting model
498 (smaller AIC and BIC). The model differs from the two previous models in that
499 space is modeled as a continuous variable. In this third case, the *Local* variable
500 measures the distance to the park, and the estimated parameters are negative.
501 This means that the further away the respondents live from the park, the lower
502 their WTP.

503 The respondents' place of residence still plays an important role in the assess-
504 ment of areas 2 and 3, especially for improvements from a *High* to *Medium* level
505 of invasion in area 2 and for improvements from a *High* to *Low* level of invasion in
506 area 3. Consistent with the literature on distance decay and as mentioned previ-
507 ously, we find that the further away from the park respondents live, the less they
508 value management. On average, for a 1% increase in distance to the park, respon-
509 dents are willing to pay about 1.92 € less for moderate improvements in area 2
510 (*High* to *Medium* invasion levels) and about 2.72 € less for large improvements of
511 area 3 (*High* to *Low* invasion levels) (see Table A2 in the appendix).

512 Moreover, contrary to the two previous models in which all the estimated pa-
513 rameters were significant, the model with the continuous distance variable shows
514 that the parameters for areas 1 and 5 as well as the *ASC* are not significant. The
515 contrasting results obtained when comparing the three models with three different
516 distance indicators can be explained by the discrete versus continuous treatments
517 of distance. This reflects complex relationships between respondents' residential
518 location and their preferences, which can be explained by boundary effects (living
519 inside versus outside the park or the subregion) and distance effects (living closer
520 to or further away from the center of the park).

521 Taken together, interactions with the three different variables describing resi-
522 dential location indicate that local residents are globally willing to pay more than
523 "outsiders" to improve the invasion situation, but mostly in area 3. These re-
524 sults can indicate that residents are probably more use-value oriented than non-
525 residents, this preference for area 3 being justified by the fact that this area is
526 home to *Saint Joachim*, a typical Brierson village and the center of the regional
527 park's recreational activities. Distance is also an important variable in confirming
528 the specific status of areas 2 and 3 and, in particular, the priority given to area 3
529 by respondents living close to the park.

¹⁷For the 307 individuals whose responses are used for the last column of model 2 in Table 5, the mean distance to the park is about 111.1 km (SD: 189.27). The first quartile is 7.4 km, the median is 18.3 km, and the third quartile is 132.5 km.

530 **3.3 Heterogeneity analysis: respondents' characteristics and** 531 **use of the park**

532 In a third specification, we examine the interactions of the main parameters with
533 various socioeconomic characteristics (age, gender, income, education) and vari-
534 ables associated with the activities that respondents typically engage in within
535 the park (hiking, hunting, fishing, rowboat rides or work). These variables (*Age,*
536 *Gender, Income, Education, HowOften, Hike, Hunt, Fish, Boat, Work*) are defined
537 and described in Tables 1 and 2. In the interest of space, the detailed results from
538 this enlarged model are shown in Appendix A, Table A1, where only significant
539 estimated interaction parameters are reported.

540 Supporting the arguments that women may be more motivated by public good
541 issues than men (e.g. Bruner et al., 2017), we observe that women are, on av-
542 erage, more averse to the *status quo* than men (i.e., more willing to implement
543 management of the invasion), although this result is not confirmed in area 1.

544 Regarding the overall preference for preserving areas 2 and 3, two major results
545 show up. The first is that working in the park is a key factor explaining preferences
546 for preserving these areas. We speculate that, just like respondents living in the
547 park, respondents working there are better aware of the importance of these areas
548 for recreational and economic activities.

549 A second result is that preferences for invasion management in area 3 are
550 stronger among respondents who visit the park often. Like residents of the park
551 and people working in the park, respondents who come often prefer area 3, which
552 may be explained by the fact that they are aware of the specificity and emblematic
553 characteristics of this area. Parameter estimates also show that respondents who
554 hike in the park value more area 2 than the average. Interestingly, these same
555 respondents give area 3 a lower than average value, which is consistent with the
556 fact that the main hiking trail circles the park and does not cross area 3.

557 **4 Discussion and conclusion**

558 As noted in the Summary for Decision Makers of the IPBES Global Assessment Re-
559 port on Biodiversity and Ecosystem Services (IPBES, 2019), inclusive governance
560 through the development and implementation of invasive alien species management
561 with relevant stakeholders is essential to achieving sustainability goals. Assessing
562 public preferences for invasive species management, including prioritizing sites, is
563 a prerequisite for this goal. In this study, we develop an original discrete choice
564 experiment to evaluate the spatial preferences of individuals regarding the man-
565 agement of an invasive alien species. The originality of the method is twofold:
566 (1) it relies on a representation of different management options in the form of

567 stylized geographical maps to assess respondents' preferences for the management
568 of an invasion on different invaded sites, and (2) it incorporates distance decay
569 modeling to estimate the influence of respondents' location on their preferences.

570 We assess public preferences for primrose willow management in the Brière
571 Regional Park in France and obtain three main results relevant to decision making.
572 The first result is strong spatial heterogeneity in preferences with, on average, areas
573 in which respondents are willing to pay two to three times more than in other
574 areas. We find that respondents are willing to pay annually from 5 € for the
575 lowest-valued area to 17 € for the highest-valued area to reduce the invasive alien
576 species from a medium to a low invasion level; they are willing to pay 17 € for the
577 lowest-valued area and 28 € for the highest-valued area annually to reduce the
578 invasive alien species from a high to a medium invasion level. We show that these
579 preferences for spatially targeted management are highly significant among park
580 residents and/or regular visitors and less so among respondents who live far away,
581 favoring a more homogeneous management across space. The main implication of
582 this result is that monitoring efforts should be targeted foremost in the central and
583 southwest areas of the marshland at the expense of the other areas, particularly
584 the eastern area. This is especially true when the preferences considered, and thus
585 the stakeholders deemed relevant, are residents and regular park users who have
586 unambiguous preferences for targeting control efforts in those areas and in the
587 central area of the marshland in particular.

588 The second result is that WTP varies significantly across respondents according
589 to their living locations and activities. The WTP of residents and regular users
590 of the park is much higher than non-residents and occasional users. This result
591 implies that the former are more concerned, which makes them legitimate and
592 relevant stakeholders.

593 Finally, a third result concerns the monetary envelope allocated annually to
594 management. Assuming that each tax household pays the minimum average WTP
595 obtained in our study (5 €), this envelope amounts to about 283,000 € if the
596 tax households are those of the residents of the park and 623,000 € if the tax
597 households are those of the Saint-Nazaire metropolis. These amounts, which we
598 estimate assuming the lowest WTP obtained in our study, are more than twice
599 the average budget currently allocated in the first case and more than five times
600 in the second. The main implication of this result is that it suggests an increase
601 in management budgets or, at least, the organization of an audit to better survey
602 the willingness to pay of taxpayers.

603 This work opens multiple research perspectives. The main one is to couple the
604 analysis of relevant stakeholders' preferences with a joint analysis of the spatial
605 heterogeneity of management costs and the spatial dynamics of the invasion. We
606 showed in the study an unambiguous preference for invasion control in the central

607 and southwestern areas of the marshland. But what if management is particularly
608 costly in these areas, or if limiting the dynamics of spread requires management
609 in other areas? Accounting for the spatial heterogeneity of management costs
610 and the spatial dynamics of the invasion may counterbalance the results of our
611 analysis, justifying a prioritization strategy that considers all three ingredients
612 simultaneously.

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626 **Ethics declarations**

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759 A Impact of respondents' activities

Table A1: Random parameter logit with interactions with respondents' characteristics and activities

	Parameter coefficient (SE)	SD coefficient (SE)
ASC	-3.368* (1.984)	4.773*** (0.513)
x <i>Gender</i>	-1.694** (0.834)	
area 1: Green	2.051*** (0.564)	0.856*** (0.155)
x <i>Gender</i>	-0.419* (0.232)	
x <i>Age</i>	-0.013* (0.007)	
x <i>Education</i>	-0.410* (0.245)	
x <i>Hike</i>	0.552** (0.234)	
area 2: Medium	0.233 (0.680)	0.004 (0.180)
x <i>Fish</i>	-0.802* (0.413)	
x <i>Hike</i>	0.952*** (0.277)	
area 2: Green	1.134* (0.651)	0.503*** (0.177)
x <i>Hike</i>	0.449* (0.266)	
x <i>Work</i>	0.622* (0.357)	
area 3: Medium	1.095** (0.493)	0.044 (0.155)
x <i>Education</i>	0.474** (0.221)	
x <i>HowOften</i>	0.718*** (0.218)	
x <i>Work</i>	0.498* (0.284)	
area 3: Green	1.596** (0.741)	1.106*** (0.165)
x <i>HowOften</i>	1.389*** (0.335)	
x <i>Hike</i>	-0.792** (0.317)	
x <i>Work</i>	0.741* (0.420)	
area 4: Green	0.349 (0.516)	0.047 (0.284)
area 5: Green	-0.607 (0.374)	0.143 (0.214)
x <i>Income</i>	0.000** (0.000)	
x <i>Hike</i>	0.355** (0.162)	
x <i>Work</i>	0.684*** (0.223)	
Tax	-0.070*** (0.006)	
Log L	-1673.8***	
#Obs.	7,104	
#Ind.	296	

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; Only significant interaction effects are reported.

760 **B Estimated willingness to pay for RPL models**
761 **with interactions**

Table A2: Estimated willingness to pay (€) and bootstrapped confidence intervals from the RPL with interactions (Model 2) in Table 5) - reported only for areas for which the parameters for the interaction variables are statistically significant

	WTP for improving the level of invasion	
	from <i>High</i> to <i>Medium</i>	from <i>High</i> to <i>Low</i>
Model 2: RPL with interaction variables: "Live in the Park"		
area 3	25.12 [20.12, 30.63]	38.22 [31.53, 46.24]
<i>x Local</i>	6.98 [0.62, 12.93]	14.78 [4.74, 23.06]
Model 2: RPL with interaction variables: "Live in the subregion"		
area 2	10.42 [2.81, 17.92]	29.14 [21.98, 36.78]
<i>x Local</i>	8.40 [10.46, 17.46]	6.18 [-2.86, 15.46]
area 3	24.46 [18.49, 31.01]	38.85 [30.61, 48.21]
<i>x Local</i>	4.82 [-1.45, 11.29]	7.05 [-2.45, 16.65]
Model 2: RPL with interaction variables: "Log(Distance to Park)"		
area 2	36.85 [8.16, 65.53]	
<i>x Local</i>	-1.92 [-4.67, 0.83]	
area 3		68.65 [41.32, 95.97]
<i>x Local</i>		-2.72 [-5.62, 0.17]

762 C Script of the DCE presentation

763 The presentation was made with the support of a PowerPoint displaying illustra-
764 tions. The presentation consisted of five main components : a description of the
765 study, a description of the park and the invasion, a detailed presentation of the
766 impacts of the primrose willow in the park, a description of the attributes and of
767 the *status quo*, and the key objective of the study. The script is detailed below.

768 General presentation of the study

769 As part of a research project conducted by INRA in partnership with Onema and
770 the Brière Regional Natural Park, you will be asked to answer a questionnaire on
771 the management of the primrose willow invasion in the Briéron marshland. This
772 will make it possible to set up management methods adapted to your preferences
773 and in particular to your use of the Park. We will first introduce you to the issues
774 related to the invasion of the marshland, then a series of questions will be asked
775 to you. Note that your answer will be communicated to Park managers in order
776 to design control strategies.

777 Description of the Park and the primrose willow invasion

778 The Park has an area of 55,000 ha, including 20,000 ha of wetlands (marshes,
779 canals, etc.). 80,000 people live there and many activities are carried out in the
780 park, such as tourism with rowboat rides and hiking and recreational activities
781 such as waterfowl hunting or fishing. Finally, agriculture is an important economic
782 activity in the marshland and consists mainly of cattle breeding. All these activities
783 are threatened by the primrose willow, a water plant native from Latin America
784 that has proliferated in the Park since the late 1990's.

785 On the images presented to you we observe from left to right a state of gradual
786 flooding:

- 787 • On the left, the primrose willow starting to invade a canal.
- 788 • In the middle a canal blocked by the primrose willows, severely affecting
789 navigability in the marsh and associated activities
- 790 • Finally, on the right, the canal and its banks are completely invaded, making
791 it impossible to use the park for cattle breeding, hunting, fishing or tourism.
- 792 • Biodiversity is also at risk because where the primrose willow proliferates,
793 most of the other species in the marsh disappear.

794 **Impacts of the invasion**

795 The invasion is located in the wetland and its contours, the primrose willow can
796 only reproduce in very wet areas. We have divided this study area into 5 sub-areas
797 of relatively similar size. The southeastern part of the wetland is excluded from the
798 study because it is the subject of a salt experiment and no manual or mechanical
799 controls will be carried out in the coming years.

800 Activities practiced in the five study areas are distinct:

- 801 • Tourism and in particular barge trips are practiced in the south-western area
802 of the marsh and in the area surrounding Saint Joachim
- 803 • Fishing is practiced throughout the wetland and in particular around Saint
804 Lyphard and Saint Joachim
- 805 • Waterfowl hunting is conducted on water bodies in the central and southern
806 part of the marshes
- 807 • Finally, livestock farming is mainly found in the southern area of the marsh
808 as well as in the eastern area, which is a less humid agricultural area.

809 **Presentation of attributes and of the *status quo* situation**

810 You can see on the left image the current invasion situation. The green color
811 represents a low or non-existent level of flooding that does not harm users while
812 the yellow color represents a level of fragmented invasion likely to hinder uses.
813 Finally, the red color represents a drastic level of flooding that makes it very
814 difficult to carry out agricultural or recreational activities . In the image on the
815 right, you can see the so-called "*status quo*" map representing the state of invasion
816 in 5 years if no management action is taken during this period.

817 **Objective of the study**

818 The objective of our study is to gather the preferences of the main users of the
819 park of which you are a part. To do this, we will present you with a succession of
820 choice cards representing management choices.

821 The choice cards look like this. Each time we have three management options that
822 outline the state of the invasion in five years.

823 For local inhabitants : Each option corresponds to a management strategy and
824 is likely to involve an additional cost added to the housing tax of the inhabitants
825 of the 21 communes of the park.

826 For tourists : Each option corresponds to a management strategy and involves
827 a cost to which park visitors are likely to contribute. The contribution could

828 be financed in part by an increase in the tourist tax on accommodation and an
829 increase in the rates for rowboat riding.

830 On the right we see the so-called *status quo* option, which describes the state of
831 the park in 5 years if no action is taken. This option has no cost. We can note that
832 Option A described here is a strategy to focus control efforts in the eastern part
833 of the park. It encourages breeding and fishing activities in this area and allows a
834 cost of 5 €, which will be added to your tax. The more ambitious Option B aims
835 to deploy control efforts throughout the fleet. It makes it possible to maintain the
836 state of invasion we are currently experiencing but is more expensive.

837 You will have to choose the option you prefer. Eight choice cards will be
838 presented to you in succession. Each time you will have to choose 1 of the 3
839 management options proposed to you. The analysis of your choices will allow us to
840 better understand your preferences and will be used to define the most appropriate
841 management strategy for the next five years.

842 We thank you for your participation and start the questionnaire now with some
843 general questions to get to know you better.