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1 **Explaining the rank order of invasive plants by stakeholder**
2 **groups**

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25 **Abstract**

26 Debates surrounding the use of policies to avoid further spread of invasive species
27 highlight the need to establish priorities in public resource allocations. We explore the
28 consistency or discrepancy among stakeholder groups involved in the risk and control
29 management of invasive species to identify the extent to which different factors
30 influence stakeholder choices of major relevant plant invaders. Based on stakeholder
31 ranking of invasive plants, we explore the reasons behind stakeholders' support for
32 policy management. Data were collected in Galicia, Spain, where a catalogue of
33 prohibited entry and trade of invasive species is currently under debate. We estimate a
34 rank ordered logit model using information from semi-structured interviews conducted
35 with respondents from four stakeholder groups: public administration sector,
36 ornamental sector, research and social groups. The characteristics of plant invaders that
37 provoke stakeholders to rank a species more highly are wide distribution of plant
38 invaders, existence of public control programmes, use and sale of species in the
39 ornamental sector and media coverage. The influence these aspects have in the selection
40 of top-ranked invaders varies across different stakeholder groups and with stakeholders'
41 level of knowledge, awareness and attitudes towards different potential policy
42 measures. A small group of invaders are perceived as top rated by all stakeholder
43 groups.

44 **Keywords:** invasive plants; stakeholder choices; rank ordered logit; factor analysis;
45 Galicia; Spain.

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48

49 **1 Introduction**

50 The prevention and control of biological invasions are important elements for the
51 conservation of biodiversity and ecosystem services (MEA, 2005; Perrings et al., 2010;
52 Vilà et al., 2011), and are the subject of an increasing number of policy responses
53 (Butchart et al., 2010). The success of control and eradication of invasive species, as
54 well as the policies governing their management in general (e.g. inspection regulations,
55 codes of conduct, or economic incentives to reduce threats), are highly dependent on the
56 acceptance and support by all affected stakeholders (Bremner and Park, 2007; Fischer
57 and van der Wal, 2007; García-Llorente et al., 2008; Sharp et al., 2011; Ford-Thompson
58 et al., 2012). The high percentage of invasive species which are either deliberately or
59 accidentally introduced for socio-economic reasons linked to commerce (e.g. Mack and
60 Erneberg, 2002; Pyšek et al., 2002; Westphal et al., 2008; Dehnen-Schmutz et al., 2007;
61 Carrete and Tella, 2008; Hulme 2009) and the rising social costs of invaders (e.g.
62 Pimentel et al., 2005; Xu et al., 2006) illustrate the need for stakeholder analysis when
63 managing invasions. In fact, stakeholder analysis is increasingly recognised as a key
64 factor in the success of managing natural resources (Reed et al., 2009; White and Ward,
65 2010), as stakeholders are not only affected by policy decisions but they also have the
66 power to influence their outcome.

67 Invasive species that are often deliberately introduced for commercial purposes provide
68 a particularly interesting example of how stakeholders with conflicting interests from a
69 wide range of backgrounds may be affected. This is the case for ornamental plants
70 where the horticultural industry and consumers benefit from the use of non-native
71 plants, which in some cases are invasive species or at risk of becoming invasive if
72 widely planted (Barbier and Knowler, 2006; Dehnen-Schmutz et al., 2007; Pemberton
73 and Liu, 2009). Different perceptions towards ornamental plants may develop over time

74 when highly regarded species become invasive and develop into an expensive
75 management problem (Bailey and Conolly, 2000; Starfinger et al., 2003; Dehnen-
76 Schmutz and Williamson, 2006). However, policy challenges become more acute when
77 species could generate income for some stakeholder groups (e.g. nurseries, gardening
78 firms or forestry owners), while imposing damage and management costs on other
79 stakeholder groups, or when generating both income and costs within a stakeholder
80 group. A study in Belgium found that even though nursery owners were aware of the
81 problem of invasive species in general, and 45% of them reported that they did not sell
82 any invasive species, all of them were selling at least one species listed in the Belgian
83 invasive species inventory (Vanderhoeven et al., 2011). With an increasing number of
84 invaders and limited financial resources, policy-makers have a critical interest in
85 understanding how stakeholders differ in their level of concern about biological
86 invasions and how different stakeholder groups perceive key invaders.

87 We focus particularly on invasive plants given the prevalence of their deliberate
88 introduction, mainly through ornamental trade, as a key pathway for the establishment
89 of non-native plant species as has been shown in other countries (Perrings et al., 2005;
90 Hulme 2009; Bradley et al., 2012). Several papers have analysed different stakeholder
91 perceptions regarding invasive species. Previous studies which focused on stakeholders
92 in the horticultural industry have aimed to decipher, for instance, stakeholders' levels of
93 awareness about invasions (Vanderhoeven et al., 2011), acceptance and support for
94 existing management and potential new policies (Coats et al., 2011) or voluntary
95 measures (Burt et al., 2007). Some papers also include a stakeholder analysis on
96 invasive species issues that are not specific to the horticultural trade. These may analyse
97 questions regarding specific species, for example, ability to name known invasive
98 species or ability to identify species from a list provided. It is important to understand

99 how stakeholder knowledge and perceptions regarding biological invasions at the
100 species level are formed, as this may influence policy coherence and the identification
101 of key management criteria. Bremner and Park (2007) illustrate that the level of support
102 for control and eradication programmes is influenced by specific species that are
103 currently being managed. Bardsely and Edwards-Jones (2007) illustrate certain levels of
104 consensus across stakeholders in the Mediterranean islands (Sardinia, Mallorca, Crete)
105 when asked to name five invasive plants. While on the other hand, García-Llorente et al
106 (2008) show that stakeholder groups (local users, tourists and conservation
107 professionals) varied in the number and particular species they mentioned, as well as in
108 their willingness to pay for eradication programmes for given species. These studies
109 conclude that people are more aware of species that have been the subject of
110 information or education campaigns. Andreu et al. (2009) focused more on the species-
111 level criteria for management and concluded that according to interviews undertaken
112 with natural resource managers, the most frequently managed species are the most
113 widespread in each region and the ones perceived as causing the highest impacts.
114 Eiswerth et al. (2011) measured invasion awareness by local residents' ability to name
115 at least one invasive aquatic species.

116 In this paper, we study the determinants of stakeholders' preferences over an open list
117 of invasive plant species. We use survey data to analyse how stakeholders involved in
118 the deliberate introduction and spread of non-native plants, as well as stakeholders
119 affected by invasions, select key invasive plant species and prioritise them in order of
120 importance. In the classical choice experiment setup, individuals are asked to select
121 their most preferred option out of a fixed set of alternatives, but additional information
122 about relative preferences can be obtained if individuals are asked to rank a set of
123 alternatives instead. We therefore asked stakeholders to name and rank the six most

124 important invasive plants from the perspective of their working organisation, and we
125 econometrically evaluated the factors that influenced these rankings. A rank ordered
126 logit analysis was used to explain the stakeholders' ranking of plant invaders influenced
127 by: species life-form (eg. tree, shrub, herb, annual), its use in the ornamental sector,
128 public control activities and media coverage. We identify consistencies and
129 discrepancies in the perceptions and rankings by stakeholders, who represent the
130 interests of the public sector environmental management, the ornamental plant sector,
131 research institutions and experts, and also social groups (e.g. agricultural unions,
132 forestry associations, environmental NGOs). Thus, we adopt a multi-stakeholder
133 framework. We also acknowledge that perceptions may vary within institutions and/or
134 across individuals in each of these groups and therefore, a re-estimation of the rank
135 ordered logit for stakeholder groups is required, classified by individual stakeholders'
136 general knowledge of invasions, their level of awareness and concern, and their interest
137 in the development of policy measures. This allows us to explore the variability in
138 awareness and prioritisation of particular invaders across different social groups, taking
139 into account the influence of differing stakeholder perceptions of the problem of
140 biological invasions in general. This study contributes to the development of invasive
141 species management practices by assessing stakeholders' perceptions towards invasive
142 species and the determinants of their preferences in their selection of key plant invaders.

143 **2 Material and methods**

144 **2.1 Study area**

145 This study takes place in Galicia, in the northwest of Spain, where over the past five
146 years (2005-2011) the Galician government has spent about 1.1 million Euros on
147 control and eradication measures for invasive plants in protected nature conservation

148 areas¹. The government has also funded the publication of a report of invasive plants in
149 the region (Xunta de Galicia, 2007). This report considers 73 plant species of which 31
150 are classified as posing a significant threat or as having the potential to do so. Out of
151 those 31 species, 68% are associated with introductions for ornamental use, suggesting
152 that the ornamental trade is a significant pathway for potential plant invasions in
153 Galicia.

154 The Spanish Law 42/2007, on Natural Heritage and Biodiversity, establishes a basic
155 legal framework for nature conservation and proposes the creation of a national
156 catalogue of invasive species; while also entitling different Spanish regions to establish
157 their own catalogues. This law specifies that the inclusion of any species in the
158 catalogue implies the general prohibition of possession, transportation, traffic or trade in
159 such species. The Royal Decree 1628/2011² regulates the Spanish List and Catalogue of
160 Invasive Species, containing two annexes, a catalogue of invasive species and a list of
161 alien species with invasive potential. However, this Royal Decree was fully in force
162 only for a few months. Stakeholder pressure from hunting and fishing groups, lead to
163 the exclusion of certain invaders from the catalogue, and claims from certain Spanish
164 regions led to the cancelation of the list of potentially invasive species³. The new Royal

¹ Information received from Nature Conservation Department of the regional government (Xunta de Galicia).

² <http://www.boe.es/boe/dias/2011/12/12/pdfs/BOE-A-2011-19398.pdf>

http://www.magrama.gob.es/es/biodiversidad/legislacion/real_decreto_1628_2011_listado_exoticas_invasoras_tcm7-211976.pdf.

³ http://www.boe.es/diario_boe/txt.php?id=BOE-A-2012-8569

165 Decree 630/2013 regulating the Catalogue of Invasive Species⁴ has been recently
166 approved, therefore the effectiveness of current legislation is difficult to assess.
167 Moreover, Galicia does not have its own catalogue of alien species to which legally
168 binding limitations would specifically apply. In fact, only Valencia (south-east of Spain)
169 has so far succeeded in establishing regional regulation of exotic alien species⁵.

170 **2.2 Survey design and administration**

171 This study was conducted by personal interviews using a semi-structured questionnaire,
172 in order to study the determinants of stakeholder prioritisation of the most relevant
173 invasive plants, as well as general information about stakeholders' awareness and
174 perceptions. Four stakeholder groups were interviewed: the ornamental plant sector,
175 public sector environmental management, research institutions and experts, and
176 representatives of different social groups (e.g. environmental NGOs, agricultural
177 unions, forest managers, hunting and fishing associations, and political parties). Thus,
178 the respondents were public or private organizations/individuals (*i*) involved in the
179 introduction or spread of invasive plants, (*ii*) affected by potential impacts of invasives,
180 and/or (*iii*) involved in management of invasives. Stakeholders interviewed included
181 corporate producers/sellers of ornamental plants, garden managers of public and private
182 parks and gardens, forestry associations, industries, and public sector administrators,
183 nature conservation organisations, water resource managers, environmental NGOs,
184 agricultural unions, hunters and recreational fishermen's associations, political parties,
185 and research centres and experts. Fieldwork was undertaken between December 2009
186 and March 2010. All stakeholders were first contacted by letter; this was followed by a

4 <https://www.boe.es/boe/dias/2013/08/03/pdfs/BOE-A-2013-8565.pdf>

5 <http://www.cma.gva.es/web/indice.aspx?nodo=73375&idioma=C>

187 telephone call, in order to correctly identify the person to be interviewed in each
188 institution/organization and to formalize the date of the interview. The initial recipients
189 of the letters and their contact details were identified through the internet, and by the
190 snowball sampling technique⁶ (e.g. Kumar and Kant, 2007; Bardsley and Edwards-
191 Jones, 2006; Andreu et al., 2009). In relation to gardening and plant production firms, a
192 list of 82 firms from ASPROGA (Galician Association of Ornamental Plant Growers
193 <http://www.asproga.com/>) and AGAEXAR (Galician Association of Gardening Firms
194 <http://www.agaexar.com/>) was produced. 40% of these firms were randomly selected to
195 be contacted by post. The initial list excluded 27 plant growers who were highly
196 specialized in single species groups (camellias, kiwis, hedges, etc.) and large garden
197 centres that were part of ASEJA (Spanish Association of Gardening Firms
198 <http://www.aseja.com/>) but did not have a registered business in Galicia. However,
199 ASEJA members were also considered in the study as they were involved in the
200 management of urban parks. Our data include the views of urban park managers for
201 three Galician cities.

202 All respondents were informed that the purpose of the questionnaire was to collect the
203 views of the organization they represented. The introductory section of the
204 questionnaire included a definition of invasive species as those that establish and spread
205 outside their natural range, producing adverse effects. It also provided an illustrated list
206 of 29 plants selected for their current and potential impacts in the studied region (Xunta
207 de Galicia, 2007; Sáenz-Elorza et al., 2004) in order to provide an identical framework

⁶ As defined by Kumar and Kant (2007), “snowball sampling technique is a special non-probability method used when the desired sample characteristic is rare. It may be extremely difficult or cost prohibitive to locate respondents in these situations. Snowball sampling relies on referrals from initial subjects to generate additional subjects”.

208 for all respondents. Interviewees were asked about their knowledge of the invasive
209 species in the list and asked to mention other known invasive plants. The survey
210 included a question to assess which were the most important invasive plants for the
211 stakeholders' organisation. Interviewees were then requested to rank up to six of the
212 most relevant invasive plants from those mentioned. We restricted the ranking set to six
213 plants, given that it has been shown in the literature that respondents may not be able to
214 prioritize between their less-preferred alternatives if they are faced with too many
215 options to rank (e.g. Chapman and Staelin, 1982). Stakeholders were also asked about a)
216 perceived impacts; b) knowledge and assessment of alternative policy options and c)
217 general perception of invasive species relative to other environmental problems. The
218 questionnaire used questions on a Likert-like five-point scale (from 1="none" to
219 5="extremely high") to explore perceptions of the problem of biological invasions,
220 environmental issues (wildfires, habitat loss, climate change, pollution, overfishing,
221 urbanisation), and their willingness to support given policy options (social awareness,
222 voluntary codes of conduct, measures regulating high risk activities, preventive
223 measures, establishing an early warning system, eradication and control, habitat
224 restoration). No socio-demographic information was required because respondents acted
225 as representatives of their organisations, not as individuals. A total of 61 personal
226 interviews were undertaken, 57 of which provided the ranking of invasive plants and
227 were used in this analysis.

228 **2.3 Factor Analysis**

229 Given the large set of variables derived from stakeholders' responses to the
230 questionnaire, we used factor analysis (FA) to analyse correlations among variables and
231 to explore the latent factors that caused the variables to covary. FA assumes that the
232 variance of a single variable can be decomposed into a common variance that is shared

233 by other variables included in the model, a unique variance that is specific to a
234 particular variable, and an error component. This technique analyses only the common
235 variance of the observed variables.

236 Data exploration started with the inspection of the correlation matrix for sets of related
237 variables. Given that most of our variables are ordinal, we employed the polychoric
238 correlation matrix. This technique estimates the correlation between two theorised
239 normally distributed continuous latent variables from two observed ordinal variables. In
240 addition, our dataset included binary variables for which an underlying latent
241 continuous dimension could not be assumed, as cross-tabulations of any two variables
242 were not symmetric. This prevents the use of the tetrachoric correlation, which is a
243 special case of the polychoric correlation for binary variables (Drasgow, 1988; Olsson,
244 1979). Therefore, for these variables, a nonparametric scale construction was calculated
245 with the Mokken cumulative scaling analysis (Mokken, 1971; Sijtsma and Molenaar,
246 2002). This method assumes that the probability of a positive response for the different
247 impacts increases monotonically with increasing values of a latent construct. Loevinger
248 coefficients (H_i) were calculated to test for this monotonicity assumption, and the factor
249 was calculated as the total number of positive responses.

250 The suitability of our survey data for FA was assessed using the Kaiser-Meyer-Olkin
251 (KMO) index, which is a measure of sampling adequacy that ranges from 0 to 1. The
252 KMO index compares the values of correlations between variables and those of the
253 partial correlations, which measure the relation between each two variables by
254 removing the effects of the remaining ones. Thus, high values of the index indicate that
255 FA is appropriate. Kaiser (1974) labelled KMO values greater than 0.5 as acceptable
256 and 0.8 or higher as desirable.

257 We next extracted the factors using the Iterated Principal Factor method, which replaces
258 the diagonal elements of the correlation matrix by communalities, that is, the common
259 variance we are trying to explain. This method provides initial estimates of the
260 communalities and then iteratively improves them (Gorsuch 1983; Loehlin 2004; Yanai
261 and Ichikawa 2007). Determining the number of factors to retain after extraction is not
262 straightforward since there is no an exact quantitative solution. This decision was
263 guided by several considerations that are commonly used in the literature. Firstly, we
264 employed the Kaiser-Guttman's rule, which consists of obtaining the eigenvalues of the
265 correlation matrix and extracting as many factors as eigenvalues greater than one
266 (Kaiser, 1960; Guttman, 1954). Secondly, we employed the Scree test that plots the
267 eigenvalues in decreasing order. They tend to decrease rapidly at first and then level off.
268 The point at which the curve bends is taken as the maximum number of factors to
269 extract (Cattell, 1966). Thirdly, all factors extracted should be readily interpretable.

270 Factors are weighted combinations of variables. Factor loadings indicate the relative
271 importance of each variable to each factor. We excluded variables with factor loadings
272 lower than 0.3. The internal consistency of each factor was checked using Cronbach's
273 alpha, which is a reliability measure to indicate how well a set of variables measures a
274 single one-dimensional latent construct. It ensures that the factors produced are
275 meaningful and interpretable (Cronbach, 1951). The 95% confidence intervals for
276 Cronbach's alpha were obtained using bootstrap.

277 Finally, we computed the standardised factor scores using the least squares regression
278 approach (Tabachnick and Fidell, 2001). We used imputation techniques for those
279 isolated cases where missing values resulted from no responses or responses
280 corresponding to "Don't know".

281 Factor analysis was applied using STATA 11. The estimated factors derived from the
282 FA were later employed in the regression analysis. In addition, stakeholders'
283 perceptions captured via the questionnaire variables and these latent factors, were
284 compared using nonparametric Kruskal-Wallis and Fisher's exact tests.

285 **2.4 Rank ordered logit model**

286 The standard procedure to handle rank data is the rank ordered logit model⁷. In the
287 economics literature, this model was first introduced by Beggs et al. (1981) and further
288 developed by Hausman and Ruud (1987), building on the well-known conditional logit
289 (CL) regression model introduced by McFadden (1974). This model was independently
290 formulated under the name of exploded logit model in the marketing literature (Punj and
291 Staelin, 1978; Chapman and Staelin, 1982). Allison and Christakis (1994) introduced it
292 in sociology and generalized it to accommodate ties in the rankings.

293 In its general formulation, we consider a model with N respondents and J invasive
294 species, where i represents the respondent and j indicates the species. Each respondent
295 is asked to assign a rank to the complete set of J plant invaders. For ease of exposition,
296 we assume that all plant invaders are ranked and there are no ties, even though both
297 assumptions could be relaxed in this model. Thus, each respondent i gives to plant
298 invader j a rank R_{ij} , which can take any integer value from 1 to J , where 1 represents the
299 "best" rank (the most prioritized invader) and J the "worst" (the least prioritized). We

⁷ The list of invasive plant species is an unordered choice set as we cannot specify that species 1 is more invasive than species 2, based on a natural ordinal ranking. Thus, we cannot use alternative methods to analyze rank ordered data such as the ordered probit model used in Paudel et al. (2007) to analyse the ranking of hypothetical termite control options in the United States. As an alternative, Hajivassiliou and Ruud (1994) presented various simulation and estimation methods to estimate a rank ordered probit model in Monte Carlo experiments.

300 also use an equivalent notation where r_{ij} denotes the invasive species that receives rank j
 301 by individual i . Thus, if plant invader k receives a rank j ($R_{ik}=j$), this means that k is the
 302 j th ranked species ($r_{ij}=k$). The rank ordered logit model can be derived from a familiar
 303 random utility model as in the usual CL model. Thus, for each plant invader j , a
 304 respondent i associates a level of impact on his utility U_{ij} , which is the sum of a
 305 systematic component μ_{ij} and a random component ε_{ij} :

$$306 \quad U_{ij} = \mu_{ij} + \varepsilon_{ij}$$

307 The systematic component could be decomposed into a linear function of a set of
 308 column vectors of variables related to the characteristics of the respondent x_i , attributes
 309 of the ranked plant z_j , and attributes that may vary with both respondent and plant w_{ij} :

$$310 \quad \mu_{ij} = \beta_j x_i + \gamma z_j + \theta w_{ij} \quad (1)$$

311 where β_j , γ , and θ are the row parameter vectors of interest⁸. The model is estimated
 312 assuming that the random component is independent and identically distributed with a
 313 Type-I extreme value distribution⁹.

314 Even though the level of impact U_{ij} is unobserved, we can observe stakeholder
 315 decisions. Assuming that a respondent i will give plant invader k a higher rank than
 316 invader j whenever $U_{ik} > U_{ij}$, a complete set of rankings of invaders from a stakeholder
 317 implies a complete ordering of the underlying utilities: $U_{ir_{i1}} > \dots > U_{ir_{ij}}$. To interpret the

⁸ Parameter identification requires setting one of the β_j vectors to zero. Also, to avoid linear dependence, the number of z_j variables must be less than or equal to $J-1$. See Allison and Christakis (1994) for further details on identification requirements.

⁹ It is also known as Gumbel or double exponential distribution, and it has the following cumulative distribution function $Pr(\varepsilon_{ij} \leq t) = \exp(-\exp(-t))$, $-\infty < t < \infty$.

318 model, we can treat data as a sequence of choices, in which the plant invader with the
 319 highest importance is chosen over the entire set of J plant invaders. When this choice
 320 has been made, among the $J-1$ remaining species, the plant with the second highest
 321 importance is chosen, and so on. Thus, the observed rank ordering of the J plant
 322 invaders is exploded into $J-1$ independent observations, given that the ranking of the
 323 least preferred alternative is assigned with probability 1. This implies the following
 324 likelihood for a single respondent:

$$325 \quad L_i = \Pr(U_{ir_1} > \dots > U_{ir_j}) = \prod_{j=1}^{J-1} \left[\frac{\exp(\mu_{ir_j})}{\sum_{k=j}^J \exp(\mu_{ir_k})} \right]$$

326 The rank ordered logit model can be seen as a series of CL models, where the
 327 probability of a complete ranking is made up of the product of separate CL
 328 probabilities, one for each species ranked. This explosion is possible due to the well-
 329 known independence from irrelevant alternatives (IIA) assumption, which characterizes
 330 the CL model and states that the relative preference for species k over species j is
 331 invariant to all other features of the choice set. The IIA assumption is no less plausible
 332 for ranked data than for data in which individuals choose only the most preferred
 333 alternative (see Allison and Christakis 1994).

334 We cannot assume that stakeholders are able to rank each plant invader according to the
 335 underlying utilities (Chapman and Staelin, 1982). As a solution to this potential ranking
 336 inability, the survey does not include a fixed set of alternatives that respondents are
 337 forced to consider in the ranking. The choice set J comes from the stakeholders'
 338 selection of the most important plant invaders for their organisation, and they were
 339 asked to rank only their top k_i plant invaders with $k_i \leq 6$ (Hausman and Ruud, 1987;

340 Fok et al., 2012)¹⁰. Following the literature, this simply requires the assumption that all
 341 the plant invaders that were not chosen by the stakeholder, $J-k_i$, are ranked lower than
 342 his last choice invader. The probability of observing a particular ranking for a single
 343 respondent i now becomes:

$$344 \quad \tilde{L}_i = \Pr(U_{ir_{i1}} > \dots > U_{ir_{ik_i}} > \max \{U_{ir_{ik_i+1}}, \dots, U_{ir_{ij}}\}) = \prod_{j=1}^{k_i} \left[\frac{\exp(\mu_{ir_{ij}})}{\sum_{l=j}^J \exp(\mu_{ir_{il}})} \right] \frac{1}{(J-k_i)!} \quad (2)$$

345 The last term in (2) represents the probability of observing one particular ordering of the
 346 last $J-k_i$ items, which are assumed to be ordered randomly.

347 Based on (2), the estimation of this model implies the following log-likelihood for a
 348 sample of N independent respondents:

$$349 \quad \log \tilde{L} = \sum_{i=1}^N \sum_{j=1}^{k_i} \mu_{ir_{ij}} - \sum_{i=1}^N \sum_{j=1}^{k_i} \log((J-k_i)!) - \sum_{i=1}^N \sum_{j=1}^{k_i} \log \left[\sum_{l=j}^J \exp(\mu_{ir_{il}}) \right]$$

350 We estimate a simple model where explanatory variables are only plant attributes, thus
 351 (1) reduces to $\mu_{ij} = \gamma z_j$. We use the *rologit* command in STATA 11 to obtain maximum
 352 likelihood estimates of the γ coefficient vector. Robust standard errors are computed to
 353 account for potential model misspecification or heteroskedasticity in the data. This
 354 *rologit* command permits rankings to be incomplete at the bottom, i.e. the ranking of the
 355 least preferred plant invaders for stakeholders may not be known. For instance, this
 356 occurs if stakeholders are asked explicitly to rank their top 6 alternatives and some of
 357 them fail to complete this task and only assign the top ranks (e.g. 1 to 4) and leave the
 358 rest blank. Appendix A illustrates that the potential unobserved heterogeneity in

¹⁰ In an intuitive sense, this also plays in favour of our model being robust to the IIA assumption. One might conjecture that most preferred alternatives are correctly ranked by stakeholders (Hausman and Ruud, 1987).

359 respondents' ranking ability can be treated alternatively using a latent-class rank-
 360 ordered logit (LCROL) (Fok et al. 2012, Hurley et al. 2012)¹¹. Table A.1 reports the
 361 LCROL model with six classes indicating that stakeholders cannot rank at all (p_0), rank
 362 only the most preferred item (p_1), the first 2,3, 4 most preferred items (p_2, p_3 and p_4) and
 363 all items (p_5). We compute the LR statistic for the restriction $p_5=1$, which leads to the
 364 ROL model. The value of the statistic is 6.65 and hence we cannot reject this restriction,
 365 which implicitly assumes that each stakeholder is capable of performing the complete
 366 ordering task of his most preferred alternatives.

367 In addition, for the estimated value of γ , we can produce a set of predicted choice
 368 probabilities for each individual in the sample. In particular, if invader k is the top-
 369 ranked plant invader, i.e. it has the highest utility impact among the entire set of J
 370 invaders, this leads to the well-known expression for the probability that species k is the
 371 most preferred by individual i in a CL model:

$$372 \quad P_{ik} = \Pr[U_{ik} \geq \max\{U_{i1}, \dots, U_{iJ}\}] = \frac{\exp(\gamma z_k)}{\sum_{j=1}^J \exp(\gamma z_j)} \quad (3)$$

373 Based on (3), we can also compute the marginal effect on the probability of alternative k
 374 being top-ranked when one of its attributes changes as:

$$375 \quad \frac{\partial P_{ik}}{\partial z_k} = P_{ik}(1 - P_{ik})\gamma$$

376 Turning to explanatory variables, the independent variables included in this study aimed
 377 to assess the effects of the species life-form, the extent of the species' geographical
 378 distribution in the region, the role of pathways of introduction of the species, the
 379 existence of public control activities and the publicity regarding plant invasions in the

¹¹ We thank an anonymous referee for this suggestion. The implemented code to estimate the LCROL model was written in R.

380 media. These variables were chosen because of their potential impact on respondents'
381 awareness of the species and the response to invasions. For example, the more
382 widespread the species is in an area, the more likely the species is known and the more
383 visible may be its impacts and management related activities (e.g. Andreu et al. 2009;
384 Bardsley and Edward-Jones, 2007). Similarly, whether a species has been introduced
385 deliberately for ornamental or forestry purposes, or whether a species is subject to
386 public control and eradication activities, can also influence attitudes and views towards
387 invasion management (e.g. Bremner and Park, 2007; Cook and Proctor, 2007; García-
388 Llorente et al. 2008). Life-form was captured with a dummy that indicates whether the
389 ranked plant invader is woody (i.e. tree or shrub). For the geographical distribution in
390 Galicia, we categorised this variable (1=low, 2=medium, 3=high) following the same
391 approach as in the official list of most problematic invasive plants in Galicia (Xunta de
392 Galicia, 2007); with the exception for 4 species for which this information was not
393 available. In those cases, we used the number of records in 10x10 km sized quadrants
394 covering Galicia as used in the SITEB (Territorial Information System of Biodiversity)
395 database¹² and local expert knowledge. The role of the pathway of introduction was
396 included with a dummy that indicates whether the ornamental sector sells or uses the
397 plant. We captured the influence of public control activities by using a dummy variable
398 that indicates, for each species in the dataset, if control activities were undertaken in
399 protected areas in the years prior to the survey (2007-2009) by the Nature Conservation
400 Department of the regional government (Xunta de Galicia).

401 Finally, our model investigates the potential influences of media coverage on the
402 invader rankings of stakeholder groups. Media coverage is increasingly associated with

12 The SITEB database can be consulted at <http://inspire.xunta.es/siteb/acceso.php>

403 individual and institutional decisions about the perceived risk posed by natural hazards
404 (e.g. Vilella-Villa and Costa-Font, 2008; Donovan et al., 2011). For invasive species,
405 Gozlan et al. (2013) found a strong correlation between public awareness toward certain
406 invaders and the number of pages listed in popular internet search engines that mention
407 a particular species. However, the literature has also shown that the general public's
408 perception may differ from perceptions of key stakeholders such as managers, scientists,
409 or conservation organisations (e.g. García-Loriente et al. 2008; Sharp et al, 2011;
410 Gozlan et al., 2013). This is because stakeholders have a higher knowledge and personal
411 experience of the benefits and costs posed by the invaders and their management. Media
412 coverage of invasions may focus on different interests or issues. Articles may focus on
413 highly visible species or species that are not yet present but could have a potentially
414 high future impact. They could be short notices mentioning planned management
415 activities that affect established invaders (or those with the risk of becoming
416 established) invaders, or detailed articles potentially contributing more to the general
417 knowledge of invasive species. We measured media coverage by focusing on
418 newspaper articles and searching for the words “plant invaders”, “invasive species”,
419 “biological invasions” and “exotic species” for the two years previous to our survey in
420 the digital libraries of national newspapers with a regional edition for Galicia (2),
421 regional newspapers (2), and provincial and local newspapers (6). If an article explicitly
422 mentioned a plant invader that appeared in the stakeholders' rankings, we recorded the
423 number of words in the article¹³. Table 1 reports descriptive statistics for the

¹³ The presence of a potential endogeneity issue arising from bi-directionally causality between media coverage and stakeholders' perceptions was tested by using the two-stage-residual inclusion (2SRI) method (Terza et al., 2008). We instrumented media coverage with the 2009 amount of regional government funding to control/eradicate plant invaders in the region. At the theoretical level, we would expect this to be significantly related to press articles because regional/local newspapers cover these management activities often funded by the regional government. The first step of our 2SRI analysis supports this view, as the amount of public investment in control actions was shown to be a statistically

424 stakeholders' ranked choices of plant invaders and for the plant attributes used as
425 explanatory variables.

426 **3 Results**

427 **3.1 Brief overview of sample characteristics**

428 The results show that respondents are aware of more than 90% of the species included
429 in the Galician list of most problematic invasive plants (Xunta de Galicia, 2007).
430 Seventy-five percent of those interviewed stated that they were affected by invasive
431 plants in their working activities. Their level of concern about biological invasions has a
432 mean value of 3.7 on a five-point Likert scale, which is similar to the concern expressed
433 for environmental pollution or overfishing problems. The most highly regarded policy
434 response was education and social awareness, followed by habitat restoration; while the
435 policy response with the lowest support was “measures for high risk activities e.g. a tax
436 on sales”.

437 When respondents were asked about the relevance of non-native species to their
438 organization, only a total of 44 plants were mentioned. This list includes two weed
439 species, Rumex spp. and Chenopodium spp., which were known by the respondents at
440 the genus level only and cannot be categorised as native or non-native; and one species
441 considered native Pinus pinaster (Carrión et al., 2000), mentioned by two stakeholders.
442 These three species were excluded from our analysis. Four of the remaining species are
443 not included in the report of non-native invasive plants published by the regional
444 government (Xunta de Galicia, 2007). This is the case for Quercus rubra, which may be

significant predictor of the number of words in the press ($p < 0.001$). We could also expect the 2009 amount of regional government funding not to have an effect on stakeholders' ranking given the model covariates used, such as the dummy that captures whether a species has been subject to control in protected areas. The inclusion of the first-stage residuals in the rank-ordered logit model shows that these are statistically non-significant ($p > 0.10$), rejecting the hypothesis of endogeneity.

445 planted but does not propagate itself, and Baccharis halimifolia, which seems only
446 recently to have been recognized as problematic in one single locality in Galicia but
447 appears to be spreading in estuaries in Northern Spain in recent years (Caño et al.,
448 2013). One stakeholder mentioned both of these species. Six stakeholders from the
449 ornamental sector mentioned bamboo (probably mostly referring to Phyllostachys spp.),
450 which seems to be a problem in gardens, although its impacts outside gardens are
451 increasingly recognized in the study area (La Voz de Galicia, 2012). The most striking
452 case of discrepancy in the perception of invasiveness between stakeholders and the
453 regional administration is Eucalyptus globulus. This species is not included in the
454 regional government publication, even though at the national level it is classified as
455 invasive for this region (Sánchez-Elorza et al., 2004), and was frequently mentioned by the
456 stakeholders. The ten most frequently mentioned species were Acacia dealbata. (41
457 responses), Eucalyptus globulus (30), Cortaderia selloana (30), Carpobrotus edulis (19),
458 Robinia pseudoacacia (12), Stenotaphrum secundatum (11), Azolla filiculoides (9),
459 Acacia melanoxylon (9), Ailanthus altissima (9), and Cyperus eragrostis (7). With the
460 exception of S. secundatum, all these species were deliberately introduced for
461 ornamental use and forestry purposes. Further descriptive details about this dataset can
462 be found in Dehnen-Schmutz et al. (2010).

463 **3.2 Latent perception factors on plant invasions**

464 Description of the latent perception factors supported by the FA is presented below.
465 Table 2 shows the results for the five perception latent factors extracted: plant invasion
466 awareness, environmental concern, perceived population environmental concern,
467 recognised impacts, and policy measure acceptability. The KMO measure of sampling
468 adequacy showed adequate fit (KMO ranged from 0.63 to 0.78). The internal
469 consistency of the items within each factor is satisfactory, as Cronbach's alpha ranged

470 from 0.60 to 0.79. Overall, we found that invasive plant perception factors do not differ
471 substantially between stakeholder groups with the exception of their level of awareness
472 (Table 2). This suggests that perceptions of these factors do not clearly depend on this
473 stakeholder classification, i.e. none of our stakeholder groups can be associated with a
474 unique perceptual set of values related to their level of awareness, environmental
475 concern, impacts, and support for the development of policy measures surrounding
476 invasive plant species.

477 - **Awareness and concern about invasions**

478 The FA of awareness gave rise to an optimal one-factor solution that accounted for
479 100% of the variance; and the eigenvalue for this factor was 1.37. It consisted of three
480 variables for which factor loadings ranged from 0.50 to 0.84 (Appendix B). We named
481 this factor “awareness score”, and the three items contributing to it are *(i)* concern about
482 biological invasions, *(ii)* knowledge of invasive plants in Galicia, and *(iii)* the number of
483 invasive plants perceived to have an impact on stakeholder organisations. Table 2 shows
484 that stakeholders in the public administration sector and research experts are
485 significantly more familiar with invasive plants in the region, indicating a higher
486 number of species that are important for the interests of their organisations; and they are
487 also more concerned about biological invasions. Table 2 also shows that these
488 respondents in the research and public administration groups score significantly higher
489 than other stakeholder groups on this factor, as expected.

490 - **Perception towards other environmental problems**

491 The second factor consisted of five variables, related to stakeholders’ scores for
492 different environmental problems (habitat loss, climate change, pollution, overfishing
493 and urbanization). This factor accounts for the 100% of the observed variance, and
494 variables’ factor loadings ranged from 0.55 to 0.89 (Appendix B). This factor was

495 named “environmental concern score” as it expresses the stakeholder’s overall
496 perception of major environmental conservation issues. The average degree of
497 environmental concern expressed for each of the problems explored is high, but there
498 are no significant differences among stakeholder groups, with the exception of climate
499 change (Table 2), about which, public administration and ornamental sector
500 stakeholders were less concerned.

501 - **Perceived opinion of Galician population’s concern for environmental problems**

502 The FA of the respondents’ scores related to their perceptions of the Galician
503 population’s concern for environmental problems resulted in an optimal one-factor
504 solution (Appendix B). Loading factors relating the observed variables to the factor
505 ranged from 0.39 to 0.69 (Appendix B). Given that this factor assesses the weight that
506 stakeholders placed on the environmental concern of the general population, it was
507 named “perceived population environmental concern score”. It could be interpreted as
508 the perceived environmental conscience within the stakeholders’ social surroundings.
509 Note that the FA could not identify significant differences in stakeholders' beliefs
510 regarding the Galician public's concerns towards environmental problems, except for
511 beliefs regarding public concern for habitat loss and climate change (Table 2).

512 - **Perceived invasion impacts**

513 The estimated Loevinger H-coefficients confirm that the three items related to
514 economic, social and health impacts follow a Mokken scale. The values of these H-
515 coefficients vary between 0.55 and 0.70 (Appendix B). These results show that the
516 economic impact of invaders is most widely recognised, followed by their social and
517 health impacts. Stakeholders from the ornamental sector show significantly lower levels
518 of perception of the social impacts caused by invasive species (Table 2).
519 Acknowledgment of ecological impacts is not included in this analysis as almost the

520 whole sample of respondents (88%) recognised this type of impact.

521 - Perceptions on invasive species management options

522 Stakeholders' support for alternative policy measures was also explored in the FA,
523 emerging as one factor with a large eigenvalue (2.37), which accounted for 100% of the
524 total variance. The four variables included had factor loadings that ranged from 0.65 to
525 0.91 (Appendix B). This factor, named "policy measures acceptability score",
526 represents the stakeholders' acceptability of policy measures based on economic
527 instruments, regulations that either dis-incentivise or limit the use of particular plant
528 invaders, as well as early warning systems, and control/eradication measures. No
529 significant differences were identified in stakeholders' views of the acceptability of the
530 various policy measures proposed to manage invasive plant species (Table 2).

531 3.3 Determinants of Stakeholders Invasive Species Ranking

532 The choices stakeholders made when asked to select and rank the six most important
533 invasive plants from the species that they mentioned as important for their organization,
534 lead to a total of 30 species being included in the stakeholders' rankings (i.e. $J=30$ and
535 $M=6$). Table 1 shows that the average number of plant invaders ranked by each
536 stakeholder was 2.84. There was a strong positive correlation between the number of
537 species listed by stakeholders as important for their interests and the number of species
538 that they subsequently included in the ranking (Spearman correlation=0.80, $p<0.001$).
539 Table C.1 (Appendix C) reports the fifteen plant species that appeared most frequently
540 in the ranking, and also in the first three positions.

541 The rank ordered logit model was estimated in order to explore the role played by
542 natural and social attributes of the plant species in shaping stakeholder's ranking of the
543 plant invaders. Table 3 shows coefficient estimates and robust standard errors for the
544 model when the full sample of stakeholders is considered. It also shows the results when

545 stakeholders are classified according to their represented interests: public sector,
546 research, ornamental sector, and social groups. When considering the full sample of
547 stakeholders, all plant attributes considered have a positive and statistically significant
548 influence on the rank order of plant invaders. However, we found differences in the
549 significance of the role played by these predictors across stakeholder groups. Media
550 coverage is the only predictor that is consistently significant at the 1% level across
551 stakeholder groups. That is, higher media coverage of an invader increases its
552 probability of being higher in the ranking; all else being equal. The distribution of the
553 species, however, is not statistically significant for those respondents working in the
554 public sector. However, the use of a species in the ornamental sector has a significant
555 effect on the rankings of stakeholders working in this sector. Ornamental sector
556 respondents were more likely to rank a species as high risk if that species was traded by
557 the ornamental sector. This makes sense, as they may be less familiar with non-
558 ornamental plants. If public administration undertakes control or eradication measures
559 in protected areas, this significantly affects the rankings produced by those holding
560 positions in the ornamental sector and the administration.

561 Table 3 also presents the results for the rank ordered model with stakeholders classified
562 according to their perceptual latent dimensions, i.e., where each group includes those
563 respondents with score perceptual values which are higher than the median. Again,
564 even though signs are consistent, some predictors no longer exert statistically significant
565 influences on rankings for some stakeholder groups according to this classification. For
566 instance, results show that woody life-form has a significant effect on the probability of
567 choosing a plant over other species in the ranking for those stakeholders who are more
568 highly aware of impacts, and have higher concern regarding environmental issues. For
569 all different groups, the extent of the geographic distribution of the plants has a

570 significant influence in the rank ordering. Finally, stakeholders with higher invasion
571 awareness, environmental concern, recognition of impacts and higher willingness to
572 accept policy developments rank plants that are being used in the ornamental sector
573 more highly.

574 Table 4 reports the marginal effects on the probability of a plant invader with mean
575 attribute values being the top-ranked choice when one of its attributes changes for all
576 stakeholders. A hypothetical plant with average characteristics has a 1.71% probability
577 of being ranked first. For the continuous variable media coverage, we estimated the
578 elasticity. A 1% increase in the average number of words in press articles about a plant
579 will increase the probability that it is the first chosen invader in the ranking by over
580 0.4%. For categorical and dummy variables, values in Table 4 show the proportional
581 change in the probability of an invader being top-ranked when there is a discrete
582 change. For example, if there is a discrete change of a species distribution from 2 to 3,
583 the change in the probability of an invader being top-ranked would be 1.26%.

584 Our results also provide estimates of the probability of the different stakeholder groups
585 ranking a particular species first (Table 5). This analysis shows the differences between
586 stakeholder group rankings, in particular for those species that appear more frequently
587 in the newspapers, and are more clearly associated with forestry impacts. According to
588 our predictions, stakeholders in the social group have a 35% probability of choosing
589 Acacia dealbata as top-ranked invader, while also a 20% probability of having
590 Eucalyptus globulus as a first choice. In contrast, natural resource managers in the
591 public administration only assign first choice probabilities of 15% and 13%,
592 respectively, to these species. Similarly, the ornamental sector displays much lower
593 probabilities of choosing these species as the top-ranked invaders. All stakeholders,
594 with the exception of those in the social groups have a higher probability of choosing

595 Carpobrotus edulis as a top-ranked invader over Eucalyptus globulus. This is also true
596 for stakeholders with higher awareness of invasions and their impacts, higher level of
597 environmental concern and higher policy acceptability.

598 **4 Conclusions**

599 Management of invasive species has become a major public policy concern worldwide.
600 Public authorities need to identify invasive species, prioritize their responses to
601 potential ecological and economic impacts, and allocate scarce resources to the control
602 of specific invaders in order to minimize overall damages. In addition, successful
603 policies depend on the level of support by the different stakeholder groups toward these
604 public authorities' decisions (e.g. Stokes et al. 2006; Sharp et al., 2011; Ford-Thompson
605 et al., 2012).

606 Our study provides useful insights into stakeholders' selection of key invaders in order
607 to increase the efficiency of policies that aim at controlling and eradicating invaders.
608 We evaluated stakeholders' perceptions toward invasions, their impacts and policies,
609 and compared them across stakeholder groups, including public administration,
610 research, ornamental sector and social groups. We show that a wide distribution of plant
611 invaders, the existence of public control programmes, the use and sale of the species in
612 the ornamental sector and the level of publicity through media coverage exerted
613 significant influence over the stakeholders' ranking of plant invaders. Most importantly,
614 we found that these explanatory variables influence stakeholder groups' rankings
615 differently. This influence is also dependent on how stakeholders perceive the general
616 problem of invasions.

617 Our analysis reveals that none of the stakeholder groups is associated with a unique set
618 of perceptual values relating to their level of awareness, environmental concern,
619 awareness of impacts, and support for the development of policy measures. We find that

620 public administrators and researchers show a higher level of awareness of plant
621 invasions. Stakeholders from the ornamental sector show significantly lower levels of
622 perception of the social impacts; while stakeholder groups have no significant
623 differences in their level of awareness of ecological, economic and health impacts. In
624 addition, stakeholder groups do not differ significantly in their view regarding the
625 acceptability of the various policy options, i.e. no policy is particularly preferred by any
626 group. This is an important issue for policy-making, and can be crucial for the
627 facilitation of consensus. When analysing all stakeholders together, education and
628 increasing social awareness of invasive plants is the preferred policy option for
629 managing invasives (see also Dehnen-Schmutz et al., 2010). This is in line with
630 previous literature (Vanderhoeven et al., 2011), and may be generally perceived as the
631 policy response which is most easily achievable and carries the fewest direct
632 implications for these stakeholders. In our case, the high regard for this policy option is
633 also consistent with the general agreement among stakeholder groups about the low
634 level of environmental concern in the general public. It may also reflect the
635 respondents' awareness of the importance of ornamental use of plants for invasions in
636 the study area. Similarly to Barbier et al. (2013), we found that sales taxes are the least
637 preferred policy option. This can be explained by the lack of familiarity with these
638 instruments, and their expected results. Stakeholders may also be concerned with the
639 information required to implement such instruments, as this may affect their usefulness
640 to curb invasions (Barbier et al. 2013).

641 Our study reveals that a relatively small group of species are perceived as key invaders
642 by all stakeholder groups. Even though the choice set of species ranked by the
643 stakeholders included thirty plants in total, only four species have a significant
644 probability of being top-ranked invaders. Thus, only Acacia dealbata, Eucalyptus

645 globulus, Carpobrotus edulis, and Cortaderia selloana consistently show a probability of
646 around 10% or higher of being ranked as the invasive species of highest concern, among
647 all the plant species mentioned by stakeholders as being relevant to their organisations.
648 In fact, invasion by Acacia dealbata, seems to be a particular concern for the social
649 groups surveyed, being the priority species for 35% of those in this group. All the key
650 species of concern are deliberate introductions, which are still generating commercial
651 benefits, even though they are spreading as invasives in natural areas. This result is
652 consistent with the Galician government's expenditures on invasion management,
653 allocating 68% of the budget on control and eradication of invasive plant species in
654 protected areas to programmes that deal with Acacia dealbata, Cortaderia selloana and
655 Carpobrotus edulis. Such policy does not extend to Eucalyptus globulus, whose control
656 has just recently started in a couple of protected areas (El País, 2012), even though this
657 species has absorbed an important percentage of public spending on control of invasive
658 species in other parts of Spain, particularly in the Southwest (Andreu et al., 2009). This
659 may be explained by the significant benefits generated by commercial forestry
660 exploitation of Eucalyptus globulus plantations in Galicia, to the extent that
661 monospecific stands of this tree species have increased more than 40% in the last
662 decade, accounting for 17% of the wooded forest area in the region (MAGRAMA,
663 1999; 2011).

664 We also studied the critical role of media publicity on invaders on stakeholders'
665 perceptions. In particular, we provided evidence that media coverage plays an important
666 role in the rank order choices of all stakeholder groups in their perception of the key
667 invaders in the studied area. Newspaper coverage on a certain invasive plant increases
668 the probability that it is chosen as top-ranked invader by stakeholders. However, it
669 should be noted that media attention may not be directly linked to species impacts. For a

670 sample of five invasive species in Britain, Gozlan et al. (2013) found that species
671 receiving highest internet presence were not the ones with the highest ecological impact.
672 Our results highlight the importance of publicity accompanying any control actions, as
673 well as research outputs regarding, for example, species distribution or pathways of
674 introduction, thus building a strong foundation for the support of prevention policies by
675 stakeholders.

676 Our analysis has several implications for environmental policy. Firstly, the absence of
677 distinctly different viewpoints among these stakeholder groups implies that an open
678 dialogue on this topic, if promoted by the public administration, may lead to a political
679 consensus to curb invasions. Lack of cohesion among stakeholders on the decisions
680 taken at all stages of the invasion process could lead to policy failure (Stokes et al.,
681 2013). The existing stakeholders' agreement on key top invaders found in this study
682 may help to achieve this political consensus, and to develop specific regional legislation
683 in relation to the introduction and further spread of invasions in the territory, including
684 legally binding limitations for specific invaders. Secondly, it illustrates that stakeholders
685 would be receptive to education and increasing awareness through media campaigns. As
686 our econometric model shows, media communication clearly influences perceptions of
687 the risk posed by different species. Thirdly, single widespread invasive species, which
688 attract high media attention, could be used to highlight the role of the deliberate
689 introduction and planting of alien plants to gain support for prevention policies for less
690 well-known species.

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