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Explaining the rank order of invasive plants by stakeholder groups

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Abstract

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

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

1 Introduction

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

Invasive species that are often deliberately introduced for commercial purposes provide a particularly interesting example of how stakeholders with conflicting interests from a wide range of backgrounds may be affected. This is the case for ornamental plants where the horticultural industry and consumers benefit from the use of non-native plants, which in some cases are invasive species or at risk of becoming invasive if widely planted (Barbier and Knowler, 2006; Dehnen-Schmutz et al., 2007; Pemberton and Liu, 2009). Different perceptions towards ornamental plants may develop over time when highly regarded species become invasive and develop into an expensive management problem (Bailey and Conolly, 2000; Starfinger et al., 2003; Dehnen-Schmutz and Williamson, 2006). However, policy challenges become more acute when species could generate income for some stakeholder groups (e.g. nurseries, gardening firms or forestry owners), while imposing damage and management costs on other stakeholder groups, or when generating both income and costs within a stakeholder group. A study in Belgium found that even though nursery owners were aware of the problem of invasive species in general, and 45% of them reported that they did not sell any invasive species, all of them were selling at least one species listed in the Belgian invasive species inventory (Vanderhoeven et al., 2011). With an increasing number of invaders and limited financial resources, policy-makers have a critical interest in understanding how stakeholders differ in their level of concern about biological invasions and how different stakeholder groups perceive key invaders.

We focus particularly on invasive plants given the prevalence of their deliberate introduction, mainly through ornamental trade, as a key pathway for the establishment of non-native plant species as has been shown in other countries (Perrings et al., 2005; Hulme 2009; Bradley et al., 2012). Several papers have analysed different stakeholder perceptions regarding invasive species. Previous studies which focused on stakeholders in the horticultural industry have aimed to decipher, for instance, stakeholders' levels of awareness about invasions (Vanderhoeven et al., 2011), acceptance and support for existing management and potential new policies (Coats et al., 2011) or voluntary measures (Burt et al., 2007). Some papers also include a stakeholder analysis on invasive species issues that are not specific to the horticultural trade. These may analyse questions regarding specific species, for example, ability to name known invasive species or ability to identify species from a list provided. It is important to understand how stakeholder knowledge and perceptions regarding biological invasions at the species level are formed, as this may influence policy coherence and the identification of key management criteria. Bremner and Park (2007) illustrate that the level of support for control and eradication programmes is influenced by specific species that are currently being managed. Bardsely and Edwards-Jones (2007) illustrate certain levels of consensus across stakeholders in the Mediterranean islands (Sardinia, Mallorca, Crete) when asked to name five invasive plants. While on the other hand, García-Llorente et al (2008) show that stakeholder groups (local users, tourists and conservation professionals) varied in the number and particular species they mentioned, as well as in their willingness to pay for eradication programmes for given species. These studies conclude that people are more aware of species that have been the subject of information or education campaigns. Andreu et al. (2009) focused more on the species-level criteria for management and concluded that according to interviews undertaken with natural resource managers, the most frequently managed species are the most widespread in each region and the ones perceived as causing the highest impacts. Eiswerth et al. (2011) measured invasion awareness by local residents' ability to name at least one invasive aquatic species.

In this paper, we study the determinants of stakeholders' preferences over an open list of invasive plant species. We use survey data to analyse how stakeholders involved in the deliberate introduction and spread of non-native plants, as well as stakeholders affected by invasions, select key invasive plant species and prioritise them in order of importance. In the classical choice experiment setup, individuals are asked to select their most preferred option out of a fixed set of alternatives, but additional information about relative preferences can be obtained if individuals are asked to rank a set of alternatives instead. We therefore asked stakeholders to name and rank the six most important invasive plants from the perspective of their working organisation, and we econometrically evaluated the factors that influenced these rankings. A rank ordered logit analysis was used to explain the stakeholders' ranking of plant invaders influenced by: species life-form (eg. tree, shrub, herb, annual), its use in the ornamental sector, public control activities and media coverage. We identify consistencies and discrepancies in the perceptions and rankings by stakeholders, who represent the interests of the public sector environmental management, the ornamental plant sector, research institutions and experts, and also social groups (e.g. agricultural unions, forestry associations, environmental NGOs). Thus, we adopt a multi-stakeholder framework. We also acknowledge that perceptions may vary within institutions and/or across individuals in each of these groups and therefore, a re-estimation of the rank ordered logit for stakeholder groups is required, classified by individual stakeholders' general knowledge of invasions, their level of awareness and concern, and their interest in the development of policy measures. This allows us to explore the variability in awareness and prioritisation of particular invaders across different social groups, taking into account the influence of differing stakeholder perceptions of the problem of biological invasions in general. This study contributes to the development of invasive species management practices by assessing stakeholders' perceptions towards invasive species and the determinants of their preferences in their selection of key plant invaders.

2 Material and methods

2.1 Study area

This study takes place in Galicia, in the northwest of Spain, where over the past five years (2005-2011) the Galician government has spent about 1.1 million Euros on control and eradication measures for invasive plants in protected nature conservation areas[1]. The government has also funded the publication of a report of invasive plants in the region (Xunta de Galicia, 2007). This report considers 73 plant species of which 31 are classified as posing a significant threat or as having the potential to do so. Out of those 31 species, 68% are associated with introductions for ornamental use, suggesting that the ornamental trade is a significant pathway for potential plant invasions in Galicia.

The Spanish Law 42/2007, on Natural Heritage and Biodiversity, establishes a basic legal framework for nature conservation and proposes the creation of a national catalogue of invasive species; while also entitling different Spanish regions to establish their own catalogues. This law specifies that the inclusion of any species in the catalogue implies the general prohibition of possession, transportation, traffic or trade in such species. The Royal Decree 1628/2011[2] regulates the Spanish List and Catalogue of Invasive Species, containing two annexes, a catalogue of invasive species and a list of alien species with invasive potential. However, this Royal Decree was fully in force only for a few months. Stakeholder pressure from hunting and fishing groups, lead to the exclusion of certain invaders from the catalogue, and claims from certain Spanish regions led to the cancelation of the list of potentially invasive species[3]. The new Royal

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[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

Decree 630/2013 regulating the Catalogue of Invasive Species[4] has been recently approved, therefore the effectiveness of current legislation is difficult to assess. Moreover, Galicia does not have its own catalogue of alien species to which legally binding limitations would specifically apply. In fact, only Valencia (south-east of Spain) has so far succeeded in establishing regional regulation of exotic alien species[5].

2.2 Survey design and administration

This study was conducted by personal interviews using a semi-structured questionnaire, in order to study the determinants of stakeholder prioritisation of the most relevant invasive plants, as well as general information about stakeholders' awareness and perceptions. Four stakeholder groups were interviewed: the ornamental plant sector, public sector environmental management, research institutions and experts, and representatives of different social groups (e.g. environmental NGOs, agricultural unions, forest managers, hunting and fishing associations, and political parties). Thus, the respondents were public or private organizations/individuals (*i*) involved in the introduction or spread of invasive plants, (*ii*) affected by potential impacts of invasives, and/or *(iii)* involved in management of invasives. Stakeholders interviewed included corporate producers/sellers of ornamental plants, garden managers of public and private parks and gardens, forestry associations, industries, and public sector administrators, nature conservation organisations, water resource managers, environmental NGOs, agricultural unions, hunters and recreational fishermens' associations, political parties, and research centres and experts. Fieldwork was undertaken between December 2009 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

telephone call, in order to correctly identify the person to be interviewed in each institution/organization and to formalize the date of the interview. The initial recipients of the letters and their contact details were identified through the internet, and by the snowball sampling technique[6] (e.g. Kumar and Kant, 2007; Bardsley and Edwards-Jones, 2006; Andreu et al., 2009). In relation to gardening and plant production firms, a list of 82 firms from ASPROGA (Galician Association of Ornamental Plant Growers http://www.asproga.com/) and AGAEXAR (Galician Association of Gardening Firms http://www.agaexar.com/) was produced. 40% of these firms were randomly selected to be contacted by post. The initial list excluded 27 plant growers who were highly specialized in single species groups (camellias, kiwis, hedges, etc.) and large garden centres that were part of ASEJA (Spanish Association of Gardening Firms http://www.aseja.com/) but did not have a registered business in Galicia. However, ASEJA members were also considered in the study as they were involved in the management of urban parks. Our data include the views of urban park managers for three Galician cities.

All respondents were informed that the purpose of the questionnaire was to collect the views of the organization they represented. The introductory section of the questionnaire included a definition of invasive species as those that establish and spread outside their natural range, producing adverse effects. It also provided an illustrated list of 29 plants selected for their current and potential impacts in the studied region (Xunta de Galicia, 2007; Sánz-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".

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

2.3 Factor Analysis

Given the large set of variables derived from stakeholders' responses to the questionnaire, we used factor analysis (FA) to analyse correlations among variables and to explore the latent factors that caused the variables to covary. FA assumes that the variance of a single variable can be decomposed into a common variance that is shared by other variables included in the model, a unique variance that is specific to a particular variable, and an error component. This technique analyses only the common variance of the observed variables.

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

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

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

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

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

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

2.4 Rank ordered logit model

The standard procedure to handle rank data is the rank ordered logit model[7]. In the economics literature, this model was first introduced by Beggs et al. (1981) and further developed by Hausman and Ruud (1987), building on the well-known conditional logit (CL) regression model introduced by McFadden (1974). This model was independently formulated under the name of exploded logit model in the marketing literature (Punj and Staelin, 1978; Chapman and Staelin, 1982). Allison and Christakis (1994) introduced it in sociology and generalized it to accommodate ties in the rankings.

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

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

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

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

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

where β_j, γ, and θ are the row parameter vectors of interest[8]. The model is estimated assuming that the random component is independent and identically distributed with a Type-I extreme value distribution[9].

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

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[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 $Pr(\varepsilon_{ij} \leq t) = exp(-exp(-t))$, $-\infty < t < \infty$.

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

$$L_i = \Pr(\mathrm{U}_{\mathrm{ir}_{i1}} > \ldots > \mathrm{U}_{\mathrm{ir}_{iJ}}) = \prod_{j=1}^{J-1} \left[\frac{\exp(\mu_{ir_{ij}})}{\sum_{k=j}^{J} \exp(\mu_{ir_{ik}})} \right]$$

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

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

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

$$\widetilde{L}_i = \Pr(\mathrm{U}_{\mathrm{ir}_{i1}} > \ldots > \mathrm{U}_{\mathrm{ir}_{ik_i}} > \max\{\mathrm{U}_{\mathrm{ir}_{ik_i+1}}, \ldots, \mathrm{U}_{\mathrm{ir}_{iJ}}\}) = \prod_{j=1}^{k_i}\left[\frac{\exp(\mu_{ir_{ij}})}{\sum_{l=j}^{J}\exp(\mu_{ir_{il}})}\right]\frac{1}{(J-k_i)!} \quad (2)$$

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

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

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

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

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

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

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

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

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

Turning to explanatory variables, the independent variables included in this study aimed to assess the effects of the species life-form, the extent of the species' geographical distribution in the region, the role of pathways of introduction of the species, the 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.

media. These variables were chosen because of their potential impact on respondents' awareness of the species and the response to invasions. For example, the more widespread the species is in an area, the more likely the species is known and the more visible may be its impacts and management related activities (e.g. Andreu et al. 2009; Bardsley and Edward-Jones, 2007). Similarly, whether a species has been introduced deliberately for ornamental or forestry purposes, or whether a species is subject to public control and eradication activities, can also influence attitudes and views towards invasion management (e.g. Bremner and Park, 2007; Cook and Proctor, 2007; García-Llorente et al. 2008). Life-form was captured with a dummy that indicates whether the ranked plant invader is woody (i.e. tree or shrub). For the geographical distribution in Galicia, we categorised this variable (1=low, 2=medium, 3=high) following the same approach as in the official list of most problematic invasive plants in Galicia (Xunta de Galicia, 2007); with the exception for 4 species for which this information was not available. In those cases, we used the number of records in 10x10 km sized quadrants covering Galicia as used in the SITEB (Territorial Information System of Biodiversity) database[12] and local expert knowledge. The role of the pathway of introduction was included with a dummy that indicates whether the ornamental sector sells or uses the plant. We captured the influence of public control activities by using a dummy variable that indicates, for each species in the dataset, if control activities were undertaken in protected areas in the years prior to the survey (2007-2009) by the Nature Conservation Department of the regional government (Xunta de Galicia).

Finally, our model investigates the potential influences of media coverage on the 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

individual and institutional decisions about the perceived risk posed by natural hazards (e.g. Vilella-Villa and Costa-Font, 2008; Donovan et al., 2011). For invasive species, Gozlan et al. (2013) found a strong correlation between public awareness toward certain invaders and the number of pages listed in popular internet search engines that mention a particular species. However, the literature has also shown that the general public's perception may differ from perceptions of key stakeholders such as managers, scientists, or conservation organisations (e.g. García-Lorrente et al. 2008; Sharp et al, 2011; Gozlan et al., 2013). This is because stakeholders have a higher knowledge and personal experience of the benefits and costs posed by the invaders and their management. Media coverage of invasions may focus on different interests or issues. Articles may focus on highly visible species or species that are not yet present but could have a potentially high future impact. They could be short notices mentioning planned management activities that affect established invaders (or those with the risk of becoming established) invaders, or detailed articles potentially contributing more to the general knowledge of invasive species. We measured media coverage by focusing on newspaper articles and searching for the words "plant invaders", "invasive species", "biological invasions" and "exotic species" for the two years previous to our survey in the digital libraries of national newspapers with a regional edition for Galicia (2), regional newspapers (2), and provincial and local newspapers (6). If an article explicitly mentioned a plant invader that appeared in the stakeholders' rankings, we recorded the number of words in the article[13]. 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

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

3 Results

3.1 Brief overview of sample characteristics

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

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

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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.

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

3.2 Latent perception factors on plant invasions

Description of the latent perception factors supported by the FA is presented below. Table 2 shows the results for the five perception latent factors extracted: plant invasion awareness, environmental concern, perceived population environmental concern, recognised impacts, and policy measure acceptability. The KMO measure of sampling adequacy showed adequate fit (KMO ranged from 0.63 to 0.78). The internal consistency of the items within each factor is satisfactory, as Cronbach's alpha ranged from 0.60 to 0.79. Overall, we found that invasive plant perception factors do not differ substantially between stakeholder groups with the exception of their level of awareness (Table 2). This suggests that perceptions of these factors do not clearly depend on this stakeholder classification, i.e. none of our stakeholder groups can be associated with a unique perceptional set of values related to their level of awareness, environmental concern, impacts, and support for the development of policy measures surrounding invasive plant species.

- **Awareness and concern about invasions**

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

- **Perception towards other environmental problems**

The second factor consisted of five variables, related to stakeholders' scores for different environmental problems (habitat loss, climate change, pollution, overfishing and urbanization). This factor accounts for the 100% of the observed variance, and variables' factor loadings ranged from 0.55 to 0.89 (Appendix B). This factor was named "environmental concern score" as it expresses the stakeholder's overall perception of major environmental conservation issues. The average degree of environmental concern expressed for each of the problems explored is high, but there are no significant differences among stakeholder groups, with the exception of climate change (Table 2), about which, public administration and ornamental sector stakeholders were less concerned.

- Perceived opinion of Galician population's concern for environmental problems

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

- Perceived invasion impacts

The estimated Loevinger H-coefficients confirm that the three items related to economic, social and health impacts follow a Mokken scale. The values of these H-coefficients vary between 0.55 and 0.70 (Appendix B). These results show that the economic impact of invaders is most widely recognised, followed by their social and health impacts. Stakeholders from the ornamental sector show significantly lower levels of perception of the social impacts caused by invasive species (Table 2). Acknowledgment of ecological impacts is not included in this analysis as almost the whole sample of respondents (88%) recognised this type of impact.

- Perceptions on invasive species management options

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

3.3 Determinants of Stakeholders Invasive Species Ranking

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

The rank ordered logit model was estimated in order to explore the role played by natural and social attributes of the plant species in shaping stakeholder's ranking of the plant invaders. Table 3 shows coefficient estimates and robust standard errors for the model when the full sample of stakeholders is considered. It also shows the results when stakeholders are classified according to their represented interests: public sector, research, ornamental sector, and social groups. When considering the full sample of stakeholders, all plant attributes considered have a positive and statistically significant influence on the rank order of plant invaders. However, we found differences in the significance of the role played by these predictors across stakeholder groups. Media coverage is the only predictor that is consistently significant at the 1% level across stakeholder groups. That is, higher media coverage of an invader increases its probability of being higher in the ranking; all else being equal. The distribution of the species, however, is not statistically significant for those respondents working in the public sector. However, the use of a species in the ornamental sector has a significant effect on the rankings of stakeholders working in this sector. Ornamental sector respondents were more likely to rank a species as high risk if that species was traded by the ornamental sector. This makes sense, as they may be less familiar with non-ornamental plants. If public administration undertakes control or eradication measures in protected areas, this significantly affects the rankings produced by those holding positions in the ornamental sector and the administration.

Table 3 also presents the results for the rank ordered model with stakeholders classified according to their perceptional latent dimensions, i.e., where each group includes those respondents with score perceptional values which are higher than the median. Again, even though signs are consistent, some predictors no longer exert statistically significant influences on rankings for some stakeholder groups according to this classification. For instance, results show that woody life-form has a significant effect on the probability of choosing a plant over other species in the ranking for those stakeholders who are more highly aware of impacts, and have higher concern regarding environmental issues. For all different groups, the extent of the geographic distribution of the plants has a significant influence in the rank ordering. Finally, stakeholders with higher invasion awareness, environmental concern, recognition of impacts and higher willingness to accept policy developments rank plants that are being used in the ornamental sector more highly.

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

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

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

4 Conclusions

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

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

Our analysis reveals that none of the stakeholder groups is associated with a unique set of perceptional values relating to their level of awareness, environmental concern, awareness of impacts, and support for the development of policy measures. We find that public administrators and researchers show a higher level of awareness of plant invasions. Stakeholders from the ornamental sector show significantly lower levels of perception of the social impacts; while stakeholder groups have no significant differences in their level of awareness of ecological, economic and health impacts. In addition, stakeholders groups do not differ significantly in their view regarding the acceptability of the various policy options, i.e. no policy is particularly preferred by any group. This is an important issue for policy-making, and can be crucial for the facilitation of consensus. When analysing all stakeholders together, education and increasing social awareness of invasive plants is the preferred policy option for managing invasives (see also Dehnen-Schmutz et al., 2010). This is in line with previous literature (Vanderhoeven et al., 2011), and may be generally perceived as the policy response which is most easily achievable and carries the fewest direct implications for these stakeholders. In our case, the high regard for this policy option is also consistent with the general agreement among stakeholder groups about the low level of environmental concern in the general public. It may also reflect the respondents' awareness of the importance of ornamental use of plants for invasions in the study area. Similarly to Barbier et al. (2013), we found that sales taxes are the least preferred policy option. This can be explained by the lack of familiarity with these instruments, and their expected results. Stakeholders may also be concerned with the information required to implement such instruments, as this may affect their usefulness to curb invasions (Barbier et al. 2013).

Our study reveals that a relatively small group of species are perceived as key invaders by all stakeholder groups. Even though the choice set of species ranked by the stakeholders included thirty plants in total, only four species have a significant probability of being top-ranked invaders. Thus, only Acacia dealbata, Eucalyptus globulus, Carpobrotus edulis, and Cortaderia selloana consistently show a probability of around 10% or higher of being ranked as the invasive species of highest concern, among all the plant species mentioned by stakeholders as being relevant to their organisations. In fact, invasion by Acacia dealbata, seems to be a particular concern for the social groups surveyed, being the priority species for 35% of those in this group. All the key species of concern are deliberate introductions, which are still generating commercial benefits, even though they are spreading as invasives in natural areas. This result is consistent with the Galician government's expenditures on invasion management, allocating 68% of the budget on control and eradication of invasive plant species in protected areas to programmes that deal with Acacia dealbata, Cortaderia selloana and Carpobrotus edulis. Such policy does not extend to Eucalyptus globulus, whose control has just recently started in a couple of protected areas (El País, 2012), even though this species has absorbed an important percentage of public spending on control of invasive species in other parts of Spain, particularly in the Southwest (Andreu et al., 2009). This may be explained by the significant benefits generated by commercial forestry exploitation of Eucalyptus globulus plantations in Galicia, to the extent that monospecific stands of this tree species have increased more than 40% in the last decade, accounting for 17% of the wooded forest area in the region (MAGRAMA, 1999; 2011).

We also studied the critical role of media publicity on invaders on stakeholders' perceptions. In particular, we provided evidence that media coverage plays an important role in the rank order choices of all stakeholder groups in their perception of the key invaders in the studied area. Newspaper coverage on a certain invasive plant increases the probability that it is chosen as top-ranked invader by stakeholders. However, it should be noted that media attention may not be directly linked to species impacts. For a sample of five invasive species in Britain, Gozlan et al. (2013) found that species receiving highest internet presence were not the ones with the highest ecological impact. Our results highlight the importance of publicity accompanying any control actions, as well as research outputs regarding, for example, species distribution or pathways of introduction, thus building a strong foundation for the support of prevention policies by stakeholders.

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

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