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ORIGINAL PAPER

Invasive plant cover impacts the desirability of lands for conservation acquisition

Laura J. Martin · Bernd Blossey

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Abstract Invasive species are of increasing concern to conservation organizations due to their ecological and economic impacts. But while many studies have addressed the economic impact of invasive species, few have placed these impacts in a conservation context. In reality invasive species are only one of many challenges facing conservation practitioners. Here we use conjoint analysis, a stated preference method of economic valuation, to determine how invasive plant cover influences the desirability of land for conservation acquisition. In a web-based survey we asked public and private land managers to make choices between hypothetical land parcels that varied in area, plant species composition, and maintenance cost. We received 285 responses from managers directly involved in the management of approximately 12 % of the area of the continental United States. Rare plant richness had the strongest marginal effect on land parcel desirability, followed by invasive plant abundance, area, and finally maintenance cost. While effect ordering was consistent between federal, state, and public managers, effect strengths differed significantly; the choices of federal managers were most sensitive to invasive plant cover. Broadly speaking, our results reframe the economic impact of invasive plants in terms of trade-offs that are relevant to conservation practitioners. They also suggest that land managers, acting as public agents, are measurably concerned about the spread of invasive plants.

Keywords Non-native species · Conjoint analysis · Conservation planning · Conservation management · Land acquisition · Invasive species

Introduction

U.S. Executive Order 13112 defines invasive species as non-native species whose introduction does or is likely to cause environmental or economic harm. Today there are over 4,300 naturalized non-native species in the U.S. (U.S. OTA 1993) and in some countries

L. J. Martin (✉) · B. Blossey
Department of Natural Resources, Cornell University, Ithaca, NY 14853, USA
e-mail: LJM222@cornell.edu

non-native plants make up more than one third of the flora (Vitousek et al. 1997). These species are believed to impact ecosystem functions such as nutrient cycling, productivity, human health, and native biodiversity (Mack et al. 2000; Mooney and Hobbs 2000) and are considered to be the second greatest threat to imperiled species (Wilcove et al. 1998). Such environmental impacts are of concern to an increasing number of conservation organizations. Many organizations continue to expand their invasive species management budgets, with a particular focus on invasive plants (D'Antonio et al. 2004; Pullin and Knight 2005). For example, the 2006 U.S. federal budget for invasive species control was reported at \$466 million—an increase of \$400 million from the 2002 budget (U.S. NISC 2006).

Although economic harm is referenced in the U.S. legal definition of invasive species, there is a "dearth" of literature on the subject (Barbier 2001; Shogren 2005). Early attempts to quantify economic impact often focused on market impacts of a single species (for review, see Born et al. 2005; Lovell et al. 2006; Olson 2006). For example, Leitch et al. (1994) model the effect of leafy spurge on livestock grazing carrying capacity in upper Great Plains. And while attempts to assess the impact of invasive species at a national scale have arrived at numbers between \$128 billion (Pimentel et al. 2005) and \$185 billion (U.S. OTA 1993), these estimates are believed to be upwardly-biased because they do not account for the potential benefits of invasive species (Freeman 1993; Perrings et al. 2000; Knowler and Barbier 2005) and because they are based upon constant values of marginal damage per species, control costs, and market prices for affected products (Olson 2006; Shogren et al. 2006). While such studies are important, their focus on markets limits their applicability to conservation settings.

More recently, the economic impact of invasive species has been explored through bioeconomic modeling (Settle and Shogren 2006), travel-cost methods (Nunes and van den Bergh 2004), hedonic property value methods (Holmes et al. 2006; Earnhart 2001), documentation of land abandonment (Schneider and Geoghegan 2006) or recreational losses (Eiswerth et al. 2005). Some such studies have considered conservation settings. For example, Earnhart (2001) uses a combination of discrete-choice hedonic analysis and choice-based conjoint analysis to describe the value of marsh restoration in Connecticut. Other studies describe the non-use values of a marine protection program in the Netherlands (travel-cost and contingent valuation, Nunes and van den Bergh 2004), and invasive plant control in U.S. National Forests (dichotomous-choice with and without an "unsure" option, Champ et al. 2005).

Virtually all conservation organizations operate under limited budgets and must chose to prioritize particular projects. Invasive species management is one of many such projects. Here we use conjoint analysis to understand how the preferences of conservation practitioners are affected by invasive plant cover. In a nationwide survey we asked land managers to choose between hypothetical land parcels for conservation acquisition. Parcels varied in invasive plant cover, rare native species richness, area, and annual maintenance cost.

Methodology

Conjoint analysis

Conjoint analysis is a stated preference method used to value the individual attributes that make up a good or service. The method is based upon the consumer theory developed by Lancaster (1966, 1991) that economic utility (a measure of relative satisfaction) is derived from the individual attributes of goods. The overall utility of a good can therefore be decomposed into separate utilities for each of its attributes (Louviere 1994). While the method was first developed to elicit consumer preferences in marketing applications (Green and Wind 1975), it is also useful for valuing environmental entities consisting of multiple attributes. Conjoint analysis is increasingly applied to conservation management issues that involve tradeoffs not captured by market transactions; for example, it has been used to elicit values for protecting threatened caribou populations (Adamowicz et al. 1998), preferences for waterfowl hunting (MacKenzie 1993), watershed quality improvements (Farber and Griner 2000), and community forest contracts (Arifin et al. 2009).

In conjoint analyses respondents are given a survey in which they are asked to choose from, rank or rate hypothetical profiles (in this case, land parcels) that are composed of multiple levels of multiple attributes. The respondent will choose within multiple sets of profiles that vary in the levels of each attribute. Such stated preference experiments have both advantages and drawbacks. A hypothetical choice setting mimics real choice settings by requiring the individual to simultaneously consider multiple dimensions of alternatives. The researcher is then able to infer tradeoffs between attributes by calculating marginal values (the effect of adding one more unit of a good) and marginal rates of substitution (the rate at which a respondent is willing to give up one good in exchange for another good). However, stated preference methods are commonly critiqued because they depend upon hypothetical questions rather than observation of actual behavior (Cummings et al. 1986; Mitchell and Carson 1989; Arrow et al. 1993). Nevertheless, stated preference methods are currently the only method of measuring non-use values and are therefore frequently used to value changes in environmental quality.

Survey and data collection

In spring 2009 we conducted 20 semi-structured interviews (Lindlof and Taylor 2002) with managers from the U.S. Fish and Wildlife Service, the Nature Conservancy, and the NY Departments of Transportation and Environmental Conservation. In these interviews we identified four land attributes that managers consistently associated with land parcel desirability: area, rare native plant richness, annual maintenance cost, and invasive plant abundance. We also used the pilot interviews to determine a range of realistic attribute levels (Table 1). We then tested a draft survey instrument with two focus groups: 11 managers from New York and 18 managers from Nebraska. These focus groups included participants from multiple organizations and allowed us to incorporate feedback from both Western and Eastern contexts. Participant feedback led us to adjust the phrasing of the conjoint question and to include definitions of “invasive” and “rare” in the final survey. We also added language to make it clear that participants’ responses should reflect their

Table 1 The levels of each of the four land parcel attributes included in the conjoint analysis

Attribute	Levels
Area (acres)	10, 50, 100, 200
Non-native inv. plant cover (%)	1, 10, 50, 70
Rare plant spp. (#)	1, 5, 10, 20
Cost of management (USD/year)	1000, 3000, 5000 10000

Attributes and levels were determined through pre-test interviews and focus groups with land managers professional preferences rather than their personal preferences—in other words, they should represent their organization's interests and answer as public actors.

The final survey was disseminated in October 2009. We implemented a systematic sampling strategy adapted from Dillman's discussion of email and web-based survey design (Dillman 2007). We compiled a database of appropriate email contacts from the U.S. Fish and Wildlife Service, The Nature Conservancy, and an invasive plant management list-serv that was established at a 2007 cross-institutional conference on *Pachyornis australis* management at Cornell University ($N = 520$). On 15 October 2009 we sent email solicitations to these contacts. The solicitation emphasized the survey's usefulness and the importance of a response from each person in the sample. Two weeks later we sent a follow-up reminder email. We closed data collection in December 2009.

Survey participants remained anonymous. We first collected socio-economic data: Participants were asked to indicate their affiliation (federal, state, or private organization), the location of their management unit's, the total area of land that they were presently involved in managing, and their management unit's approximate plant management budget for 2008–2009. We then presented them with the choice experiment. They were then prompted with the question: *Your organization has the ability to purchase a new parcel of land. As a representative of your organization, which would you chose from the following three options?* Participants were told that although the questions were hypothetical, their responses would be used to better understand trade-offs involved in conservation purchases. They were asked to read all questions carefully, to answer realistically, to treat each question separately even if the options appeared similar, to assume that all other land parcel attributes were held constant, and to remember that their organizations' resources were limited.

Each participant was then presented with six choice-sets. In each choice-set they had to indicate their preferred land parcel out of three options. Land parcels varied in the levels of four attributes: area, rare plant richness, invasive plant abundance, and maintenance cost (cost of management/acre/year) (Table 2). Invasive plant species were defined, as "plant species not native to a particular ecosystem whose introduction does or is likely to cause economic or environmental harm or harm to human health, as per U.S. Executive Order 13112." Rare plant species were defined as "native plant species that are known to be endangered, threatened, or locally rare." Maintenance cost was defined as "the total cost of management per acre per year, inclusive of *all* costs (personnel, invasive species management, etc.)." At the end of the survey respondents could comment or report concerns in an open-ended debriefing question.

Table 2 An example choice-set

Your organization has the ability to purchase a new parcel of land. As a representative of your organization, which would you chose from the following three options?

	Area (acres)	Invasive plant abundance (% cover)	Number of rare plant species	Maintenance cost ($/acre/year)	Choice
Option 1	10	1	5	$5000	☐
Option 2	10	70	5	$3000	☐
Option 3	100	10	10	$5000	☐

Each survey participant answered six such questions that varied in area, invasive plant cover, number of rare species, and maintenance cost

Statistics

We reduced the number of profiles (land parcels) to a manageable number ($N = 54$) using an orthogonal fractional factorial design (SPSS, Chicago, IL) that treated all attributes as independent and precluded collinearity between them in an empirical model (Mackenzie 1993). An orthogonal fractional factorial design reduces the number of profiles that a respondent must evaluate, allowing the researcher to test for main effects but not interactions (Holmes and Adamowicz 2003). The respondents were randomly stratified into three pools (Holmes and Adamowicz 2003), each of which was presented with six sets of three profiles.

We fit the discrete choice data to a multinomial logit model using a variation of Firth bias-adjusted maximum likelihood estimation (Firth 1993) in the choice modeling platform of JMP 8.0 (SAS, Cary, NC). We modeled the dependent variable (respondent choice) against the following independent variables: area, invasive plant abundance, rare plant richness, maintenance cost, and the interactions between these attributes and the covariates of organizational affiliation and plant management budget. The JMP platform selects the model with the lowest corrected Akaike's Informaiton Criterion (AICc) and $-2 \times$ Firth Loglikelihood values. We tested the model for independence of irrelevant alternatives assumption (IIA) using Hausman's specification test (Hausman and McFadden 1984) in SAS 8.2 (SAS, Cary, NC).

Results

Participants

We received responses from 285 public and private land managers for a response rate of 54.8 %. Surveys were returned from land managers who work in 425 counties in 40 states (Fig. 1). We received the greatest number of responses from managers working for private organizations (39 %, $N = 129$), followed by state (23 %, $N = 89$) and federal organizations (24 %, $N = 67$) (Table 3). In total, the 285 land managers that participated in the survey indicated that they were personally involved in the management of a total of ~200 million acres, or 12.3 % of the area of the continental United States. Respondents indicated that their management units spent a combined \$35 million per year on the management of invasive plant species.

Conjoint analysis

We discarded the responses of three participants: two who did not complete all six choice-sets and one who indicated in the debriefing question that he or she was unsure of the directions. Hausman's specification test indicated that the assumption of IIA held for the best model ($\chi^2 = 328.7$, $P = 0.026$). The null hypothesis that all parameters are zero was rejected by the likelihood ratio test ($P < 0.0001$) (Table 4).

Land parcels with higher rare plant richness and larger areas were preferentially chosen by land managers, while increased invasive plant abundance and maintenance costs negatively impacted the desirability of land parcels. Rare plant richness had the strongest marginal effect on managers' choices ($\beta = 0.0677$), followed by invasive plant abundance ($\beta = -0.0157$), area ($\beta = 0.00701$), and maintenance cost ($\beta = -0.000106$) (Table 4). Interestingly, the respondents' annual management budgets had no measurable interaction

Fig. 1 Location (counties, $N = 425$) of areas under the management of survey respondents ($N = 285$) in the United States

Table 3 Summary of survey respondent information, including the largest area managed by each type of organization (max. acres managed) and total acres managed by organizational type

Type of organization	Responses	States represented	Counties represented	Max. acres managed	Total acres managed
State	89	29	170	315,800	11,469,470
Private	129	41	162	55,643,520	135,072,176
Federal	67	31	93	43,962,966	53,880,029
Total	285	40	425		200,421,675

with choice. There were significant interactions between organizational affiliation and invasive plant abundance and between organizational affiliation and maintenance cost (Table 4).

By comparing the coefficients of the best model, we find that a 1 % decrease in invasive plant cover has the same effect on land managers' choices as a $148.30 (federal), $111.17 (state), or $88.60 (private) reduction in maintenance cost—which is the same as an addition of 2.4 (federal), 4.4 (state), or 4.1 (private) rare plants (Fig. 2).

Discussion

The survey results have two applications that are broadly relevant to conservation organizations. First, we are able to order the relative importances that land managers of different agencies assign to conservation land attributes. We find that the preferences of private, state, and federal managers are most impacted by marginal changes in native plant richness, followed by non-native plant cover (NNIP), area, and cost of management. Second, by comparing model coefficients we are able to calculate the levels at which

Table 4 Multinomial logit model estimates for the choice experiment

Variable	Coefficient (β)	SE	χ^2	P
Area (acres)	**0.007010**	0.0009	83.796	<0.0001
Invasive plant abundance (% cover)	**−0.015700**	0.0027	50.284	<0.0001
Rare plant richness (no. of spp.)	**0.067700**	0.0105	53.816	<0.0001
Maintenance cost (USD/acre/year)	**−0.000106**	0.0000	49.505	<0.0001
Federal × area	0.000064	0.0007	1.231	0.267
Private × area	0.000160	0.0006	3.274	0.070
State × area	−0.000224	0.0007	3.004	0.083
Federal × invasive	**0.003440**	0.0021	38.221	<0.0001
Private × invasive	**0.002667**	0.0018	39.198	<0.0001
State × invasive	**−0.006106**	0.0020	28.412	<0.0001
Federal × rare	0.005174	0.0083	2.855	0.091
Private × rare	−0.002516	0.0071	2.998	0.083
State × rare	−0.002658	0.0020	0.0354	0.851
Federal × maintenance	**0.000067**	0.0000	17.391	<0.0001
Private × maintenance	**−0.000013**	0.0000	20.974	<0.0001
State × maintenance	**−0.000054**	0.0000	24.658	<0.0001
Budget × area	0.004721	0.0382	0.831	0.362
Budget × invasive	0.003816	0.0437	0.043	0.836
Budget × rare	0.84677	0.1986	0.321	0.571
Budget × maintenance	0.000381	0.0494	2.320	0.128

Criterion	Value
AICc	774.1357
BIC	790.0715
−2 × Firth Loglikelihood	708.8370

Significant variables in bold ($P \leq 0.05$)

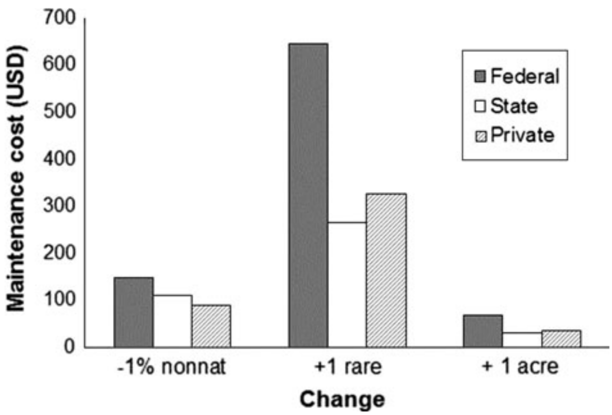

Fig. 2 Marginal rates of substitution between maintenance cost (USD/year on management) and NNIP cover, number of rare plants, and acres by organizational type

conservation management is economically optimized. We find that a 1 % reduction in NNIP cover had the same effect on the preference of an averaged manager as a $142.72/acre/year reduction in cost of management; therefore invasive plant control that costs less than $142.72/acre/year to maintain a 1 % reduction to NNIP cover would be a favored outcome. Control programs that are more expensive than this would not be economically efficient in the context of this survey. Similarly, our results suggest that it is worth spending up to but no more than $638.68/acre/year for the establishment of one new rare plant species.

It must be remembered that the results of this survey reflect the preferences of land managers acting as public agents; a survey of the general public might yield very different preferences. The survey is useful, however, in better understanding how conservation institutions' goals are expressed by their employees. The organizations captured in this survey spend a combined total of approximately $35 million per year on the management of invasive plant species. In comparison, the U.S. federal budget for overall invasive species control was reported at $466 million in 2006 (U.S. NISC 2006). There was, however, a regional bias—a disproportionate number of individuals from the Northeast participated in the survey, as can be seen in Fig. 1. It is possible that land managers from different regions of the U.S. who experience very different ecologies and management challenges may have differing visions of their "ideal" land parcel for conservation acquisition. However, the fact that the ranking of attributes is consistent between private, federal, and state organizations that operate across the U.S. suggests that preferences may be broadly uniform in ranking, even if they do differ in scale.

Conjoint analyses are limited by the fact that individual respondents can only respond to a limited set of attributes. While we based our attribute selection on pre-test interviews and focus groups, we were unable to include other attributes that may be of equally high importance. For example, hypothetical land parcels did not differ in their distance to existing conservation holdings. Many conservation organizations are concerned with connectivity, and this could affect the valuing of land parcels. We are able, however, to demonstrate that both rare plant richness and non-native invasive plant abundance have measurable impacts on land desirability. In the qualitative stage of this research many managers expressed their concern over the ecological impacts of non-native invasive species, and suggested that this concern is what drives their management actions.

It is commonly believed that invasive plants are in direct competition with rare native plants. While we did not find colinearity between these two variables in managers' responses, NNIP cover may imply reduced rare plant richness. Furthermore, as a linear model, our results are limited by the fact that they do not reflect a diminishing effect of increasing NNIP cover—in other words, it seems unlikely that an increase from 0 to 10 % NNIP cover would have the same effect as an increase from 80 to 90 % percent cover. To our knowledge no researchers have explored whether there is a threshold of invasion at which the marginal value of invasion decreases. Here we assume that at the margin a linear approximation is likely acceptable, though this would be an exciting area of future research.

Conclusions

Importantly, our results suggest that rare species richness is highly valued by land managers. An increase of 1 rare plant species was "worth" a 4.31 % reduction to non-native invasive plant cover. At the present time, many natural area management programs focus on the invader rather than the invaded ecosystem (Hobbs and Humphries 1995), yet ultimately it will be impossible to control the more than 4,300 non-native species found in the U.S. (U.S. OTA 1993). Previous surveys of land managers in Australia (Reid et al. 2009) and the northeastern U.S. (Acharya 2009) suggest that eradication of target non-native species is rarely accomplished. Our results suggest that substantial gains in utility can be made without the complete eradication of NNIP cover. It is often taken for granted that NNIP control is equivalent to native plant protection, but this is rarely the case (Smith et al. 2006). Restoration activities that reduce but do not eliminate non-native species may have a positive impact on utility, as would the planting of rare species. The resources available to conservation organizations are limited (Barnett et al. 2007; Bergstrom et al. 2009), and the decision to allocate resources towards NNIP management inherently takes resources away from other forms of management. Modeling the economic cost of plant invasion in the language of management tradeoffs can help us to develop a more holistic approach to land management.

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