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Valuing ecosystem restoration: tradeoffs, experience and design[§]

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[§]**Older Titles:** **Economic valuation of ecosystem attributes for optimal ecosystem restoration design**

Estimating values, tradeoffs, and complementarities in ecosystem attributes: Evidence from a choice experiment survey

Abstract: Sophisticated non-market valuation techniques have been developed by economists to estimate the value to society of goods not sold in the marketplace such as environmental quality and mortality risk reduction. In environmental economics, these value estimates have been used primarily as critical inputs to cost-benefit analyses and to estimate damages for which firms can be held liable after events such as oil spills. In this paper, we demonstrate how a relatively new tool in the valuation toolkit – choice experiment survey methods – can also be used for another important use: guiding complex decisions about how best to carry out and manage ecosystem restoration projects. We use a choice experiment survey of Illinois residents to estimate willingness to pay (WTP) for different attributes of restored grassland ecosystems: species richness, bird population density, presence of endangered species, and presence of wildflowers. The results reveal several interesting patterns of consumer preferences and choice. First, we find that the presence of nearby existing grasslands actually increases a respondent's WTP for restoring a new grassland; this result is counter to what would be expected from neoclassical economics and can possibly be explained by endogenous preferences. Second, we find that respondents treat the conservation success measures (species richness, population density and endangered species) as substitutes for each other; the marginal value of one measure is lower when the levels of the other two measures are high, and contours of total value are concave in pairs of attributes rather than convex. This latter finding implies that value-maximizing grassland design might well display corner solutions in which restoration ecologists maximize the value of a single conservation goal – producing endangered-species havens or duck factories – rather than aiming for balanced bundles of these attributes.

Keywords: choice experiment, habitat restoration, grassland, species richness, population density, non-market valuation

JEL Codes: Q51, Q57

1. Introduction

Non-market valuation techniques have been developed by economists to estimate the value to society of goods not sold in the marketplace such as environmental quality and mortality risk reduction. In environmental economics, these value estimates have been used primarily as critical inputs to cost-benefit analyses and to estimate damages for which firms can be held liable after events such as oil spills. In this paper, we demonstrate how a tool in the environmental-economics valuation toolkit – choice experiment survey methods – can also be used for another important use: guiding complex decisions about how best to carry out and manage ecosystem restoration projects. We do this by estimating consumer preferences over multiple conservation attributes of restored ecosystems.

Large scale conversion of many natural habitats has put pressure on rare and endangered species and decreased the flows of many ecosystem services. In response, conservation organizations seek to protect and restore land with high conservation and biodiversity values; this has led to much research on optimal protected area planning (e.g. Ando et al., 1998; Margules and Pressey, 2000; Primack, 1993) and restoration (Loomis et al., 2000; Meyerhoff and Dehnhardt, 2007; Milon and Scrogin, 2006). Most of that research uses production-side factors – the locations of endangered species, the cost of land, the threat posed to natural areas by development - to guide decisions about where to locate dedicated natural areas and what features those areas should have. However, Ando and Shah (2010) show that conservation activity can yield higher social benefits if decision makers consider the preferences of people when they plan their network of natural areas.

Two features of consumer preferences are important for deciding how best to invest social resources in restoration projects. First, the structure of preferences over multiple attributes of a given restoration project affects the nature of the value-maximizing bundle of attributes. Most existing non-market valuation research that identify values for restoration use contingent valuation (CV), which does not allow relationships in the values of multiple attributes to be analyzed. The studies of restoration values that use choice experiment (CE) surveys (Birol et al., 2006; Carlsson et al., 2003; Christie et al., 2006) do not use attribute interaction terms; the standard econometric specification of that research implicitly assumes consumers have linear indifference curves between pairs of attributes that comprise the good. This paper uses CE valuation techniques to estimate the values of and the nature of substitutability between multiple facets of a restored ecosystem by including interaction terms between attributes. This allows the estimation of how the marginal value of any one measure of conservation success - species richness, population density, and the presence of endangered species - is affected by the levels of the other two.

Second, optimal positioning of a restored area in the landscape depends on how the value people derive from an area varies with proximity and with features of the landscape around it. Competing economic theories yield diverse predictions about how the existing quantity of an environmental public good (an existing natural area) affects the WTP for providing more of that good (restoring more of that ecosystem). Neoclassical economic consumer theory predicts that marginal willingness to pay for an increase in a public good will be lower for consumers who already have access to a relatively large quantity of that good. On the other hand, endogenous preferences or experience can lead to the opposite effect (Bowles, 1998; Cameron and Englin, 1997; Gowdy, 2004; Zizzo, 2003). We evaluate these competing theories by analyzing how the willingness to pay to restore a new grassland is affected by the presence of grassland areas nearby. We also estimate how consumer WTP for a restored area varies with how far they live from it, contributing more evidence to the growing body of work on this subject (e.g. Bateman et al., 2006)

We carry out our research on the structure of consumer preferences over restoration projects in a setting that has been neglected by the valuation literature: grassland ecosystems. Though there have been many CV (and more recently CE) studies estimating the values of conserving and restoring ecosystems such as wetlands and forests, economic valuation efforts have not been focused on estimating the social value of grassland ecosystems. Massive conversion of grassland in North America to urban and agricultural use has stressed wildlife and cut ecosystem service provision in large swaths of the continent. This problem can be addressed with grassland restoration activities, but such projects are costly and require difficult and seemingly arbitrary choices to be made about the exact nature of the grasslands created. The restoration ecologists who carry out grassland restoration have no guidance from the economic valuation literature about the preferences people have over the characteristics of restored grasslands. In this paper we meet that need for knowledge by using a choice experiment survey of Illinois residents to analyze willingness to pay (WTP) for grassland habitat restoration.

We find that that species richness, population density, presence of endangered species, presence of wildflowers, and distance from an individual's home are all significant factors that affect consumers' WTP to restore an endangered ecosystem. This challenges the common practice of using just one measure, such as species richness, as a stand-alone indicator of conservation success. We also find that respondents with existing grasslands nearby have a higher WTP for restoring a new grassland; this result is counter to what would be expected from neoclassical economics and can possibly be explained by endogenous preferences. Finally, the marginal value respondents place on any one conservation goal (species richness, population density and endangered species) is lower if the levels of the other two conservation goals are high. This finding implies that respondents have convex total willingness to pay contours, as opposed to linear or concave. Thus, the bundle of conservation attributes that maximize TWTP has positive levels for only one of the conservation success measures (e.g. a corner solution where only the number of endangered species has a positive value). This result changes only if physical factors constraint the levels of conservation success values.

2. Literature Review

There is a fairly extensive literature on using non-market valuation to obtain values for restoring ecosystems. Examples include studies of; the values for restoring an impaired river basic using a CV study by Loomis et al. (2000); the total economic value of restoring ecosystem services in Ejina region in a CV study by Zhongmin et al. (2003); the benefits of woodland restoration in native forests in UK in a CV study by Macmillan and Duff (1998);the benefits of riparian wetland restoration focused on the river Elbe in Germany in a CV study by Meyerhoff and Dehnhardt (2007); the factors that lead to community participation in mangrove restoration in India in a CV study by Stone et al. (2008); the preferences for river restoration in a combined CE and CV study by Weber and Stewart(2009); the socioeconomic factors and psychometric measures that effect wetland restoration in latent class choice model by Milon and Scrogin (2006); the WTP for the conversion of cropland to forest and grassland program in North West China in a CE survey by Wang et al. (2007). Much of this literature uses CV studies and therefore is unable to identify the structure of consumer preferences between various facets of ecosystem services.

A single measure of conservation success, such as species richness or the number of endangered species has been used in many ecological and protected areas selection studies

(Ando et al., 1998; Cabeza et al., 2004; Csuti et al., 1997; Haight et al., 2000; Kharouba and Kerr, 2010; Possingham et al., 2010; Pressey et al., 2007; Önal, 2004; Önal and Briers, 2005) . Studies such as Loomis and Larson (1994) and Fletcher and Koford (2002) demonstrate that wildlife population density is also an important variable affecting the public's WTP for habitats. Further, in terms of maximizing benefits from conservation and restoration it is important to understand how each of these conservation success measures influences the WTP and how they are related to each other (i.e. do respondents treat the conservation success measure as substitutes or complements). Christie et al. (2006) study public preferences and WTP for biodiversity in general and Meyerhoff et al. (2009) find that the species richness is a significant attributes that determines the WTP for forest conservation. However, neither of the above studies includes wildlife population density as an attribute, making it difficult to understand the role that each of these attributes play in determining the WTP for restoration projects.

Much of the non-market valuation literature on conservation and restoration has focused on wetland preservation and restoration (Boyer and Polasky, 2004; Heimlich et al., 1998; Woodward and Wui, 2001), forest preservation and restoration (Adger et al., 1995; Baarsma, 2003; Lehtonen et al., 2003), the protection of individual endangered bird species (Bowles, 1998; Loomis and Ekstrand, 1997) or recreation and hunting (Boxall et al., 1996; Hanley et al., 2002; Horne and Petajisto, 2003; Roe et al., 1996). To our knowledge, no economic valuation study to date has analyzed preferences for grassland ecosystems. The closest study is a paper by Earnhart (2006) that estimates the aesthetic benefits generated by open space adjacent to residential locations, where the open space is denoted by prairie, but this paper does not analyze the preferences for characteristics of grassland ecosystems nor the WTP to restore grasslands.

Identifying whether existing and new environmental public goods act as substitutes or complements, especially with regard to restoration of ecosystems and natural habitats, will enable conservation organizations to better target conservation efforts. Carson et al. (2001) discuss how public goods will act as substitutes and the WTP will decrease as more of the public good is provided. This follows from a neoclassical consumer framework that the demand function is downward sloping. At the same time, the presence of an environmental public good can lead to learning, experience and appreciation such that agents who currently experience high levels of the public good may have a higher willingness to pay for more of that good (Cameron and Englin, 1997; O'Hara and Stagl, 2002). This can be explained using endogenous preference theory, which argues that consumers who are familiar with a good may be willing to pay more than consumers who are unfamiliar with the good (Bowles, 1998; Gowdy, 2004; O'Hara and Stagl, 2002; Zizzo, 2003). Cameron and Englin (1997) show that experience can lead to higher resource values using a CV study of WTP for trout fishing. They find that experience, measured by the number of years in which the respondent has gone fishing, has a significant positive impact on the WTP. A related theory of planned behavior proposed by Ajzen (1991) states that WTP is expected to increase with a more favorable attitude toward paying for a good (Liebe et al., 2011). Therefore if a favorable attitude towards grasslands can arise from opportunities to experience existing nearby grasslands, respondents with grasslands nearby will have a higher WTP to restore a new grassland.

3. Background on Grassland Ecosystems

Grasslands are open land areas where grasses and various species of wildflowers are the main vegetation. In North America there are three main types of grassland ecosystems. The short-grass ecosystem predominantly occurs on the western and more arid side of the Great Plains. The mixed-grass ecosystem is located farther to the east. The tall-grass ecosystem occurs on the eastern side of the Great Plains. Tall grass can grow up to 4-6 feet. Figure 1 presents the distribution of grassland ecosystems in North America (O'Hanlon, 2009).

The loss of grassland in North America is attributed to deforestation in the eastern United States, fragmentation and replacement of prairie vegetation with a modern agricultural landscape, and large-scale deterioration of western U.S. rangelands (Brennan and Kuvlesky Jr, 2005). The loss of grassland ecosystems in most areas of North America has exceeded 80% since the mid-1800s (Brennan and Kuvlesky Jr, 2005; Knopf, 1994; Noss et al., 1995). As depicted in Figure 2.a and Figure 2.b, Illinois has lost 99.9% of its original prairie since the early 1800s, and currently has 424 state and 24 federally listed threatened and endangered species within its boundaries (Illinois Department of Natural Resources, 2010).

Samson and Knopf (1994) state that North America prairies are a major priority in biodiversity conservation. The loss of grasslands has contributed to a widespread and ongoing decline of bird populations that have affinities for grass-land and grass-shrub habitats (Askins et al., 2002; Brennan and Kuvlesky Jr, 2005; Vickery and Herkert, 1999). An analysis of the Breeding Bird Survey routes between 1966 and 2002 showed that only 3 of 28 species of grassland specialists increased significantly, while 17 species decreased significantly (Sauer et al., 2003). During the 25-year period ending in 1984, grassland songbirds in Illinois declined by 75% - 95% (Heaton, 2000). Vickery and Herkert (1999) state that given the extent of the decrease in grassland habitat, widespread restoration of grasslands throughout the U.S. is the most effective approach to restoring bird populations.

In an effort to address these growing concerns, ecologists and conservation biologists are engaged in restoring grassland habitats to protect endangered flora and fauna. Restoration ecologists have the ability to structure the restoration to emphasize certain attributes in restored ecosystem but such restoration projects are currently informed by knowledge only from the physical, biological, and ecological sciences (Fletcher and Koford, 2002; Hatch et al., 1999; Howe and Brown, 1999; Martin et al., 2005; Martin and Wilsey, 2006). Restoration planners must make choices about exactly how and where to carry out ecological restoration, and those choices entail physical tradeoffs between the exact types of restored ecosystems that result, the kinds of animals and plants that inhabit the restored areas, the variety of species that are supported by the project, the density of wildlife populations that will be present, and the types of management tools used to maintain these areas. These choices must currently be made in an absence of knowledge about public preferences regarding the characteristics of grassland restoration projects.

4. Methodology

Choice Experiment Surveys

CE surveys are being used by economists to elicit public preferences for environmental goods and policies that are typically not related to existing markets (Boxall et al., 1996; Louviere et al., 2000). CE surveys are based on Lancaster's (1966)consumer theory that consumers obtain utility from the characteristics of goods rather than the good itself. Therefore, CEs can be considered the equivalent of hedonic analysis for stated preference valuation methods. Though CE surveys are more complex to analyze and implement than contingent valuation studies, they allow the researcher to a detailed understanding of the respondents' preferences for the policy or scenario being analyzed. Unlike CV surveys, CE surveys allow the calculation of part worth utilities for attributes, which is necessary to answer the research questions in this paper. Hanley et al. (2001) and Hoyos (2010) provide reviews of the choice experiment methodology.

In a typical CE survey, the respondent repeatedly chooses the best option from several hypothetical choices that have varying values for important attributes. Choice experiment surveys require the use of experiment design techniques to identify a combination of attributes and levels to create the profiles appearing on each survey.

Survey Instrument

The survey for this research will present respondents with opportunities to express preferences over pairs of hypothetical restored grasslands that have the following attributes: species richness, wildlife population density, number of endangered species, frequency of prescribed burning, prevalence of wildflowers, distance to the site from the respondent's house, and cost. Some attributes were motivated by our intent to explore preferences regarding common measures of conservation success. The exact list of grassland attributes was refined after studying the grassland restoration literature and nonmarket valuation literature.

A CV study on preferences for urban green space in Montpellier, France and a CV study on preference for protecting or restoring native bird populations in Waikato, New Zealand find that providing information about the presence of birds significantly effects the WTP. Therefore we include information about bird species in the survey. A study by Gourlay and Slee (1998) on public preferences for landscape features find that wildflowers were one of the features most frequently valued 'highly' or 'very highly'. Since wildflowers are an integral part of the grassland ecosystems we include the area covered by wildflowers as an attribute. Historically, fire has been a natural component of grassland ecosystems and many grassland restoration efforts require management by fire to prevent woody succession and to eliminate invasive species (Copeland et al., 2002; Howe, 1995; Schramm, 1990; Vogl, 1979). At the same time smoke and ash from prescribed burns can be hazardous to motorists and become a problem for local residents. Therefore we include the use of prescribed burns as an attribute in the survey.

Once an initial list of attributes was developed we conducted informal focus groups with potential survey respondents and discussed the survey with ecologists and land managers at grasslands. Formal pre-tests of the survey were conducted at the University of Illinois. The final survey instrument contains background information about grasslands, a description of the attributes and the levels, 7 sets of binary choice question sets, and a small demographic questionnaire. Appendix A contains an example of one choice question. For each of the binary choice sets the respondents choose between the two given alternatives and the status quo option. The choices will contain different features of the restored area and specific values for these features. The demographic questionnaire has two questions regarding the presence of nearby grasslands and non-grassland nature areas. The answers to these questions are used to test whether the presence of nearby grasslands and nature areas has a significant impact on the WTP to provide a new grassland.

The survey was mailed to a random sample of 2000 addresses in Illinois, stratified according to population density. The addresses were obtained from the Survey Research Lab at the University of Illinois. The addresses were oversampled from two counties with existing grasslands and two counties without existing grasslands. One dollar bills were included half of the surveys to increase the survey response rate.

Empirical Design

Given that each choice profile is a binary choice question with a status quo option, a full factorial survey design would include 3^6*3^6*6*6= 19131876 possible profiles. Clearly, conducting a survey with this many profiles is impractical. Therefore, we follow standard practice in the choice modeling literature (Adamowicz et al., 1997; Adamowicz et al., 1998; Louviere et al., 2000) and create an efficient experiment design that will allow both main effects and interaction effects to be estimated. Given that we are interested in studying the interaction effects between different indicators of conservation success the design incorporates pairwise interactions between species richness, population density and number of endangered species. The design for the 7 attributes is presented in Appendix A.[1] The design achieves a 99.57% D-efficiency and can be implemented with 54 choice profiles[2]. The first column in Appendix A identifies the profile set and the last 7 columns identify the levels of each attribute that will appear on the survey. We created a block design where the 54 choice sets were separated into blocks of 6 choice profiles, giving 9 unique surveys with 6 questions each. Carlsson et al. (2010), test for learning and ordering effects in CE surveys and show that dropping the first choice question can decrease the error variance of estimates. Therefore, we add an additional choice question before the six choice questions and drop the first choice question when conducting the analyses to account for possible learning effects. In order to account for possible ordering effects we reversed the order of the questions in half the surveys and obtained 18 unique versions of the survey.

Model and Estimation

CE surveys are based on random utility theory (RUM) in which the utility gained by person *q* from alternative *i* in choice situation *t* is made up of a systematic or deterministic component (*V*) and a random, unobservable component (ε) (Hensher and Greene, 2003; Hensher et al., 2005; Rolfe et al., 2000).

$$U_{qit} = V_{qit} + \varepsilon_{qit} \tag{1}$$

[1] The experiment design was conducted using the SAS experiment design ((Kuhfeld, 2010)).
[2] D-efficiency is the most common criterion for evaluating linear designs. D-efficiency minimizes the generalized variance of the parameter estimates given by D = det [V(X,β)1/k] where V(X, β) is the variance-covariance matrix and k is the number of parameters ((Kuhfeld, 2010; Vermeulen et al., 2008)). (Huber and Zwerina, 1996)identify four criteria, orthogonality, level balance, minimum overlap and utility balance, which are required for a D-efficient experiment design ((Kuhfeld, 2010)).

Following Rolfe et al. (2000) and Hensher et al. (2005) the systematic component in (1) can be separated by the characteristics of the alternative i (X_{in}) and the characteristics of the individual q as below.

$$U_{qit} = V(X_{qit}, Y_{qit}) + \varepsilon_{qit} \tag{2}$$

An individual will choose alternative i over alternative j in choice set t if and only if $U_{qit} > U_{qjt}$.

Thus, the probability that person q will choose alternative i over alternative j is given by:

$$P_{ij} = \text{Prob}(V_{iq} + \varepsilon_{iq} > V_{jq} + \varepsilon_{jq}; \forall j \in C \; and \; j \neq i) \tag{3}$$

where C is the complete set of all possible sets from which the individual can choose. If the error term ε is assumed to be IIA and Gumbel-distributed the choice probabilities can be analyzed using a standard multinomial logit model and the probability of choosing alternative i can be calculated by the following equation where μ is a scaling parameter (Hensher et al., 2005; Mcfadden, 1974; Rolfe et al., 2000):

$$\text{Prob}_{qit} = \frac{\exp(\mu v_{qit})}{\sum_{j \in C} \exp(\mu v_{qjt})}. \tag{4}$$

The standard multinomial logit model generates results in a conditional indirect utility function of the form,

$$V_{iq} = \text{ASC}_i + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_a Y_1 + \beta_b Y_2 + ... + \beta_k Y_n \tag{5}$$

where ASC_i is an optional alternative-specific constant which can capture the influence on choice of unobserved attributes relative to specific alternatives (Carlsson et al., 2003; Hensher et al., 2005).[3] The β 's represent the coefficients on the vector of attributes and individual characteristics. A willingness-to-pay compensating variation welfare measure can be obtained

[3] For the empirical specification we do not include an ASC term since the specific alternatives are generic and unlabeled.

from the above estimates as

$$WTP = \beta_{\cos t}^{-1} \ln \left[\frac{\sum_i \exp(v_i^1)}{\sum_i \exp(v_i^0)} \right] \tag{6}$$

where $\beta_{\cos t}^{-1}$ is the marginal utility of income ((Hanley et al., 2002)).[4] The part-worth marginal value of a single attribute can be represented as

$$WTP_k = -\beta_k \,/\, \beta_{\cos t}\,. \tag{7}$$

Though the standard multinomial logit model has been used in many valuation studies of environmental goods, it assumes that the respondents are homogeneous with regard to their preferences (the βs are identical for all respondents). This is a strong and often invalid assumption. Therefore, we use a mixed multinomial logit model[5] (Carlsson et al., 2003; Hensher and Greene, 2003) that incorporates heterogeneity of preferences. Assuming a linear utility, the utility gained by person *q* from alternative *i* in choice situation *t* is given by

$$U_{qit} = \alpha_{qi} + \beta_q X_{qit} + \gamma_i Y_q + \varepsilon_{qit} \tag{8}$$

where X_{qit} is a vector of non-stochastic explanatory variables, and Y_q is a vector of socio-economic characteristics. The parameters α_{qi} and γ_i represent an intrinsic preference for the alternative and the heterogeneity of preferences respectively. Following standard practice for logit models we assume that ε_{qit} is independent and identically distributed extreme value type I.

We assume the density of β_q is given by $f(\beta \mid \Omega)$ where the true parameter of the distribution is given by Ω. The conditional choice probability alternative *i* for individual *q* in

[4] The β's represent marginal utilities ($\beta_k = \partial U / \partial Z_k$)
[5] Also referred to as mixed logit, hybrid logit and random parameter logit, random coefficient logit model

choice situation t is logit[6] and given by

$$L_q(\beta_q) = \prod_t \frac{\exp(\alpha_{qi} + \beta_q X_{qit} + \gamma_i Y_q)}{\sum_{j \in J} \exp(\alpha_{qj} + \beta_q X_{qjt} + \gamma_j Y_q)} . \quad (9)$$

The unconditional choice probability for individual q is given by,

$$P_q(\Omega) = \int L_q(\beta) f(\beta \mid \Omega) d\beta . \quad (10)$$

The above form allows for the utility coefficients to vary among individuals while remaining constant among the choice situations for each individual (Carlsson et al., 2003; Hensher et al., 2005). There is no closed form for the above integral, therefore P_q needs to be simulated. The unconditional choice probability can be simulated by drawing R drawings of β, β_r, from $f(\beta \mid \Omega)$ [7] and then averaging the results to get

$$\tilde{P}_q(\Omega) = \frac{1}{R} \sum_{r \in R} L_q(\beta_r) . \quad (11)$$

The interpretation of the coefficient values for the above mixed multinomial model is complicated. Therefore following Carlsson et al. (2003) we calculate the marginal rates of substitution between the attributes using the coefficient for cost as numeraire and we interpret the ratios as average marginal WTP for a change in each attribute.

Econometric Specification

We use three econometric specifications to test for robustness of the results and to incorporate individual heterogeneity.

The conditional logit is:

$$V_{ni} = \beta_1 X_{richness} + \beta_2 X_{density} + \beta_3 X_{endangered} + \beta_4 X_{wildflowers} + \beta_5 X_{burning} + \beta_6 X_{distance} + \beta_7 X_{cost} + \varepsilon_{ni}$$

[6] The remaining error term is iid extreme value.

[7] Typically $f(\beta \mid \Omega)$ is assumed to be either normal or log-normal but it needs to be noted that the results are sensitive to the choice of the distribution.

$$(12)$$

The mixed multinomial logit is:

$$V_{ni} = \beta_{1n}X_{richness} + \beta_{2n}X_{density} + \beta_{3n}X_{endangered} + \beta_{4n}X_{wildflowers} + \beta_{5n}X_{burning} + \beta_{6n}X_{distance} + \beta_{7n}X_{cost} + \varepsilon_{ni} \quad (13)$$

The mixed multinomial logit with interaction terms is:

$$\begin{aligned} V_{ni} = {} & \beta_{1n}X_{richness} + \beta_{2n}X_{density} + \beta_{3n}X_{endangered} + \beta_{4n}X_{wildflowers} \\ & + \beta_{5n}X_{burning} + \beta_{6n}X_{distance} + \beta_{7n}X_{cost} + \beta_{8n}X_{richness} * X_{density} \\ & + \beta_{9n}X_{density} * X_{endangered} + \beta_{10n}X_{endangered} * X_{richness} \\ & + \beta_{11n}X_{cost} * Y_{grassland\ near?} + \beta_{12n}X_{cost} * Y_{nature\ reserve\ near?} \\ & + \varepsilon_{ni} \end{aligned} \quad (14)$$

This most complex specification (14) includes three variables that are interactions between the conservation success attributes. A significant and positive coefficient on an interaction term implies that the respondent has higher marginal utility for increases in one conservation success measure when the levels of the other conservation success terms are high. This would lead to concave TWTP contours between conservation attributes as depicted in Figure 3a. A significant and negative coefficient on the interaction terms implies the opposite and would lead to convex TWTP contours as depicted in Figure 3c. If the coefficient is insignificant, then the contours are linear (Figure 3b); this is the standard implicit assumption of most CE econometric specifications.

This specification also includes terms that interact the cost attribute with person-specific dummy variables that indicate the presence of grasslands and the presence of non-grassland natural areas nearby. These interaction terms allow us to analyze the impact of existing natural areas on the WTP for a new hypothetical grassland. If the coefficient is positive (negative) and significant this implies that respondents who have a nearby natural area are willing to pay more (less) to restore a new grassland.

The conditional logit model was estimated using the built in function within STATA. The mixed multinomial logit and the mixed multinomial logit with interaction terms were estimated using the user written STATA routine by Hole (Hole, 2007).

5. Results and Discussion

Out of the 2000 surveys that were mailed out, 48 were undeliverable. Of those that were delivered, 316 surveys were returned out of which 263 were complete yielding 1578 choice question observations with an overall response rate of 16.19%. Each of the 18 different survey versions was returned at least 10 times.[8] This ensures that each of the 54 choice profiles was represented in the final analysis. Of the 316 surveys that were returned, 196 were surveys that included the dollar bill. Therefore, including the dollar bill increased the response rate by 63%. Table 2 compares the demographic characteristics of the state and the respondents, showing our sample to be reasonably representative of adults in the state.

The results for the main-effects regressions (conditional logit and mixed logit) models are presented in Table 3. These specifications do not include interaction terms. The last column of Table 3 indicates that individual heterogeneity is significant for many attributes and should be taken into consideration. However, the parameter estimates are qualitatively similar across the two models. The three conservation attributes and wildflowers all have positive and significant coefficients, while distance and cost are negative and significant.

For each set of results we calculate the marginal willingness to pay (MWTP) for each attribute by dividing the coefficient for each attribute by the coefficient for cost as

$$MWTP_i = \frac{\beta_i}{\beta_{cost}} \tag{15}$$

[8] On average each survey versions was returned 16.6 times with a standard deviation of 0.88 a minimum of 10 and a maximum of 24.

The resulting MWTP values are shown in Table 4. Though the coefficient values for the conditional logit and the mixed logit models vary in magnitude, the MWTP values for each attribute is similar for both models. The coefficient estimates should not be compared to each other directly since the units for each attribute differ. All three of the conservation success measures (species richness, population density and endangered species) have significant per household values. A typical person is willing to pay $1.13 each year to have an additional bird species present in the grassland, and the value of an endangered species is a much higher $9.09, while increasing the population density of birds in a grassland by 1 additional bird per acre is worth $1.60. This latter result reinforces the findings by Loomis and Larson (1994) and Fletcher and Koford (2002) that wildlife population density is an important variable affecting the public's WTP for restoring habitats.

The results for the mixed logit model with interaction terms are presented in Table 5. The coefficient for the interaction of the *cost* and the *grassland near* variable is negative. This implies that respondents who live near existing grassland areas have a higher MWTP for each of the attributes. This result contradicts what would be predicted by standard neoclassical consumer economics. This finding could be evidence of endogenous preferences - individuals who consume and experience a good can have a higher WTP for the good than individuals who have not experienced a good. It could alternatively be argued that this result is caused by locational sorting wherein respondents who have an inherent preference for grasslands choose to live close to them. We note that people with high values for grasslands may also have relatively high values for other natural areas, but the interaction effect for non-grassland natural areas being nearby is not significant in the regression; this might imply that the positive coefficient on the interaction of cost with the grassland near dummy is more likely caused by endogenous preferences than by sorting.

The two-way interaction terms between species richness, population density and endangered species are all significant and negative; the marginal value of one conservation feature is lower when the levels of the other feature is high. Figure 4 shows the TWTP as a function of species richness for different levels of population density. The TWTP increases as the value of species richness increases. The three lines in Figure 4 correspond to different levels of population density. As population density increases the TWTP at each level of species richness increases. When the interaction terms are set to zero (Figure 4.a) the increase in TWTP caused by higher population density is the same at every species richness level (the lines are parallel). When the interaction terms are included (Figure 4.b), the slope of the TWTP-species richness line decreases as the level of population density increases. This illustrates the relationship between preferences over any two conservation goals; here an increase in species richness has a smaller impact on TWTP at high levels of population density than at low levels of population density.

Further, the significant interaction terms implies that the total WTP (TWTP) curves are non-linear as depicted in Figure 5, which depicts the TWTP contour in species richness and population density space (similar to a utility function in two good space). Figure 6.a contains a TWTP contour for a TWTP of $80. This contour shows the combination of species richness and population density that yield a TWTP of $80. When the interaction terms are ignored the TWTP contour is linear, indicating a fixed marginal rate of substitution. When the interaction terms are included the TWTP contour is concave, indicative an increasing marginal rate of substitution. Figure 5.b shows the substitution between species richness and population density for different levels of TWTP and number of endangered species. The TWTP contour for $70 lies below the

TWTP for $80. As the value of endangered species increases, the TWTP contour shifts inwards since a smaller amounts of species richness and population density are required to reach the $70 TWTP contour.

Next we characterize the bundle of conservation success attributes that will provide the largest TWTP while holding other attributes of a grassland constant. We solve a simple constrained maximization problem where the TWTP is maximized as a function of the conservation success variables. The results are presented in Table 7. The first column indicates whether physical constraints are present; the first sets of results are unconstrained while the second sets of results assume physical limits on the levels of some attributes. The second column indicates the budget constraint and the third column indicates the stylized costs. We assume that each of the conservation success attributes can be produced independently and that the costs are given per unit of each attribute. We solve the problem for a range of total cost values to show how the result changes with the cost. Column four indicates whether the results include the interaction terms. Columns five through seven report the resulting optimal values of the conservation success variables and column eight contains the corresponding TWTP amount.

The first sets of results correspond to a scenario without physical constraints. When the costs are all $1 (the cost ratio is1:1:1), for both the scenarios with and without interaction terms, the result is a corner solution where only the endangered species variable has a positive value. This is to be expected given the concave TWTP curves and the fact that endangered species has the highest marginal value. Given that it is relatively difficult to manage a grassland to attract endangered species, we increase the relative cost of endangered species. When the cost of endangered species in increased to $10 (cost ratio of 1:1:10), the solution changes so that only the population density variable has a positive value. Again this result makes sense since population density has the second largest marginal value. These corner solutions are to be expected given the nature of the indifference curves depicted in Figure 4. Given the slope of the cost function the unbounded utility maximizing bundle will consist of just one attribute.

Next we present the TWTP-maximizing bundle when physical constraints are imposed on the levels of conservation goals that can be achieved. The results show that the TWTP-maximizing bundle is one with high values for the attributes that have a higher marginal contribution to the overall TWTP. For example, when the budget is unconstrained the scenario without interaction terms selects the maximum possible values for each of the three conservation success attributes. When the interaction terms are included, only the population density variable and the endangered species variable have positive values. This result makes sense since the interaction terms are negative and if the species richness variable had a positive value the net effect of its presence would be a decrease in TWTP due to the interaction terms. When the budget is constrained, for the scenario without interaction terms, the TWTP maximizing solution is the solution to the knapsack problem.[9] For the scenario with interaction terms, the conservation success variable with the lowest contribution, species richness, has zero value.[10]

Finally, we calculate the total WTP (TWTP) for a hypothetical grassland with realistic attribute values. Due to the various interaction terms, the result is best represented as the table shown in Table 6. We estimate the TWTP for a 100 acre hypothetical grassland with 30 different bird species, 15 individual birds per acres, 6 endangered species, 60% wildflower coverage, and controlled burning once every year and when no non-grassland nature area is nearby. The TWTP ranges between $60 and $109 per household per year. The results indicate that being near an

[9] Obtain as much as allowed from the attribute that has a highest marginal contribution to the objective function, then as much as allowed from the attribute with the second highest marginal contribution and so on.

[10] If the species richness value also had a positive amount the net effect will be a decrease in TWTP due to the interaction terms

existing grassland increases the TWTP for an additional grassland by as much as 43% (when the new grassland is 10 miles away). Further, as the distance to the restored grassland increases from 10 miles to 100 miles the TWPT decreases by as much as 28%.

6. Conclusion

We analyze the structure of public willingness to pay for different attributes of grassland ecosystems using a choice experiment survey. This work yields several findings that have broad implications for conservation planning and environmental valuation. First, we find that several features of an ecosystem that are used as measures of conservation success - species richness, population density, and presence of endangered species - have large positive marginal values. Much of the work on optimal protected-area planning and design uses a single measure of conservation success as the objective to be maximized. Our results imply that when there are physical tradeoffs between conservation outcomes (e.g. one can increase the population of a single species such as pheasant, but in doing so one might lower species richness) planners should be careful to consider all conservation success measures in order to maximize the social welfare obtained from conservation and restoration efforts.

Second, in an effort to analyze the structure of the preferences for the conservation success attributes in more detail we use a specification that contains pairwise interactions of the conservation success terms. We find that the values people place on any one conservation outcome is lower when the levels of other conservation outcomes are high; in other words, people seem to view these feature as substitutes rather than complements. This means, for example, that the value to society of a project that maximizes species richness will vary across sites that have different levels of wildlife population density and numbers of endangered species.

Given that restoration ecologists are able to determine the levels of species richness, population density and the presence of endangered species when undertaking conservation efforts, our results emphasize the importance of considering the levels of all these attributes when conducting restoration efforts, optimal protected area planning models, and cost benefit analysis for conservation and restoration of ecosystems.

We also show that as a result of the concave TWTP contours, the TWTP maximizing grassland only has positive values for one of the conservation success terms (there is a corner solution). If the signs on the interaction terms were reversed, i.e. the willingness to pay for a given attribute increased with the values of the other attributes, the indifference curves would be convex and this would have resulted in interior solutions with positive values for multiple conservation success attributes. These results also emphasize the importance of including interaction terms when studying the WTP for attributes that can be treated as either complements or substitutes by the respondent.

Third, we find that respondents who live near existing grassland areas have a higher MWTP for restoring additional grasslands. This result contradicts what would be predicted by standard neoclassical economics- the marginal value of a good will decline with its total quantity. Our result may reflect the existence of endogenous preferences - individuals who consume and experience a good learn to appreciate and enjoy it and can therefore can have a higher WTP than individuals who have not experienced the good. We recognize that this finding could be caused by locational sorting. However, as discussed earlier, the fact that the WTP for an additional grassland is not correlated with the presence of nearby non-grassland natural areas leads us to believe our result is evidence of endogenous preferences. We will control for possible endogeneity of proximity to grassland in future versions of this work. If the result is robust, it has implications for conservation planning in terms of locating new conservation areas; for example the welfare maximizing conservation strategy may be to have similar ecosystem types partially clustered in the landscape.

Finally, this study is the first to generate value estimates for the WTP to conserve and restore grasslands, an ecosystem type that is disappearing throughout North America. This study provides valuable information to conservation planners and ecologists engaged in restoring and conserving ecosystems regarding the values placed on grasslands by the public. The results allow policy makers to calculate the total willingness to pay for a grassland with varied characteristics. For the plausible grassland described in the results section, the annual value per household ranges between $60 and $109.[11] This information is especially important in places like Illinois where some lands could be potentially be restored as wetland, tallgrass prairie or forest with different restoration and management techniques.[12]

The results we present allow conservation organizers and land use planners to effectively conduct a cost benefit analysis of restoring grasslands, and improve restoration planning decisions about the attributes of restored grasslands. The findings also raise provocative questions about the standard economic assumption that marginal value of environmental goods diminishes with total quantity; those questions should be further explored in future research.

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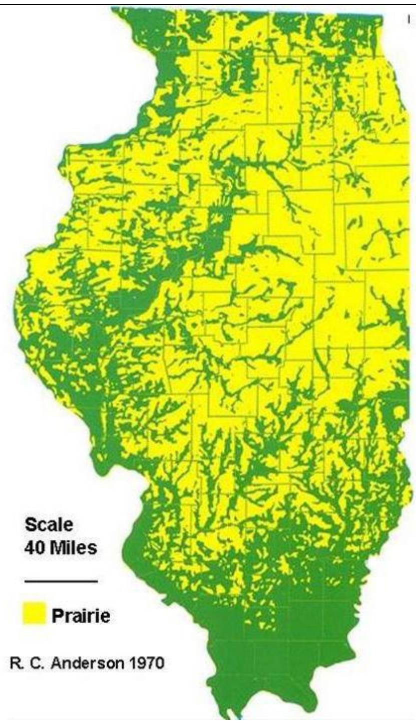
[11] For a 100 acre hypothetical grassland with 30 different bird species, 15 individual birds per acres, 6 endangered species, 60% wildflower coverage, and controlled burning once every year.

[12] To put those values in context, we list here value estimates that have been obtained for other ecosystems. Boyer and Polasky (2004) give examples of stated preference surveys that yield WTP for wetlands in the range of $15 (1987$) - $87 (1998$) per hectare per year. Brander et al (2006) conduct a comprehensive summary of stated preference studies on wetlands and find the median willingness to pay is approximately 200 1995 $ per hectare. per year. Heimlich et al. (1998) find empirical estimates of the WTP for wetlands that range between $0.02 to $8,924 per hectare. Barrio and Loureiro (2010) conduct a meta-analysis of CV studies of forests and find values that range between $0.75 (ppp 2008$) - $490 (ppp 2008$).

Figure 1: Grasslands in North America

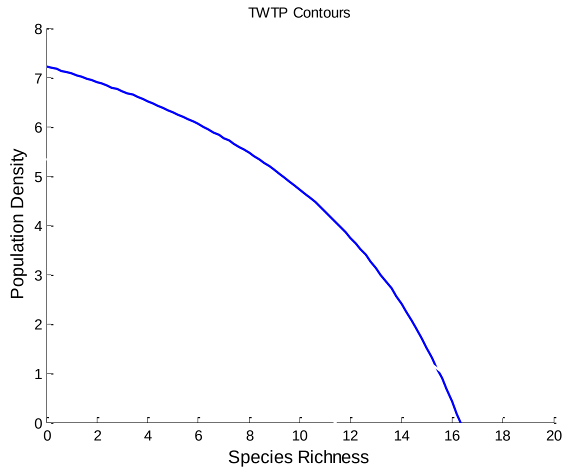
Source: (Nature Conservancy, 2008)

Figure 2: Grasslands in Illinois

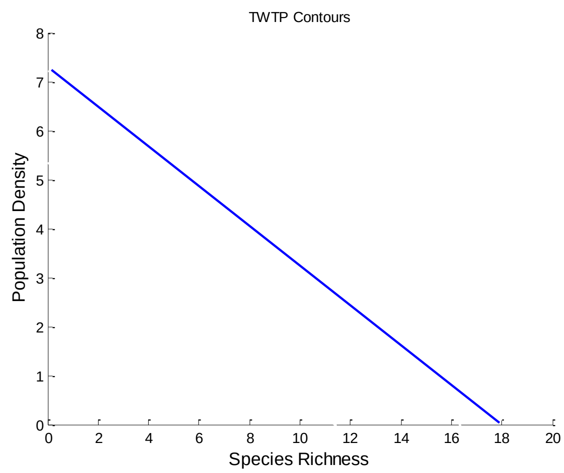


Panel 2.a: Map of Historic Prairies in Illinois from 1820 (Anderson 1970)	Panel 2.b Map of Rural Grassland in Illinois from 2000(Created from INGDCH Land Cover data)

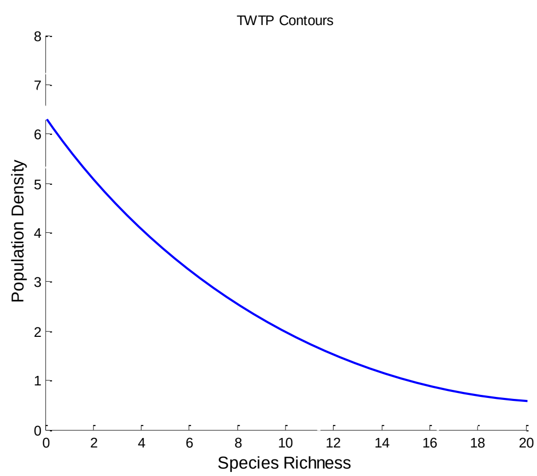
Figure 3: Concave vs. Convex TWTP Contours



Panel 4.a Concave Interaction Terms

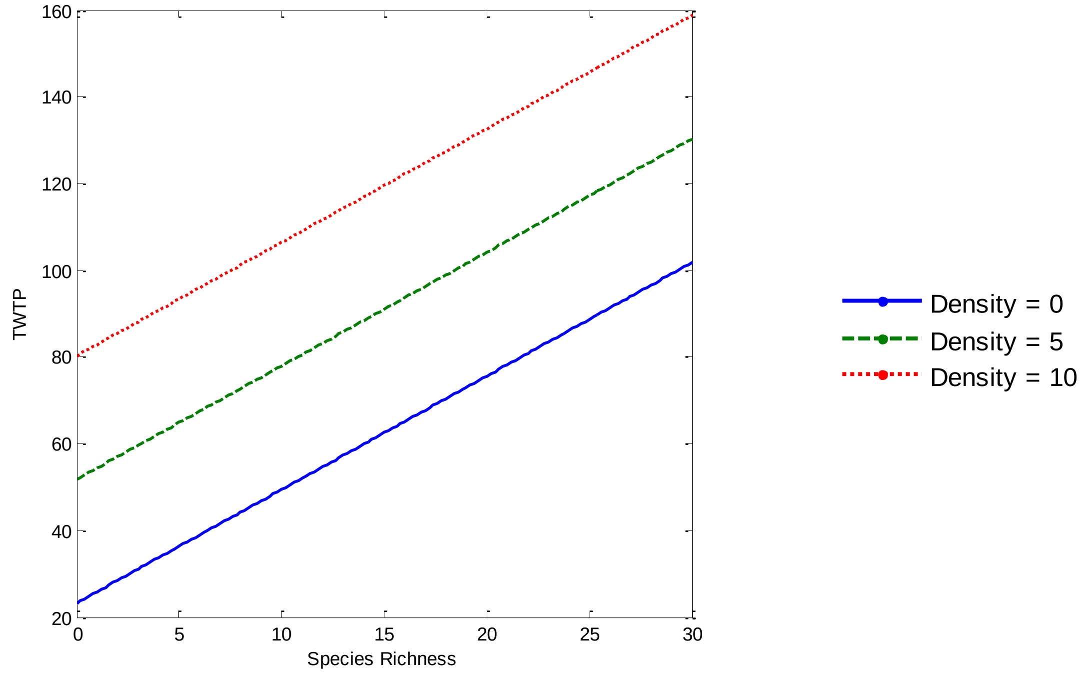


Panel 4.b Linear Interaction Terms

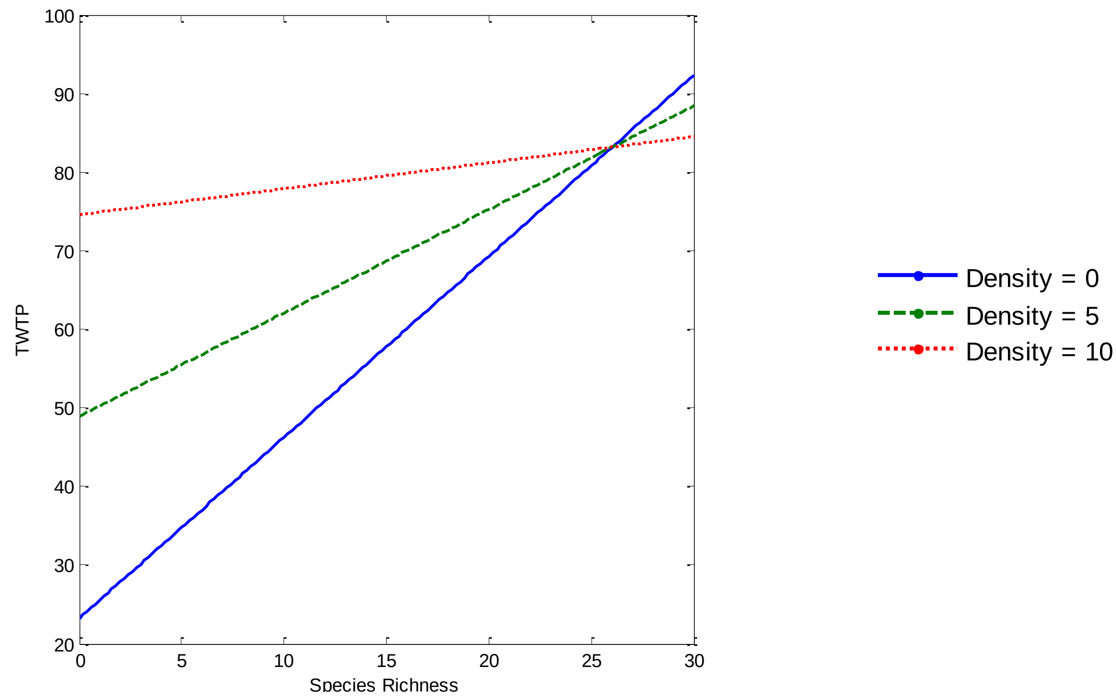


Panel 4.c Convex Interaction Terms

Figure 4: Species Richness vs. TWTP as Density Changes

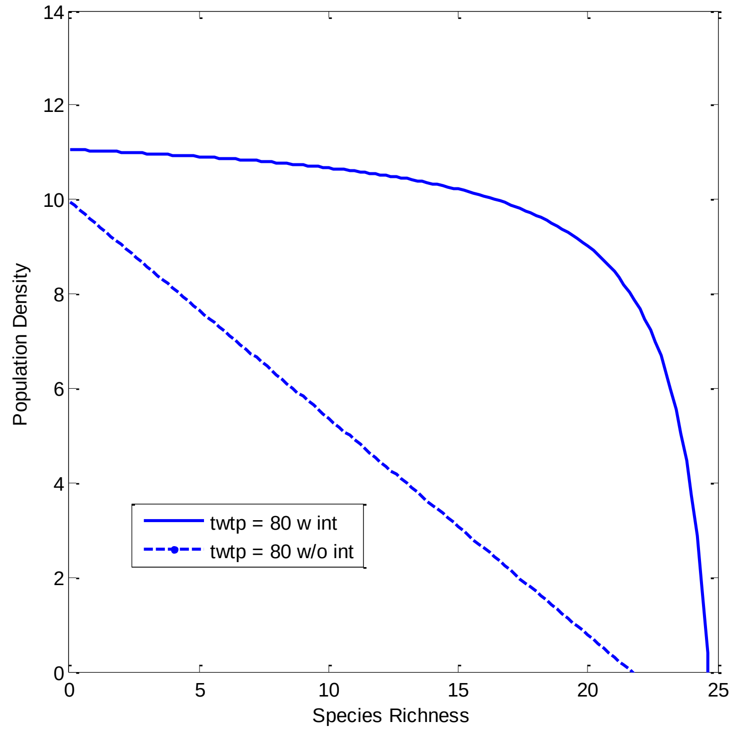


Panel a: With interaction terms set to zero

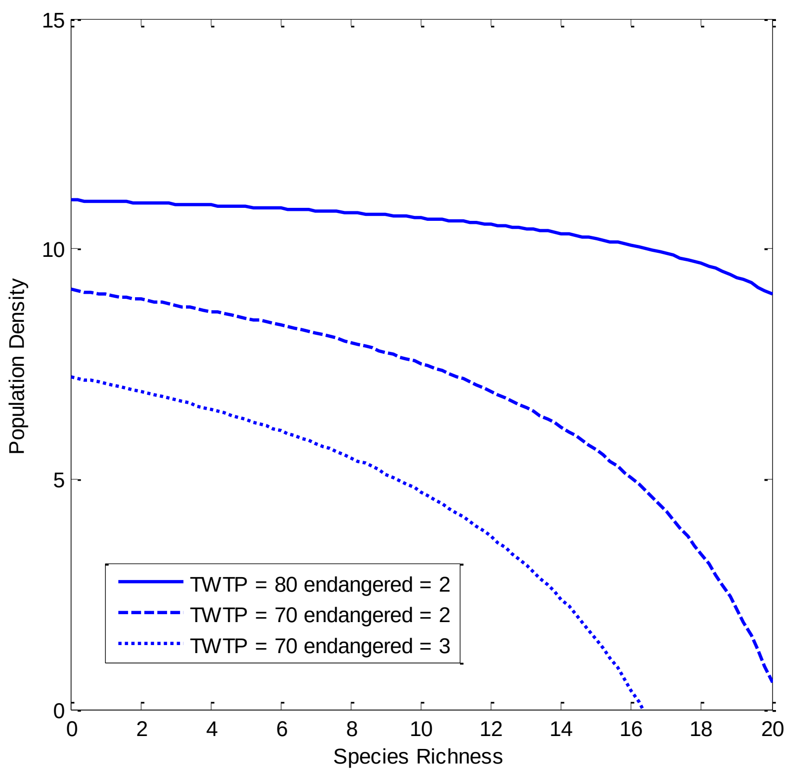


Panel b: With positive interaction terms

Figure 5: Total Willingness-to-Pay Curves



Panel a: With and without interaction terms



Panel b: With changing attribute values

Table 1: Attributes and levels for survey instrument

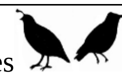
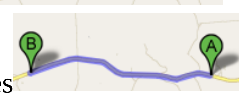
Attribute	Description	Levels
Number of Bird Species	The number of different bird species in the restored area. A high number means you are more likely to see many different **kinds of birds** in the restored area.	30 different species  20 different species  10 different species 
Density of Birds	The number of individual birds (from all species) within an acre. A high number means you are more likely to see a large **number of individual birds** in the restored areas. They may be all the same type, or they may be several different types.	15 individuals per acre  10 individuals per acre  5 individuals per acre 
Number of endangered species	The number of different endangered or threatened bird species that will live in the restored area.	6 endangered or threatened species  3 endangered or threatened species  0 endangered or threatened species
Amount of wildflowers	The percentage of restored land area that will be covered by wildflowers. A higher percentage means you are more likely to see more wildflowers in the restored area.	60% covered in wildflowers  40% covered in wildflowers  20% covered in wildflowers 
Use of prescribed burning	The possible use of prescribed burns to manage the grassland.	No prescribed burning  Prescribed burning once every other year.  Prescribed burning once every year 
Distance to restored area	The distance to the restored area from your home. This feature ranges from 10 miles (between 8 to 12 minutes) to 100 miles (between 1 1/2 to 2 hours)	10 miles  50 miles  100 miles 
Annual cost to your household	The fee that your household will have to pay every year to restore and maintain the grassland.	This value will range from $0 to $100

Table 2: Comparison of state population and sample

Variable	**State**[a]	**Dataset**
Average age over 18(years)[c]	47	55 (15)
Income, \$1,000 (median household, 2009)	54	50 – 75
Education		
High school completed	86%	96% (20)
Bachelors degree completed	30%	47% (50)
Female	51	41 (49)
Children under 18	2.5	2.7 (4.4)

[a]Based on http://quickfacts.census.gov/qfd/states/17000.html
[b]2010 census, calculated from http://factfinder2.census.gov/

Table 3: Regression Results for the Conditional Logit and Mixed Logit Models

Variable	Conditional Logit		Mixed Logit		
	Coefficient	SE	Coefficient	SE	SD^
Species richness	0.017***	0.004	0.029***	0.010	Significant
Population density	0.024***	0.008	0.092***	0.018	
Endangered Species	0.135***	0.014	0.321***	0.043	Significant
Wildflowers	0.013***	0.002	0.032***	0.005	Significant
Prescribed burning	-0.016	0.042	0.121	0.099	Significant
Distance	-0.005***	0.001	-0.011***	0.003	Significant
Cost	-0.015***	0.001	-0.042***	0.005	Significant
Number of Observations	4734		4734		
Log Likelihood	-1534.26		-1169.70		
LR chi2(7)	398.70		729.13		
Prob > chi2	0.00		0.00		

***significant at 1%, **significant at 5%, *significant at 10%
^Significance of standard deviations at 10% or less when incorporating individual heterogeneity

Table 4: Marginal Willingness to Pay Estimates

Attribute	Clogit	Mixlogit
Species Richness	$1.13	$0.71
Bird Density	$1.60	$2.22
Endangered Birds	$9.09	$7.73
Wildflowers	$0.86	$0.77
Burning	-$1.08	$2.92
Distance	-$0.31	-$0.25

Table 5: Results for the Mixed Logit Model with Interaction Terms

	Coefficient	Standard Errors	SD^
Main Effects			
Species richness	0.155***	0.028	Significant
Population density	0.337***	0.052	Significant
Endangered Species	0.692***	0.140	Significant
Wildflowers	0.020***	0.006	Significant
Prescribed burning	-0.025	0.110	Significant
Distance	-0.015***	0.003	Significant
Cost	-0.084***	0.015	Significant
Conservation Success Interaction Terms			
Richness X Density	-0.012***	0.003	Significant
Density X Endangered	-0.017*	0.010	
Endangered X richness	-0.009*	0.005	Significant
Complementarity Interaction Terms			
Grassland Near X Cost	0.025**	0.011	
Nature Near X Cost	0.009	0.014	Significant
Number of Observations	4734		
Log Likelihood	-1112.74		
LR chi2(7)	811.34		
Prob > chi2	0.00		

***significant at 1%, **significant at 5%, *significant at 10%

^ Significance of standard deviations at 10% or less when incorporating individual heterogeneity

Table 6: TWTP for a Hypothetical Grassland

Distance	Grassland Near 0	Grassland Near 1
10	$66	$93
	(47-85)	(47-140)
100	$49	$70
	(33 - 65)	(33 - 107)

Note: The 95% confidence interval for each estimate is given within the parentheses.

Table 7: Constrained Maximum TWTP

Physical Constraints	Budget Constraint	Cost Ratio	Interaction Terms	Richness	Density	Endangered	TWTP
None	$100 total	Equal (1:1:1)	No	0	0	100	$1172.3
			Yes	0	0	100	$1172.3
	$100 total	1:1:10	No	0	100		$569.9
			Yes	0	100	0	$569.9
Application	Unconstrained	Equal (1:1:1)	No	30	15	6	$234.2
bounds[13]			Yes	0	15	6	$130.12
	$30 total	Equal (1:1:1)	No	9	15	6	$179.22
			Yes	0	15	6	$130.12
	$15 total	Equal (1:1:1)	No	0	9	6	$106.12
			Yes	0	9	6	$121.45

[13] $0 \leq$ Species richness ≤ 30, $0 \leq$ Population density ≤ 15, $0 \leq$ Endangered Species ≤ 6,

Appendix A: Survey Design for 7 Attributes

Set	x1	x2	x3	x4	x5	x6	x7
1	2	1	2	3	1	2	6
	1	2	1	2	3	1	4
2	3	1	2	2	3	1	5
	2	2	1	1	2	3	2
3	2	3	2	1	2	3	5
	1	2	1	2	3	1	4
4	3	3	1	2	1	3	2
	2	2	3	1	3	2	4
5	1	3	1	1	2	3	3
	3	2	2	2	1	2	6
6	1	1	3	3	3	3	6
	3	3	1	2	2	2	5
7	2	2	2	3	2	1	1
	1	3	3	2	3	3	2
8	3	2	1	3	1	1	1
	1	1	3	2	2	2	4
9	3	3	2	1	1	1	1
	1	1	3	3	3	3	6
10	3	1	2	2	3	1	5
	2	2	1	1	2	3	2
11	3	1	2	3	2	2	2
	2	3	1	1	3	1	6
12	1	3	2	3	2	2	6
	3	1	3	1	1	3	3
13	3	2	3	3	3	3	5
	1	3	2	2	1	1	4
14	1	1	2	1	3	3	1
	2	3	3	3	2	2	3
15	2	1	1	2	2	3	3
	3	3	3	1	3	1	6
16	3	2	1	1	3	2	3
	2	3	3	2	1	3	1
17	3	3	2	3	3	3	3
	1	1	1	1	1	2	5
18	2	3	1	3	1	1	4
	1	1	2	1	3	3	1
19	1	1	2	1	3	3	1
	2	3	1	3	1	1	4
20	2	2	3	1	3	2	4
	1	1	1	3	1	1	2
21	3	3	3	1	3	1	6
	2	2	1	3	1	2	5
22	1	2	1	2	3	1	4
	2	3	3	3	2	2	3
23	2	1	1	2	3	2	1
	1	3	3	1	1	1	5
24	1	1	2	2	2	1	3
	3	2	3	3	3	3	5
25	2	3	2	1	2	3	5
	3	1	3	2	1	2	1
26	2	1	3	3	3	1	2
	1	2	1	2	2	3	6
27	1	3	1	3	3	2	1
	3	2	3	2	2	1	2
28	3	2	2	1	2	3	4
	2	1	3	3	3	1	2
29	2	2	2	2	3	1	3
	3	3	3	3	2	2	4
30	3	1	2	3	2	2	2
	2	3	3	2	1	3	1
31	1	2	3	1	1	2	3
	3	1	1	3	3	3	4
32	2	2	1	3	1	2	5
	1	1	2	2	2	1	3
33	3	3	2	1	1	1	1
	1	2	1	2	2	3	6
34	1	2	2	3	3	3	5
	3	1	1	1	2	1	6
35	1	1	3	2	2	2	4
	2	3	1	1	3	1	6
36	2	2	1	1	2	3	2
	1	3	2	2	1	1	4
37	3	3	1	2	2	2	5
	2	1	2	1	1	3	4
38	1	2	3	3	2	1	1
	2	3	2	2	3	2	2
39	3	3	2	3	3	3	3
	2	1	3	1	2	1	5
40	1	3	1	3	3	2	1
	2	2	3	2	1	3	6
41	1	1	1	3	1	1	2
	2	2	3	1	3	2	4
42	2	1	1	2	2	3	3
	1	2	2	1	1	2	2
43	3	2	2	2	1	2	6
	2	1	3	1	2	1	5
44	2	1	1	2	3	2	1
	3	2	2	1	2	3	4
45	2	1	2	3	1	2	6
	3	2	3	2	2	1	2
46	1	2	3	1	1	2	3
	3	1	1	3	3	3	4
47	3	3	3	3	2	2	4
	2	2	2	2	3	1	3
48	2	2	2	3	2	1	1
	3	1	3	1	1	3	3
49	1	2	2	3	3	3	5
	3	1	3	2	1	2	1
50	3	1	3	1	1	3	3
	2	3	2	2	3	2	2
51	1	2	3	3	2	1	1
	2	1	2	1	1	3	4
52	2	3	3	2	1	3	1
	3	2	1	1	3	2	3
53	1	3	3	2	3	3	2
	3	1	1	1	2	1	6
54	2	2	2	3	2	1	1
	1	1	1	1	1	2	5

Appendix B: The survey

Choice Question 1

Suppose Option A and Option B were the **only** grassland projects you could choose. Which **one** would you choose? Please read **all** the features of **each** option and then **check the box that represents your choice**. If you do not like either option A or option B, then please choose the box marked “No grassland project” which is Option C.

Attribute	**Number of Bird Species**	**Density of Birds**	**Number of endangered species**	**Amount of wildflowers.**	**Use of prescribed fire.**	**Distance to restored area**	**Annual cost to your household**	**I would Choose**
Option A	20 different species	5 individuals per acre	3 endangered or threatened species	60% covered in wildflowers	No prescribed burning	50 miles	$100	❒ A
Option B	10 different species	10 individuals per acre	0 endangered or threatened species	40% covered in wildflowers	Prescribed burning once every year	10 miles	$70	❒ B
Option C	No Restoration Project						No cost	❒ C

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