

Valuing preservation and restoration alternatives for ecosystem services in the southwestern USA[§]

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ABSTRACT

Conservation of freshwater ecosystems in the semi-arid southwestern USA is a critical issue as these systems support habitat for wildlife and provide consumptive use for humankind. Economists have utilized stated preference techniques to value non-marketed goods and services such as freshwater ecosystems for much of the last four decades. Recently, Boyd and Banzhaf (2007) have advocated for ecosystem accounting units to be created in valuing ecosystem services such as freshwater ecosystems. Working collectively, a team of physical and social scientists developed a set of ecological endpoints for two river regions in the southwestern USA and used these ecological endpoints in a contingent valuation survey to obtain willingness to pay values for restoration and preservation alternatives. The results demonstrate statistically significant preservation and restoration estimates for the Upper San Pedro and restoration estimates for the Middle Rio Grande ecosystems. Copyright © 2015 John Wiley & Sons, Ltd.

KEY WORDS willingness to pay; restoration; preservation; contingent valuation; ecological endpoints

Received 30 July 2014; Revised 14 March 2015; Accepted 15 March 2015

INTRODUCTION

In the southwestern USA, conservation of freshwater ecosystems is critical and influences the abundance, composition, and structure of Riparian (streamside) vegetation and

its associated wildlife. At the same time, there is rising demand for water use to address human needs (Alley *et al.*, 2002; Stromberg *et al.*, 2006). To address these conflicts, it is not only important for natural scientists to evaluate how anthropogenic changes to hydrologic regimes alter ecological systems but also to integrate the natural and social sciences to define ecological endpoints in order to obtain values for ecosystem services to better inform public policy decisions.

Daily (1997) defined ecosystem services as ‘the benefits of nature to households, communities, and economies.’ Recently, Boyd and Banzhaf (2007) highlighted the need for standardized environmental accounting units for ecosystem services in order to develop welfare estimates for environmental accounting. These estimates should include not only the negative impacts of anthropogenic changes on ecosystems but also the effects of restoring hydrologic and ecological functions to achieve ecosystem services that have been lost. The Millennium Ecosystem Assessment reported that about 60% of global ecosystem services are being degraded or used unsustainably (Millennium Ecosystem Assessment, 2005). This report demonstrates the need for accurate environmental values in order to produce accurate welfare estimates as argued by Boyd and Banzhaf (2007).

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[§]This research is supported by the U.S. Environmental Protection Agency, ‘Integrated Modeling and Ecological Valuation,’ EPA STAR GRANT Program #2003-STAR-G2, in part by SAHRA (Sustainability of semi-Arid Hydrology and Riparian Areas) under the STC Program of the National Science Foundation, Agreement No. EAR-9876800 (work related to the avian component), and the Science Impact Laboratory for Policy and Economics through the U.S. Geologic Survey’s Science and Decision Center cooperative agreement #G10AC00303, and with in kind contributions from the U.S. Department of Agriculture Research Service, Hawks Aloft Inc and The Nature Conservancy.

In this paper, we seek to develop a set of ecological endpoints that are rooted in economic and ecological theory as Boyd and Banzhaf (2007) argue for. Boyd and Krupnick (2013) define ecological endpoints as ‘...meaningful biophysical outputs that do not require expert knowledge of biophysical production functions to determine their economic value’. To develop a set of ecological endpoints for freshwater ecosystems, an interdisciplinary team of natural scientists worked collectively with a team of social scientists to examine both preservation and restoration alternatives for two river basins in the southwestern USA—the Upper San Pedro and Middle Rio Grande (MRG). These ecological endpoints were then used in a Contingent Valuation (CV) survey to estimate individual Willingness To Pay (WTP) to develop welfare estimates for preservation and restoration alternatives.

Contingent Valuation is a technique that has been utilized by economists to value non-marketed goods and services for the better part of the last four decades. Carson (2011) created a comprehensive bibliography of CV studies finding over 7500 studies at the time of publication, up from just over 2000 in 1995. As CV continues to increase in ecological valuation, it is important for researchers to focus on creating ecological endpoints that can be used to determine economic value for ecosystems. Barkmann *et al.* (2008) provide a recent example of researchers working to identify a set of ecological endpoints to obtain WTP estimates. They find that while beneficial, this approach can come with a cost as ‘basic science’ models that explain ecosystem functions are difficult for participants to comprehend. Barkmann *et al.* (2008) developed an ecosystem service approach through an extensive investigation of participant perception of hydro-logic ecosystems.

The developed approach in this research is similar to Barkmann *et al.* (2008) as multiple focus groups were conducted to define ecological endpoints from the ecological processes for two study sites. A featured difference of our CV survey is that in an attempt to inform participants about basic science models, participants were given an educational component regarding the physical and biological attributes of the study site that the ecosystem endpoints were derived from. The three ecological endpoints derived from focus group feedback and used in the CV exercise are (1) average

miles of surface water, (2) abundance of bird species classified by nest height and water dependence, and (3) the composition of Riparian vegetation classified by major vegetative species. The results of the CV surveys produce statistically significant WTP estimates for restoration activities in both river basins, with statistically significant WTP for preservation alternatives in the Upper San Pedro.

STUDY DESIGN

A traditional split sample approach is employed to value different policy scenarios for two river systems in the southwestern USA: (1) the San Pedro Riparian National Conservancy Area (SPRNCA) in southeastern Arizona and (2) the MRG in central New Mexico. In defining ecological endpoints for the two systems, a process similar to Boyd and Krupnick (2013) is followed. This process first defines the biophysical inputs that lead to a biophysical process that produces an output. After developing a suite of biophysical inputs, processes, and outputs, focus groups were conducted to identify the inputs and process that were perceived to be of most importance. A preliminary educational component was developed from focus group feedback that defined the ecological endpoints. This educational component was presented to a second set of focus groups to gather participant perceptions about the ecological endpoints prior to the survey instrument being implemented. This approach is summarized in Figure 1.

The initial stage, as shown in Figure 1, was to characterize the two ecosystems into a suite of biophysical inputs and processes. To develop this suite of information the different scientific disciplines worked collectively to characterize the two ecosystems. This is a crucial stage in defining ecological endpoints as it is important to ensure that the ecosystem is properly defined and described to participants in order to secure accurate ecosystem service values. The following sections provide background information on the two study sites with a description of how the ecosystem inputs and processes were presented to focus group participants to develop the ecological endpoints.

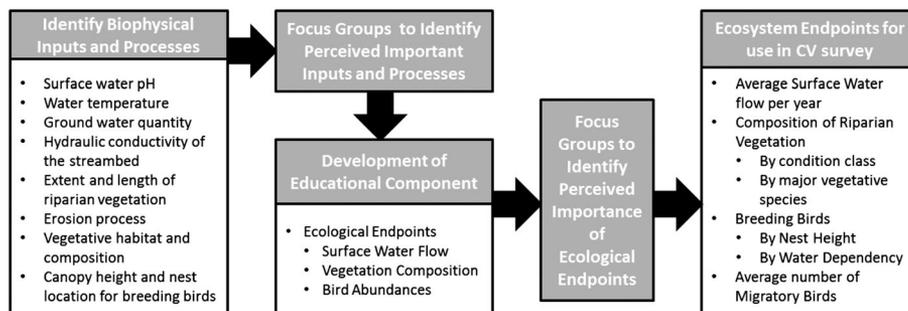


Figure 1. Defining ecosystem endpoints.

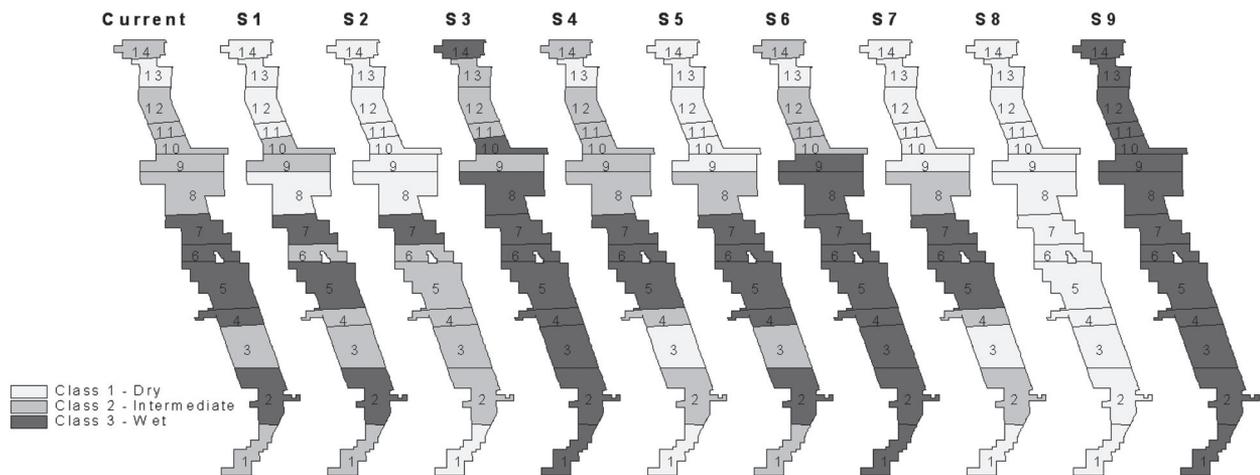
San Pedro Riparian National Conservancy Area (SPRNCA)

Flowing northward across the US Mexico border, the San Pedro River cuts through the desert of southeastern Arizona. On 18 November 1988, the US Congress designated 40 miles of the Upper San Pedro as a Riparian National Conservancy Area (SPRNCA). The primary purpose for this designation was to protect and enhance a rare remnant of the desert Riparian ecosystem, which once was a network of similar Riparian ecosystems throughout the southwestern USA. The SPRNCA contains nearly 57 000 acres of public land and is home to 84 species of mammals, 14 species of fish, 41 species of reptiles and amphibians, and over 100 species of breeding birds (Tellman and Huckleberry, 2009). In addition, the SPRNCA provides habitat for over 250 species of migrant and wintering birds travelling between temperate and tropical or sub-tropical regions (Tellman and Huckleberry, 2009).

Extensive human use of the Upper San Pedro River has led to groundwater depletion shifting the mixture of vegetation from historic cottonwood-willow (*Populus-Salix*) woodlands to *Tamarix* shrub lands (Stromberg, 1998; Lite and Stromberg, 2005). Due to the formation of the SPRNCA, the region has been passively restored but threats surrounding water use still exist in preserving this diverse ecosystem (Krueper *et al.*, 2003; Brand *et al.*, 2010;

Brand *et al.*, 2011). In the SPRNCA, ground and surface water are in high demand for the competing uses of municipal, agricultural, industrial, and Riparian ecosystem services (Stromberg *et al.*, 2006; Brand and Noon, 2011). Changes in the hydrology of the SPRNCA can end up in resultant changes in physiognomy, abundance, and the composition of Riparian vegetation (Pettit *et al.*, 2001; Stromberg *et al.*, 2006, 2009; Shaw and Cooper, 2008).

A research record over the last 20 years has led to substantial physical and biological science knowledge to develop a decision support system that allows for the prediction of different future groundwater scenarios for the SPRNCA displayed in Figure 2. These policy scenarios that allow for an understanding of the impact potential groundwater scenarios could have upon the composition of vegetation and bird abundance throughout the SPRNCA. The basic premise is that a change in groundwater availability creates a change in the composition of vegetation that leads to a change in the abundance of breeding and migratory birds throughout the SPRNCA (Brand *et al.*, 2011). These nine policy scenarios were developed using input from the Upper San Pedro Partnership, which is a consortium of 21 non-governmental organizations, a private water company, and local, state, and federal agencies (Richter *et al.*, 2009).



Current – Current Conditions of the SPRNCA	S1 – A 0.5 meter uniform decline in groundwater
S2 – A 1 meter uniform decline in groundwater	S3 – A 0.5 meter uniform increase in groundwater
S4 – Increased agricultural pumping near Palominas; new developments in areas of Palominas and Hereford	S5 – Increasing cone of depression in Sierra Vista, Ft. Huachuca, and Huachuca City with impacts toward the lower Babocomari
S6 – Large increases in groundwater due to recharge and conservation in Sierra Vista and Bisbee	S7 – combined from S4 and S5, representing effects of increased agricultural pumping and increasing cone of depression
S8 – Low extreme, river dries up	S9 – High extreme, river has surface flows throughout

Figure 2. Nine hydrologic scenarios and the current conditions for the 14 reaches of the SPRNCA.

Of the nine constructed scenarios, scenarios 1–3 illustrate the impacts of a uniform change in groundwater levels from current conditions through all sections of the SPRNCA. Scenarios 4–7 illustrate the impacts of spatially variable changes in groundwater levels as defined in Figure 2. Scenarios 8 and 9 represent extreme possible outcomes that are achieved through large changes in population growth rates and groundwater pumping rates. More detail on the development of these scenarios can be found in Brookshire *et al.* (2010). In each scenario, the conditions of each section of the river are described as either a wet, intermediate, or dry condition class. The wet condition class is defined as a section of the river that has consistent surface water flows with the major vegetative species being a cottonwood-willow forest, where the depth to ground water is less than 2.5 m. In the intermediate condition, class surface water flows are intermittent; roughly 60–90% of the year flows are present, with a mixture of cottonwood-willow and *Tamarix* species being present, depth to ground water is between 2.5 and 3.5 m. The dry condition class has surface water flow less than half of the year being dominated by *Tamarix* with isolated cottonwood snags and depth to groundwater being greater than 3.5 m.

Middle Rio Grande (MRG)

Located in central New Mexico, the MRG cuts through the desert landscape creating a Riparian ecosystem approximately 150 river miles in length. Historically, this ecosystem was dominated by woodlands of native cottonwood (*Populus fremontii*) and willow (*Salix gooddingii*) species (Crawford *et al.*, 1996). For millennia, this ecosystem was sustained by naturally occurring overbank floods that provided habitat to a diverse wildlife (Najmi *et al.*, 2005). In more recent decades, the Rio Grande's flow regime has become highly regulated through an engineering system that includes multiple dams and diversion channels, allowing for the invasion of exotic vegetation such as salt cedar (*Tamarix* spp.) and Russian Olive (*Elaeagnus angustifolia*), leading to fire becoming a dominant force in shaping this Riparian ecosystem (Crawford and Grogan, 2004). Recent restoration efforts in the MRG have focussed upon mechanically thinning non-native understory vegetative species in an effort to decrease fire risk (Najmi *et al.*, 2005).

Employing a previously developed model to a 128-km segment of the MRG that had 12 vegetation composition–structure types and five guilds of birds (canopy, mid-story, understory, water-obligates, and spring migrants), four management options within seven management scenarios applied across the MRG as displayed in Figure 3 were created. These scenarios allow for an exploration of the impact that different clearing regimes of the woody

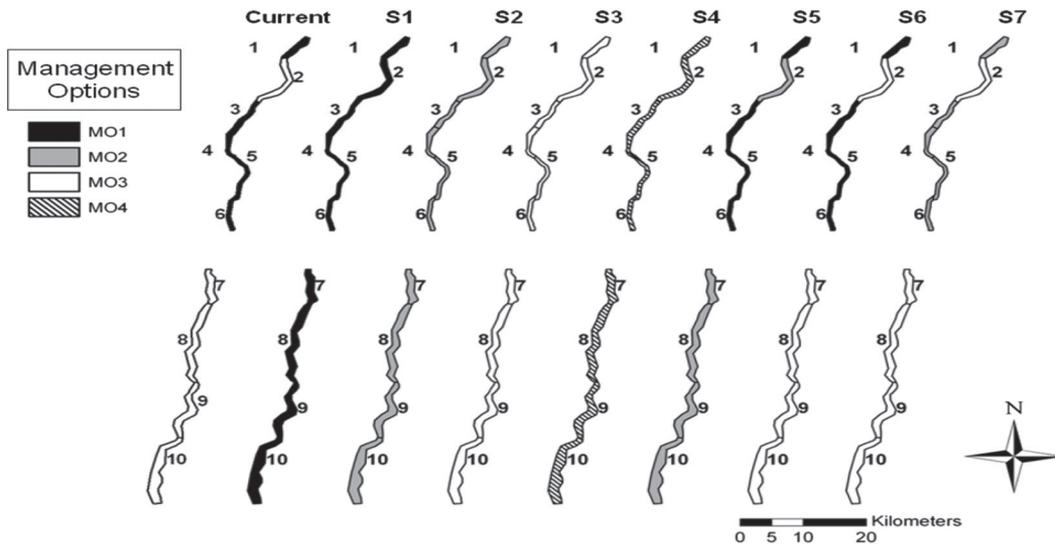
understory along the MRG could have upon the composition of vegetation and bird abundance (Brand *et al.*, 2013). The basic premise is that changing vegetation composition, through management options, alters the composition of vegetation and in turn changes abundances of breeding and migratory bird guilds.

Sections of the MRG were classified into four different management options based upon active management activities. Management Option 1 incorporates intensive mechanical clearing of all native and non-native understory to reduce the risk of fire. Management Option 2 applies selective hand-thinning of the non-native understory while retaining the native understory in an effort to reduce fire risk while maintaining native vegetation. Management Option 3 involves no clearing activities in the next 5–10 years creating a dense understory. Management Option 4 represents the projected future composition of the MRG in the absence of active management, allowing for the natural succession process to occur.

Applying these management options across the MRG, eight hypothetical scenarios were developed in consultation with the Middle Rio Grande Conservancy District. Scenarios 1–4 are a representation of applying each of the four management options across all reaches respectively. Scenarios 5–7 are three scenarios where a mixture of the management options are applied based upon if the reach is in a rural region versus an urban region. For instance, Scenario 5 in Figure 3 applies Management Option 1 to the urban reaches 1 and 3–6, while Management Option 2 is applied to the rural reaches of 2 and 7–10. Scenario 6 applies Management Option 1 to the same urban reaches, while Management Option 3 is applied to the rural reaches, and Scenario 7 applies Management Option 2 to the urban reaches, while Management Option 3 is applied to the rural reaches. Unlike the SPRNCA, the MRG is primarily driven by potential mechanical alterations to the vegetative structure and composition rather than through ground water pumping alterations.

Focus groups

After the biophysical inputs and processes were identified and scenarios were developed for the two river systems, two sets of focus groups were conducted to develop the ecological endpoints to be employed in the CV survey. The first set of focus groups presented participants with the condition class model for the SPRNCA, and the management options model for the MRG listing multiple biophysical inputs and processes displayed in Figure 1. A focus group facilitator led a group discussion about the information presented to obtain written and oral feedback about which of the inputs and processes were important in defining ecosystem endpoints. These inputs and processes included the average cubic feet per second at different river



Current – Current Conditions of the MRG	S1 – Mechanical understory clearing in cottonwood stands
S2 – Selective hand-thinning of the understory of cottonwood stands	S3 – no clearing that allows dense native and non-native understory to return or remain in the next 5-10 years
S4 – application of “no management” over the next 50-75 years, assumes that most cottonwood stands would senesce and be replaced by shrub lands	S5 – S1 is applied in reaches 1 and 2 to reduce fire risk near city areas, S2 applied in other reaches.
S6 – S1 is applied in reaches 1 and 2 to reduce fire risk near city areas, S3 applied in other reaches	S7 – S2 applied in reaches 1 and 2 to reduce fire risk while attempting to improve bird habitat, S3 applied in other reaches

Figure 3. Seven management options and the current conditions for 10 reaches of the MRG.

gages, the depth to groundwater for each section of the rivers, and the average length of the wetted stream throughout the year. Vegetation features such as the different vegetative species, the root depth for each species, and which species were native versus non-native to the region were presented. The wildlife supported by the systems focussed upon the avian species. Here, the different types of breeding bird species and the types of vegetation required to build their nests for breeding purposes were presented.

Feedback from the first set of focus groups aided in determining which of the biophysical processes were important in developing biophysical outputs or ecological endpoints as Boyd and Krupnick (2013) define. This feedback resulted in the development of a categorization of three ecological endpoints: (1) average miles of surface water flow, (2) composition of Riparian vegetation, and (3) abundance of avian species by breeding habits and water dependency. In addition, feedback from the focus groups resulted in the average number of migratory birds to be included as an ecological endpoint.

A second set of focus groups was conducted to gather written and oral feedback about the developed ecological endpoints including feedback about the presentation and organization of an educational component to inform survey

participants about basic science models. During this set of focus groups, a facilitator led a discussion to gather information about different graphics and tables to determine which of the presentation formats was desirable. In addition, focus group participants were given a copy of the survey, and feedback was solicited on its layout and different presentation formats. The preferred presentation format to display the ecological endpoints for each river system is displayed in Figure 4.

The left pane of Figure 4 displays the current conditions for the SPRNCA, while the right pane displays the current conditions for the MRG using the three developed ecological endpoints. At the top of each pane, the average miles of surface water is listed along with the average number of migratory birds. The middle graphic displays the number of breeding birds based upon two classification systems: (1) the location of where nests are built (i.e. high in the vegetative canopy, in the middle of the vegetative canopy known as ‘high shrub’, or at the bottom of the vegetative canopy known as ‘low shrub’) and (2) whether the breeding birds are dependent upon the immediate presence of surface water (i.e. the great-blue heron or black-bellied whistling fuck) or if they are not dependent upon the immediate presence of surface water. The final graphic displays the vegetative composition and the

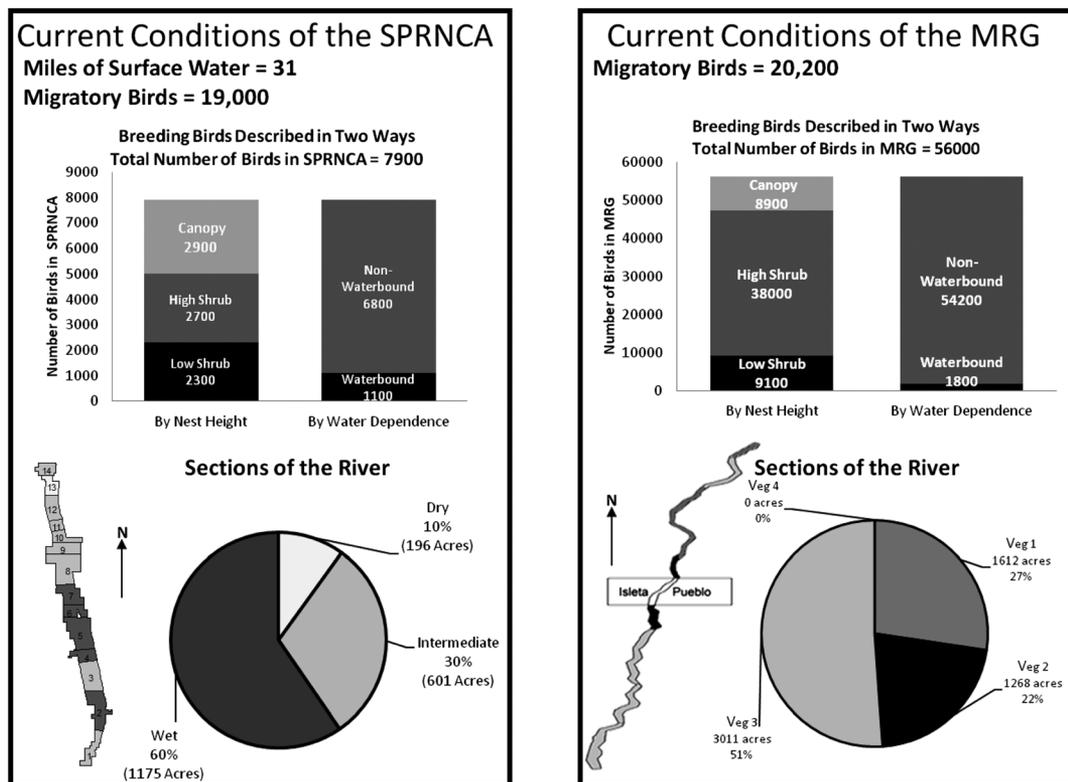


Figure 4. Summary of the current conditions for both the MRG and SPRNCA.

location of each of the different vegetative classes as defined by the condition class model for the SPRNCA and the management options model for the MRG.

Survey design and implementation

Final versions of the two surveys ended up with six main sections. The first section presented an introduction to the study site (i.e. history and location) and an explanation of possible future scenarios. The second section presented a detailed explanation of each of the main attributes for the study site: (1) water availability, (2) vegetation composition and the linking of vegetation with water availability, and (3) bird abundances presented as both breeding birds by nest height and by surface water dependency and migratory birds. The third section presented the current conditions for both study sites displayed in Figure 4. Section four provided an explanation of proposed water use programs for the SPRNCA and mechanical management options for the MRG, while the fifth section elicited responses to the CV question. Finally, section six collected demographic information for each respondent (e.g. gender, age, and mean household income).

Using the nine groundwater scenarios for the SPRNCA and the seven management options for the MRG, the survey versions were designed to elicit both WTP to obtain positive increments (restoration) and WTP to avoid

decrements (preservation) for each study site respectively. For the SPRNCA, two of the nine policy scenarios depicted in Figure 2 were employed in the CV exercise, S6 to represent a potential restoration alternative and S4 to represent a potential preservation alternative. These two scenarios were chosen based upon feedback from focus group participants. Scenarios 1–3 are uniform decreases in groundwater levels throughout the SPRNCA, which many of the focus group participants did not believe were viable alternatives. Scenarios 8 and 9 are extreme outcomes for the SPRNCA, which focus group participants also did not believe were viable alternatives. Scenario 6 is the only scenario where groundwater recharge is conducted, while scenarios 4, 5, and 7 result in a decline in groundwater at targeted locations. Focus group participants selected scenario 6 as a realistic restoration scenario, while scenario 4 was viewed as the most realistic preservation scenario or decremental scenario that participants would like to avoid.

For the MRG, two of the seven management options depicted in Figure 3 are employed in the CV exercise, S6 to represent a potential restoration alternative and S5 to represent a potential preservation alternative. Because scenarios 1–4 uniformly apply the four management options to the MRG, many of the focus group participants did not believe that they were a viable alternative. Scenario 6 was viewed as the most realistic alternative by focus group participants as this management option is the

'current restoration efforts' ongoing in the MRG. Scenario 5 was viewed as the most realistic preservation scenario or decremental scenario that participants would like to avoid. By representing potential restoration and preservation alternatives to each study site, we are able to calculate WTP values for both positive (restoration) and negative (preservation) changes. The parameter values used to populate the current conditions along with the two future scenarios for the CV question are found in Table I.

The parameter values presented in Table I define the level of each attribute for the ecological endpoints that were developed and displayed in Figure 4. For example, the first two lines of Figure 4 report the current average miles of surface water and migratory birds for each river system. The first two lines of column 2 in Table I report increases in the miles of surface water and migratory birds, while the first two lines of column 3 report decreases in these attributes. To portray these parameter values, participants in the CV surveys were presented the current conditions of the respective river system from Figure 4 with an identical pane of conditions using the parameters for each attribute from the second and third columns of Table I. Each participant only received a CV question about their WTP for restoration (S6 and S6) or preservation (S4 and S5) for the SPRNCA and MRG respectively.

The procedure outlined by Dillman (2000) was employed to implement internet and mail surveys to

residents in Arizona for the SPRNCA and New Mexico for the MRG. A cluster sampling procedure was employed using zip codes in the states to create the sampling clusters. A representative sample based on these zip code clusters was purchased from a commercial sampling firm that produced 4500 potential respondents for Arizona residents and 3500 for New Mexico. Potential respondents were contacted four times over the course of eight weeks inviting them to participate in the survey. Each participant was provided a web address with a unique username and password to access the survey along with a paper version of the survey that could be filled out and returned via standard US mail. For the SPRNCA survey, 399 online responses were received and 374 for the MRG survey. The paper version of the survey yielded 138 and 176 responses for the SPRNCA and MRG respectively. In addition, 474 potential respondents were eliminated because of bad addresses, and 14 potential respondents were eliminated as they had deceased. This led to a response rate of 12.7 and 16.7% for the SPRNCA and MRG surveys respectively.

ESTIMATION PROCEDURE

Using the theoretical model explained by Hanemann *et al.* (1991), a maximum likelihood model for the single-bounded mean WTP is estimated. A single-bounded contingent valuation method survey asks an individual a

Table I. Attribute values.

	SPRNCA		
	Current conditions	S6 (restoration)	S4 (preservation)
Water (miles)	31	35	27
Migratory bird	19 000	19 700	16 200
Canopy birds	2900	3100	2300
High shrub birds	2700	2700	3100
Low shrub birds	2300	2300	2100
Water birds	1100	1200	700
Non-water birds	6800	6900	6800
Wet acres	1175	1656	741
Intermediate acres	601	183	527
Dry acres	196	133	704
		MRG	
Understory birds	9100	10 200	4800
Mid-story birds	38 000	43 700	34 300
Canopy birds	8900	10 700	9000
Water-bound birds	1800	1900	1600
Non-water birds	7100	8800	7400
Migratory birds	20 200	23 800	16 200
Veg. type 1 acres	1612	0	1843
Veg. type 2 acres	1268	1870	3781
Veg. type 3 acres	3011	4021	267
Veg. type 4 acres	0	0	0

yes/no question whether they are WTP for increments (WTP to avoid decrements), some given amount, \$B, to obtain an improvement (or to avoid decrements) in the SPRNCA or MRG. The probability that a respondent answers ‘no’ or ‘yes’ is represented respectively, by

$$p^n(B) = F(B; \theta), \tag{1}$$

$$p^y(B) = 1 - F(B; \theta), \tag{2}$$

where $F(B; \theta)$ is a statistical distribution function with parameter vector θ . As discussed by Hanemann (1984), this statistical model can be interpreted as a utility maximization response within a random utility context, where $F(B; \theta)$ is the cumulative density function of the individual’s true maximum WTP as utility maximization implies:

$$\Pr\{NotoB\} \Leftrightarrow \Pr\{B > \text{maximumWTP}\}$$

$$\Pr\{YestoB\} \Leftrightarrow \Pr\{B \leq \text{maximumWTP}\}$$

Focussing on the maximum likelihood estimator, consider N participants in the single-bounded survey and let B_i^s be the bid offered to the i th participant. The log-likelihood function is given as

$$\begin{aligned} \ln L^s(\theta) &= \sum_{i=1}^N \{d_i^y \ln p^y(B_i^s) + d_i^n \ln p^n(B_i^s)\} \\ &= \sum_{i=1}^N \{d_i^y \ln [1 - F(B_i^s; \theta)] + d_i^n \ln F(B_i^s; \theta)\} \end{aligned} \tag{3}$$

where d_i^y is 1 if the i th participants response is yes 0 otherwise, while d_i^n is 1 if the i th participants response is no 0 otherwise. The maximum likelihood estimator denoted as $\hat{\theta}^s$ is the solution to the equation $\frac{\partial \ln L^s(\hat{\theta}^s)}{\partial \theta} = 0$. This estimator is consistent and asymptotically efficient. Because of this, the variance–covariance matrix of $\hat{\theta}^s$ is given by the Cramer–Rao lower bound

$$V^s(\hat{\theta}^s) = \left[-E \frac{\partial^2 \ln L^s(\hat{\theta}^s)}{\partial \theta \partial \theta^2} \right]^{-1} = I^s(\hat{\theta}^s)^{-1} \tag{4}$$

where $I^s(\hat{\theta}^s)^{-1}$ is the information matrix.

The maximum likelihood estimator is found using the statistical package STATA 11. The WTP estimates are obtained using the ‘singleb’ command in STATA 11 to produce mean WTP values and standard errors.

RESULTS

The administered surveys yielded demographic characteristics and visitation patterns for each of the two study sites as well as an estimate of WTP for restoration and preservation alternatives. The focus of this research was to develop a set of ecological endpoints to generate welfare estimates for ecosystem services. As such, we present

background characteristics for the survey respondents in order to provide insight to the WTP estimates.

Demographics and visitation

In addition to gathering demographic information such as age, gender, household income, and educational attainment, we asked three questions to understand if participants had ever visited the site, if they planned to visit the site in the future, and finally, if they labelled themselves as a ‘birder’. Table II presents the results of these three questions for the two study sites as well as summaries of respondents’ age, gender, household income, and college degree status. The reason for asking these three additional questions is to provide insight into what type of WTP values are estimated. For instance, an individual’s WTP for the good in question could be categorized into a use value (i.e. the utility derived from using the good in question) or a series of non-use values (i.e. the value assigned to a good that an individual has not used but may plan to use in the future). Four types of non-use values exist in the economics literature: (1) option value, the value an individual places on a good to have the ability to use it in the future; (2) bequest value, the value an individual places on a good to pass it to future generations; (3) existence value, the value an individual derives from knowing the good exists; and (4) altruistic value, the value derived from knowing that the good exists so that others may make use of the good (refer to Brookshire *et al.*, 1983; Walsh *et al.*, 1984). These questions allow for insight as to what type of value these ecosystem services are providing to society, consumptive use (use value) or non-consumptive use (non-use value).

The first of these questions asked participants ‘have you ever visited the SPRNCA or the MRG?’ for each of the respective surveys. For the SPRNCA surveys, less than a third of the respondents had visited the site, whereas for the MRG surveys roughly two thirds of respondents had visited the site. This could be an indication that the WTP values for preservation and restoration in the SPRNCA could be a non-use value as the majority of the participants had not visited the site at the time of participation, whereas the majority of participants in the MRG had visited the site meaning their WTP values could be interpreted as a use value rather than a non-use value as they have had direct contact or use of the ecosystem.

The second question asked participants ‘do you plan to visit the SPRNCA or the MRG in the future?’ For the SPRNCA, an equal split of participants answered that they have plans to visit versus that they do not have plans to visit. For the MRG, roughly two thirds of the participants have plans to visit the MRG in the future, while one third do not have plans to visit in the future. While the SPRNCA’s WTP results could be viewed as a non-use

Table II. Demographic characteristics.

		SPRNCA		RG	
		Preservation	Restoration	Preservation	Restoration
Have visited	Yes	104 (28.6%)	120 (32.5%)	253 (66.6%)	276 (70.4%)
	No	259 (71.4%)	249 (67.5%)	127 (33.4%)	116 (29.6%)
Plan to visit	Yes	172 (48.9%)	177 (49.6%)	248 (65.8%)	264 (69.3%)
	No	180 (51.1%)	180 (50.4%)	129 (34.2%)	117 (30.7%)
Birder	Yes	106 (28.5%)	99 (26.0%)	102 (25.8%)	143 (33.9%)
	No	266 (71.5%)	282 (74.0%)	293 (74.2%)	279 (66.1%)
College degree	Yes	228 (60.3%)	232 (59.3%)	234 (57.4%)	249 (58.0%)
	No	150 (29.7%)	159 (30.7%)	174 (32.6%)	180 (32.0%)
Male		265 (71.2%)	286 (73.9%)	299 (74.2%)	301 (71.3%)
Female		107 (28.8%)	101 (26.1%)	104 (25.8%)	121 (28.7%)
Age		59.99 years	61.79 years	59.93 years	60.09 years
Household income		\$67,724.87	\$62,768.54	\$63,443.63	\$67,272.73

value from question 1, it is not as clear which type of non-use value this is from as half the participants plan to visit the site (i.e. option value), while the other half do not plan to visit (i.e. bequest, existence, or altruistic value). These participants' values could be derived from their desire to bequest the site to future generations, knowing the ecosystem exists or knowing that others are receiving benefit from using the ecosystem. For the MRG, Table II demonstrates a fairly consistent pattern of responses for question 2 as with question 1. Roughly two thirds of the respondents have plans to visit the MRG with two thirds of respondents stating they had already visited the site; WTP for this system could be interpreted as a use value.

The final question asked each participant if they identified themselves as a birder, an individual that observes bird species as a recreational activity. The responses to this question are similar for both sites as less than a third of the respondents reported that they are a birder. This question was included as the SPRNCA is often identified as an excellent Riparian habitat to observe bird species with roughly half of the known breeding bird species in North America being present. Because a small proportion of the responses are from birders, these results provide little insight into the difference in use values based upon ecosystem use for birding versus other recreational activities.

The remaining demographic questions demonstrate nearly equal educational levels across the surveys with roughly 60% of respondents stating they had obtained a bachelor's degree or higher for their education level. The average age of respondents was 60 years, with 70% of the respondents being male and average household income being between 60 and 70 K/year. While demographic characteristics for the different survey types are similar, the responses to the first three questions lend insight into the type of WTP values.

WTP estimates

Using the estimation procedure outlined in section three, WTP estimates are produced for preservation and restoration alternatives for the two study sites shown in Table III. The estimates for preservation and restoration are found to be statistically significant and positive for the SPRNCA with only the restoration scenario being significant for the MRG. A unique finding for the SPRNCA estimates is that WTP to preserve the SPRNCA is larger in magnitude than WTP for further restoration, although this result cannot be inferred with great confidence as the standard errors are large enough to include the mean WTP results for both preservation and restoration scenarios in a confidence

Table III. WTP estimates.

	SPRNCA estimates	
	Preservation	Restoration
Mean WTP	52.42* (15.98) ^a	49.71** (26.82)
Observations	378	391
	MRG Estimates	
Mean WTP	-58.63 (53.65)	61.88* (25.25)
Observations	408	429

**Denotes significant difference from zero at the 10% level.

*Denotes significant difference from zero at the 5% level.

^a Numbers in parenthesis are standard errors.

interval. Since the formation of the SPRNCA in 1988, more than 2 years worth of restoration has occurred on the San Pedro River to produce the current conditions. If it could be inferred that respondents are WTP slightly more to preserve the SPRNCA, this could mean that respondents are satisfied with current restoration activities. However, further research is necessary in order to have confidence in this inferred result as the results of this study cannot infer this result because of the magnitude of the standard errors. Combining the result of Table III with Table II, the WTP results could be interpreted as a non-use value as the majority of respondents had not previously visited the site.

For the MRG, results are slightly mixed as statistically significant WTP results for restoration alternatives are obtained, whereas the estimates for preservation alternatives are insignificant and negative. This finding of insignificant WTP for preservation alternatives may stem from the fact that the educational component of the MRG survey was written from the standpoint of direct manipulation of the vegetation classes by human management options (e.g. mechanical clearing) unlike the indirect impacts on the vegetative system because of hydrologic changes for the SPRNCA. This may have biased the MRG surveys so that participants did not believe that negative changes are realistic leading to respondents not truthfully answering the CV question. From the insights in Table II, these WTP estimates for restoration efforts could be interpreted as a use value as the majority of the respondents had previously visited this section of the Rio Grande.

DISCUSSION

The first step in obtaining economic values for ecosystem services is to develop ecological endpoints that can be used to derive welfare estimates. While the results of the CV surveys do produce statistically significant WTP values for

the derived ecosystem endpoints, there are some limitations in interpreting these results. For instance, the developed ecological endpoints have a suite of attributes that describe current and future conditions for each river system (refer to Figure 4 and Table I). The CV method employed in this research is a dichotomous choice question that cannot yield marginal WTP values for each of the attributes as the attribute levels are invariant across the sample. The bid amount is the only attribute that varies across the two samples using the bid array developed by Kirchoff (1994). More recently, Choice Experiments have been employed that allow for the variation of attributes within a sample so that marginal WTP values can be derived for each of the attributes (refer to Hanley *et al.*, 2001). While a Choice Experiment could produce marginal WTP values for the attributes limitations do exist in this method as the attributes need to each vary and they cannot be co-linear (refer to Huber and Zwerina, 1996). In valuing ecosystem services, this co-linear relationship may be unavoidable as water availability and vegetation composition are closely related with vegetation and avian abundances and densities depending upon the quantity of surface and ground water in these semi-arid systems. Further research should investigate the differences of the Choice Experiments and CV methods in the context of ecosystem services that have dependencies between the ecological endpoints.

In addition, the demographic characteristics of this sample are primarily older males that are not representative of the most recent census data for Arizona and New Mexico (www.census.gov). For Arizona, 15.4% of the population is over the age of 65 with 14.7% of New Mexico residents being over 65, while the sample yielded an average age of 60 years. Gender is fairly even in both states with 49.7% male in Arizona and 47.6% male in New Mexico from the US Census, while 70% of the respondents to the survey were male. Sample demographics report that roughly 60% of the respondents have a bachelor's degree or higher. The US Census reports that 26.9% of Arizona residents and 25.8% of New Mexico residents have a bachelor's degree or higher. Finally, the sample reports an average household income of 60–70 K/year with the US Census reporting median income of 50 K for Arizona and 45 K for New Mexico. While the sampling procedure sought to create representative clusters based upon zip codes in the two states, when compared with the US Census report, the respondents in this data set do not have representative demographic characteristics. The results of this study should be interpreted with some caution if they are to be implemented in a policy context as they may not be representative of the population WTP for preservation and restoration alternatives in these ecosystems. A larger sample size is necessary to make sure that all of the sample clusters are represented based upon demographic characteristics.

Including three questions to identify if respondents had visited, if they plan to visit and if they identify themselves as a birder provides insight into the type of ecosystem value estimated. Finding that the majority of individuals have visited and have plans to visit the MRG again, versus a smaller group having visited or having plans to visit the SPRNCA provides insight into whether or not use and non-use values exist. Since Krutilla's (1967) seminal article on conservation and environmental values, it has long been debated if non-use values are relevant in policy decisions. Less than a third of the respondents in this survey have had direct interaction with the SPRNCA, and statistically significant WTP results are derived when these non-users were asked if they were WTP to conduct preservation or restoration activities. This lends empirical evidence to this debate that non-use values do exist in society and further research is necessary to determine if these values are the result of the desire to have the option to visit, the ability to bequest, or the knowledge that the ecosystem exists for others to use.

The finding that respondents are not WTP to preserve the MRG may stem from the fact that the respondents did not believe that preservation of the system would be allowed as currently the MRG has ongoing restoration activities with future plans to continue these activities. Recently, Carson and Groves (2007) postulated that if a researcher wants to obtain unbiased WTP values, participants must believe or perceive that the policy in question will be binding. It may be that the participants did not perceive the preservation alternative as realistic and binding, resulting in insignificant estimates. Further, as restoration efforts in the MRG are currently ongoing, it may be that the current conditions of the MRG have not produced enough of the good to satisfy survey respondents resulting in statistically significant mean WTP to continue restoration efforts. Further research is necessary to understand why significant findings are occurring for the restoration alternatives but not for preservation alternatives in the MRG.

CONCLUSIONS

Working as a collective team of natural and social scientists, this paper developed a set of ecological endpoints to value freshwater ecosystems in the semi-arid southwestern USA. While this approach may be difficult, we maintain that it is necessary for the disciplines to work together to quantify ecological processes if accurate values for non-marketed goods and services are to be obtained as Boyd and Banzhaf (2007) have proposed. A necessary step in developing ecosystem endpoints is soliciting feedback through focus groups in order to understand which of the biophysical inputs and processes are important in producing outputs that society derives value from. This step

ensures that the focus of the valuation exercise is placed on the ecological endpoints rather than biophysical inputs and processes.

Valuation exercises should not only focus on the benefits that are derived from restoring ecosystems but also focus on preserving ecosystems. As the Millennium Ecosystem Assessment found, 60% of global ecosystems are being degraded and it might well be that the first step in restoring these ecosystems is to work towards preserving the current conditions of the system. In eliciting WTP values, it is important to note that the results of this research provide insight into the debate that non-use values may exist for ecosystem services. Future studies should acknowledge this existence, and information from participants should be solicited to determine the type of WTP value participants that are reporting.

Defining and valuing ecosystem services will continue to be a rapidly evolving debate in the literature. In line with Boyd and Banzhaf (2007), we argue that it is important to derive a set of ecological endpoints that can clearly relate the biophysical processes and inputs of an ecosystem to society to derive economic welfare estimates. Further, as Fisher *et al.* (2009) highlight, ecosystem services are typically a function of complex biophysical interactions and society does not have enough information about these interactions to properly make decisions about their future. As such, it is necessary for the science disciplines to clearly communicate their findings with the public and decision makers in order for informed public choices to be made. In order to have better environmental policy decisions, it is necessary to develop a communicative structure between the disciplines. This research is a demonstration of how ecological endpoints can be developed through interdisciplinary work and how basic science models can be captured in this process so that participants can make informed choices.

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