

# Integrated Modeling and Ecological Valuation: Applications in the Semi Arid Southwest<sup>1, 2</sup>

David S. Brookshire<sup>3</sup>, L. Arriana Brand, Jennifer Thacher, Mark D. Dixon, Karl Benedict, Juliet C. Stromberg, Kevin Lansey, David Goodrich, Molly McIntosh, Jake Grandy, Steve Stewart, Craig Broadbent and German Izon

May 17, 2007

## I. Introduction

Conservation of freshwater systems is critical in the semi-arid Southwest where groundwater and flood regimes strongly influence the abundance, composition, and structure of riparian (streamside) vegetation. At the same time these systems are in high demand for competing human use (Stromberg et al. 2007, Alley et al. 2002). To address this conflict, natural scientists must evaluate how anthropogenic changes to hydrologic regimes alter ecological systems. A broad foundation of natural science information is needed for ecological valuation efforts to be successful. The goal of this research is to incorporate hydrologic, vegetation, avian, and economic models into an integrated framework to determine the value of changes in ecological systems that result from changes in hydrological profiles.

---

<sup>1</sup>This research is supported by the U.S. Environmental Protection Agency, "Integrated Modeling and Ecological Valuation," EPA STAR GRANT Program #2003-STAR-G2 and 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 with in kind contributions from the U.S. Department of Agriculture Research Service, Hawks Aloft Inc and The Nature Conservancy. We would like to thank, John Loomis and Bonnie Colby who participated in a workshop in Albuquerque 2006 and offered significant insights and suggestions to the overall survey design.

<sup>2</sup> Presented at the USEPA "Valuation for Environmental Policy: Ecological Benefits" workshop April 23, 24, 2007 in Washington D.C. Comments are welcome. Please send to David Brookshire (brookshi@unm.edu)

<sup>3</sup> Respectively, Professor of Economics and Director of the Science Impact Laboratory for Policy and Economics, University of New Mexico (UNM); Research Associate, Sustainability in semi-Arid Hydrologic Riparian Areas, University of Arizona (UA); Assistant Professor of Economics (UNM); Assistant Professor of Biology, University of South Dakota; Senior Research Scientist, Earth Data Analysis Center, (UNM); Associate Professor, School of Life Sciences, Arizona State University; Professor of Civil Engineering, (UA); Research Scientist, US Department of Agriculture; Attorney at Law and Bilingual Mediation and Facilitation, NM; Middle Rio Grande Conservancy District, Research Scientist, Sustainability in semi-Arid Hydrologic Riparian Areas, (UA), Research Assistant, (UNM); and Research Assistant, (UNM).

We have developed a hydro-bio-economic framework for the San Pedro River Region (SPRR) in Arizona that considers groundwater, stream flow, and riparian vegetation, as well as abundance, diversity, and distribution of birds within a protected area encompassing the San Pedro Riparian National Conservation Area (SPRNCA). In addition, we are developing a similar framework for the Middle Rio Grande of New Mexico (MRG). Distinct valuation studies are being conducted for each site with benefit-transfer tests to be conducted between the two sites. This research is novel in that it provides much more detailed scientific information for economic valuation models than is typically available

In the absence of integrated science information, stated-preference valuation studies are typically must rely on vague program descriptions and imperfect measures of the change in resource quality or quantity. The lack of a scientific foundation for economic valuation studies typically occurs either because (1) targeted scientific research on the topic of interest is lacking, or (2) scientific studies that do exist have not been adequately designed to directly inform valuation questions. Ideally, existing scientific information should provide forecasts for the area of interest, contain well-defined timescales, and speak in terms that are relevant and understandable to the lay public. This study attempts to address these issues through use of an integrated scientific/economic framework. The research team includes hydrologists, ecologists, ornithologists, geospatial geographers, facilitators, and economists, most of whom are centrally involved in varying degrees with research projects in both the SPRR and the MRG.

There are five research components for this project: (1) scenario specification and the hydrologic model, (2) the riparian vegetation model, (3) the avian model, (4) methods for displaying the information gradients in the survey instrument, and (5) the economic framework. As such, our modeling framework begins with the identification of factors that influence spatial

and temporal changes in riparian vegetation on the two rivers. For the SPRR this is principally through impacts on the availability of surface water and groundwater, while in the MRG the impacts are through regulation of flooding and human restoration activities. We use the construct of “current conditions” as a basis for making spatial predictions of vegetation change and avian populations in both river systems through linked modeling frameworks. This framework utilizes the best available information through the direct focus on science-based linkages between flow regimes, habitat quality, birds, and human values.

The goal of this paper is to provide a brief overview of the research project to date and discuss some of the issues that have been encountered in designing an integrated framework for each river system. In addition we broadly discuss issues relating to the workings of an interdisciplinary team, issues associated with defining appropriate attributes to be valued based on the scientific information available as well as how the definition of the attributes might change depending upon the goals of the valuation exercise.

## **II. Study Areas**

This project required the added complexity of selecting study areas based on natural science considerations in addition to demographic and socio-economic concerns with selecting a benefit transfer site. It was necessary, from the science perspective, to restrict the transfer site to a region having similar physical and ecological conditions to the SPRR; thus our focus was on lowland (<5,000 feet), semi-arid, Southwestern riparian vegetation. This provides sites where conflicts between human use and riparian needs are most pronounced, visitation characteristics are similar, and riparian vegetation in the recent past (i.e. past century) was historically dominated by cottonwood, willow and mesquite. On each river, environmental stresses (e.g. groundwater depletion, altered flood regimes) have led to partial replacement of these species by

non-native species better suited to the effects of anthropogenic change, specifically stands of salt cedar or Russian olive. Further, given the types of data required for the valuation exercise, we were also limited by areas for which appropriate datasets (e.g. vegetation maps, bird transect data) were available.

Two study areas for this project were selected based on both natural and social science concerns. The SPRNCA in southern Arizona encompasses an approximately 40-mile stretch of

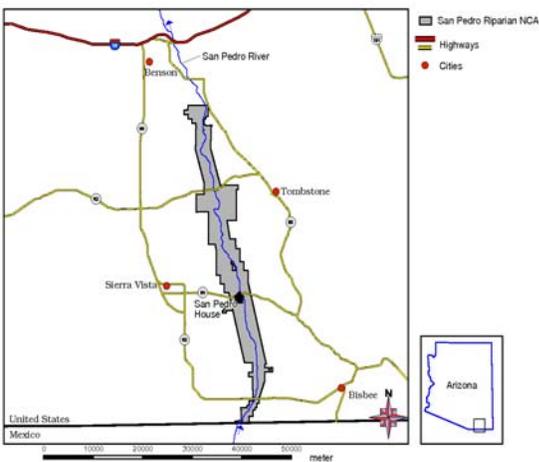


Figure 1: SPRR and SPRNCA

the San Pedro River between the U.S.- Mexico border and St. David, Arizona. The San Pedro flows north from Cananea, Mexico, enters the U.S. near Sierra Vista, and eventually reaches the Gila River, a tributary to the Colorado River (Figure 1). The San Pedro is a free-flowing river containing stretches of gallery riparian forest and represents an

extremely important semi-arid flyway. The SPRR

provides critically important habitat for resident, breeding, and migratory birds, but may be threatened by groundwater decline due to pumping of the regional aquifer. Over 400 bird species have been recorded in the SPRR; more than 200 of these are neo-tropical migrants (Krueper 1999).



Figure 2: Middle Rio Grande

The MRG covers the area from Cochiti

Dam (North of Albuquerque) to the San Acacia gage (above Elephant Butte reservoir). The

study area is approximately 140+ miles of river and includes the Rio Grande State Park, located in the Albuquerque vicinity (Figure 2). As in the SPRR, the riparian system is essentially a wooded riparian area (bosque). Even though there have been serious impacts on the riparian corridor through agricultural activities and urban development, it remains a biologically diverse community in the Southwest, providing a wealth of habitat for breeding, wintering, and migrating birds.

### **III. Overview of Project Components**

#### **a. Ecosystem Alteration Drivers, Decision Support Frameworks, and Scenarios**

Extensive human use of dryland rivers has resulted in many changes to their biota. For example, on parts of the SPRR groundwater depletion and overgrazing by livestock have contributed to shifts from cottonwood-willow (*Populus-Salix*) forests to *Tamarix* shrub lands (Stromberg 1998; Lite et al. 2005). The riparian ecosystem on the MRG has been impacted by flood control facilities, river channelization, land clearing, and agricultural activities. More recently, mechanical removal of introduced invasive species, motivated by both aesthetics and fire control, has influenced vegetation patterns in the MRG. Significant research effort has been allocated toward understanding the impacts of groundwater pumping on the SPRR biota and developing policy options that could be used to mitigate the impacts of groundwater pumping. Since agricultural activities have largely been eliminated from the SPRNCA region, the focus on policy options falls into four principal categories:

- 1) Infrastructure changes: changing the location of subdivisions and groundwater wells or recharge basins in order to reduce groundwater declines near the river;
- 2) Water augmentation: increasing the amount of water in the basin via inter-basin transfers;
- 3) Water conservation: decrease the consumption in the region through regulations and incentives;

4) Combination of all of the above

A Decision Support System (DSS) has been developed with the aid of systems dynamic modeling software (Tidwell et al., 2004 as an illustrative application of a DSS) by the San Pedro Partnership to provide the basis for understanding the impacts of alternative policy decisions and to identify the effectiveness of alternative water conservation measures for the Upper SPRR (Sumer and Lansey, 2004; Ritcher 2006<sup>4</sup>). The DSS, designed with the aid of systems dynamic modeling software, incorporates a USGS groundwater model, surface water supply, groundwater storage, and residential/commercial water uses. It allows temporally and spatially variable future population growth and associated water consumption. Each policy measure or combination of policies can be simulated for a 50 year period or less. The impacts of activities such as groundwater pumping can be determined spatially relative to specific river reaches.

Our research places additional demands upon the DSS, particularly the need to understand groundwater levels as well as changes in riparian vegetation with more spatial and temporal precision than is needed by SPRR water managers. Because the DSS is funded primarily by other entities, the more sophisticated features that this research requires can only be incorporated into major revisions of the DSS.

While operational, the DSS is still undergoing development. Additional features such as the condition class model, upon which much of this research is based, are being added to each new version of the model. Because the current version of the DSS does not include the condition class model to generate vegetation changes, we relied upon scientists' (D. Goodrich, personal communication) best estimate of the magnitudes of likely groundwater level changes in status quo, high growth and low growth/high conservation scenarios garnered from the understanding

---

<sup>4</sup>The USPP DSS has not been published in its entirety as it is still be vetted by the Upper San Pedro Partnership.

of the USGS groundwater model currently incorporated in the DSS (scenarios 4 - 7 ) in addition to uniform (scenarios 1 – 3), and end-member cases (scenarios 8 and 9) groundwater changes.

Scenario 1 = 0.5 m uniform decline in groundwater;

Scenario 2 = 1 m uniform decline in groundwater;

Scenario 3 = 0.5 m uniform increase in groundwater;

Scenario 4 = Continued and increased agricultural pumping near Palominas; new developments in unincorporated areas of Palominas and Hereford near SPRNCA;

Scenario 5 = Increasing cone of depression in Sierra Vista, Ft. Huachuca, and Huachuca City with impacts toward the lower Babocomari and northern SPRNCA;

Scenario 6 = Large increases in groundwater due to recharge and conservation efforts in Sierra Vista and Bisbee;

Scenario 7 = combined from scenarios 4 & 5, representing effects of both agricultural pumping in the south and increasing cone of depression;

Scenario 8 = Low extreme - river essentially dries up;

Scenario 9 = High extreme - river essentially has surface flows throughout SPRNCA<sup>5</sup>.

Figure 3 depicts the impact on SPRNCA of the above hydrologic scenarios. Each graph shows SPRNCA divided into 14 reaches. Based on research from project ecologists, reaches have been classified into one of three types (condition classes): wet, intermediate, dry. This classification reflects variables such as annual surface water permanence, depth to groundwater, and vegetation composition (Lite and Stromberg 2005, Stromberg et al. 2006). The SPRNCA currently consists primarily of wet and intermediate reaches; in our scenario analysis we assume

---

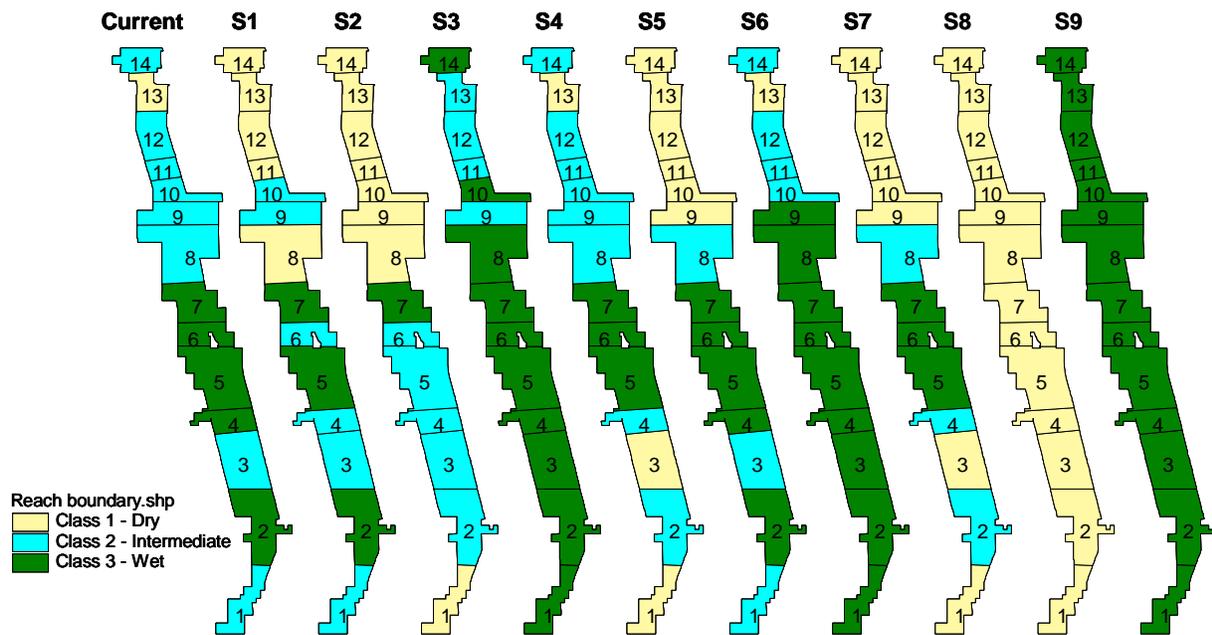
<sup>5</sup>The importance of developing plausible scenarios became apparent during the May 2006 focus groups where participants were generally frustrated with the choice question because the scenarios causing the changes in attribute levels was intentionally left ambiguous.

that changes in groundwater levels from actions such as pumping and recharge results in shifts between stream classes.

### b. Riparian and Avian Components

One of the core challenges of this project has been to quantitatively link models across the natural science disciplines, and in turn, provide usable outputs for ecological valuation. The

Figure 3: Changes in San Pedro Riparian Condition Classes by Scenario



riparian and avian components each began with different goals. The objective of the riparian component was to determine how riparian vegetation distribution, composition, and structure respond to changes in surface flow and groundwater levels in the SPRNCA. As noted above, prior riparian research yielded a condition class model based on underlying hydrologic conditions. The objective of the avian component was to determine the impact of hydrologic and vegetation changes on bird populations and communities for the different reaches of the SPRNCA, and then express these outputs in terms of bird abundance as inputs into the ecologic

valuation models. Bird abundances were assessed by migratory status, nest height, and the degree of water-dependence.

The next step was to link the riparian condition class model with avian datasets. The modeling framework used the raw data that was available for vegetation and birds (e.g. average proportion of different habitat types within a condition class and bird densities by habitat type and hydrologic class), and projected how changes in groundwater, as reflected in the condition class vegetation model, would impact bird abundances as a function of the different hydrologic scenarios by reach. While the components of this work were not new (for example, the developed methodology applied some basic approaches in space-for-time substitution modeling and the delta method to calculate errors propagated across the vegetation and bird modeling levels), the development and programming of this model was specific to the data and problem at hand. This linkage was the key step required to provide a scientific foundation to the economic valuation effort<sup>6</sup>.

### **c. Survey Component**

The foundation of the survey research program is framed by the following questions:

- 1) What is the ideal set of physical, natural, and social science information on which to build an economic research program to value ecological service flow changes?
- 2) Can alternative suites of natural science information coupled with socio-behavioral information lead to a better understanding of both intra-site and inter-site benefit transfer functions?

The research incorporates two stated preference techniques, Contingent Valuation (CVM) and Choice Modeling (CM), with three alternative information gradients, “Fine”, “Coarse” and

---

<sup>6</sup>Linking models across disciplines is inherently challenging and requires quantitative skill. As such, future interdisciplinary efforts should not underestimate the work involved in developing methods to link disciplines, since each effort is likely to require a novel methodology and approach. The research team feels that because of their quantitative nature, such efforts would also be enhanced by hiring a qualified, experienced statistician to aid with the development of methodology and programming.

“Traditional” for each technique. To date there have been few published comparisons of CVM and CM (Stevens et al. 2000; Margat et al. 1998; Barret et al. 1996; Boxall et al. 1996; Ready et al. 1995; Mackenzie 1993; Desvousges et al. 1987). All of these studies found substantial differences in willingness to pay (WTP) estimates between the various forms of CVM and CM analyses for equivalent policies. Various reasons for the disparity have been offered: first, CVM is a one shot procedure vs. the iterative nature of the CM (Takatsuka 2003); second, the presentation of alternative policies in the CM format suggests substitute (alternative) policies not available in CVM (Boxall et al. 1996; Ready et al. 1995); third, CMs allow explicit recognition of complements that CVMs may not (Morrison 2000, Stewart et al. 2002); fourth, the effects of data structure used for conditional logit vs. standard logit estimation vary (Stewart et al. 2002). In addition to these comparisons, benefit transfers will be conducted between the two test sites. The literature on benefit transfers predominately relies on the science as given (Desvousges et al. 1998). Few studies have examined the role of models across disciplines in a benefit transfer setting (Brookshire et al., 2007; Brookshire and Chermak, 2007), while few cross-method comparisons exist (Boxall et al. 1996; Stevens et al. 2000; Takatsuka, 2003).

CM, a variant of conjoint analysis, elicits an individual’s preferences by asking the subject to consider a series of alternatives. In contrast to CVM, which asks individuals to explicitly state their willingness to pay for a proposed policy change, CM requires the individual to choose from a series of possible alternatives, each having different levels of the attributes (birds, in-stream flow, riparian vegetation and cost, for example). This allows the researcher to obtain the marginal value (implicit price) of each attribute, as well as welfare measures for any policy that has attributes contained within the span of those presented in the survey. Both the CVM and CM models utilize a random-utility framework to explain individuals’ preferences for

alternative profiles and are directly estimable from the CVM and CM data (Roel et al. 1996; Stevens et al. 1997). Several iterations of the coarse scale CM surveys have been drafted with emphasis on the educational and scenario components. The educational component forms the foundation of all three information levels for both the CM and CVM surveys.

Information gradients are represented through different levels of spatial representation and / or levels of detail of ecological attributes. The “Traditional” scale will provide minimal spatial representation of the attributes<sup>7</sup>, the “Coarse” scale will provide reach scale spatial representation<sup>8</sup> with the “Fine” scale providing reach scale spatial representation giving survey participants the option to ‘drill-down’ to more detailed information on hydrologic, vegetation, and avian attributes<sup>9</sup>. In this regard different levels of scientific information are coupled with the ability to present the attributes in more advanced forms. To ensure that responses are representative of the population, both mail and internet versions of the surveys are being developed. Figure 4 shows the types of comparisons that can be made across modeling

---

<sup>7</sup> The notion of the traditional scale is that much of the scientific research has enabled an understanding of the ecological processes of the river systems in spatial detail. If this work had not been done, we would have been faced with what might be a more traditional informational setting. That is, rather than being able to divide the river into stretches as they relate to groundwater levels, we would have been faced with information such as 35% is cottonwood, 50% mesquite, etc.

<sup>8</sup> Coarse scale information uses the best available science in a spatial setting but omits within the survey some of the available detail such as reference to all types of birds.

<sup>9</sup>The fine scale incorporates within the structure of the attribute set all of the available information. For instance, the ‘drill-downs’ will allow the respondent to examine in detail changes in a particular bird species.

approaches and the types of tests that can be conducted using a benefit transfer.

Figure 4: Benefit Transfer Tests

		Traditional Survey	Coarse Survey	Fine Survey
Choice Questions	San Pedro	No spatial vegetation and bird information	<i>Spatial vegetation and bird information</i>	<i>Spatial vegetation and bird information, plus the ability to drill down by reach for additional information</i>
	Rio Grande		Spatial vegetation and bird information	
DC / CVM	San Pedro		<i>Policy attribute chosen by scientist</i>	
	Rio Grande		Policy attribute chosen by scientist	

■ Educational component is the same  
■ Educational component is the same

#### d. Focus Groups

To date, three focus groups have been conducted using a draft of the “Coarse” scale CM SPRNCA survey. These focus groups aimed to obtain specific written and oral feedback for each section of the survey as well as comments on the overall structure of the survey. Feedback indicated that although the cognitive burden of the survey was high due to the complexity of the issue, many participants wanted access to more information. Interestingly this desire was in contrast to their desires for the survey to be shorter. This apparent conflict prompted the inclusion of ‘drill-downs’ in the “Fine” scale surveys. Feedback also indicated that the overall presentation of the material needed to be changed to reduce redundancy and eliminate irrelevant information to reduce the cognitive burden of the survey. This feedback has significantly streamlined the surveys. At the writing of this paper future focus groups have been planned for the SPRNCA CM survey, utilizing laptops for presentation purposes.

#### **IV. Reflections on the Interdisciplinary Process for Organizing the Science Information**

An overarching goal of this project is to build a broad foundation across the natural and social sciences that will allow us to address the critical issue of conservation of riparian systems in the Southwest. This project has tackled the challenging task of identifying a set of feasible policy options that lead to groundwater changes that, in turn, affect vegetation and birds. The survey then presents the resulting scientific information for an educational component for survey respondents about the scientific details of the attributes to be valued within the CM framework. An important lesson learned from this process has been that the goals of the valuation process affect the instruments' attribute structure. Consider four possible stylized goals of the valuation process:

- 1) Focus only on the SPRR ecosystem: The valuation process will use the best available science information to uniquely reflect the attributes in the SPRR. No consideration will be given in the design to the issues associated with transferring the valuation results to other semi-arid riparian areas. This would lead to a more traditional benefit transfer exercise where the transfer from the SPRR to MRG are only a “rough” fit with regards to the attributes.
- 2) Focus only on the MRG ecosystem: The valuation process will use the best available science information to uniquely reflect the attributes in the MRG. No consideration will be given in the design to the issues associated with transferring the valuation results to other semi-arid riparian areas.
- 3) Design the valuation instruments with the SPRR as a base, attempting to account for the disparity in scientific information between the SPRR and the MRG (e.g. differences in types and amounts of scientific information and differences in the ecosystems themselves including the different species assemblages found in the two areas). This would engender a more robust set of benefit transfer exercises.
- 4) Design the valuation instruments in tandem, with the goal of creating a set of ecosystem values that are transferable to most semi-arid regions in the Southwest.

Depending on the goal desired, one would follow a different process, where the results of each goal may be in conflict with each other. Below we outline in more detail the oppositional nature of these goals and the process by which a compromise was achieved.

**a) Idealized Representation of the Scientific Knowledge**

In defining the attributes, the research team faced the immediate problem that the scientists ideally would like a more complete representation of the ecological processes and outputs. For instance, in the development of the SPRNCA condition class model, 9 different riparian vegetation attributes are measured (Stromberg et al 2006; Lite and Stromberg 2005) where only 4 vegetation attributes are represented in the economic survey. Likewise the avian component estimated over 45 possible single-species and 21 grouped-species abundance attributes for breeding and migratory birds as well as species richness and nest success with only 3 attributes being used in the ecological valuation study.

Clearly the level of detail normally addressed by science goes far beyond the cognitive burden of survey respondents and beyond the study design requirements for the ecological modeling effort. Structuring and simplifying the science inputs from the ecologic models has required an iterative and multi-pronged process. First, based on the initial attempts of the ecologists, plant and bird species were isolated and aggregated into groups that best represent the primary impacts of hydrologic and/or restoration change profiles on both birds and vegetation. Second, feedback from focus group surveys was presented back to the ecologists. Finally, simplification of the science has depended on the needs of the experiment and study design of the ecological valuation models. Thus, the final set of vegetation and bird attributes represent a compromise between maintaining a foundation in meaningful and accurate scientific findings

and simplifying the results so that survey designers and respondents can handle the cognitive burden.

### **Different Goals would lead to Different Approaches**

In what follows, we will briefly detail the compromise from the scientific perspective, first noting the key “drivers” of ecological change (e.g. ground water depletion) followed by a discussion as to the resulting structure of the information for vegetation and birds. We will then discuss the compromises from the perspective of designing a CM framework followed by extracted text from the “Coarse” SPRNCA survey to illustrate the final form that the compromise took.

#### **i. Goal 1-Focus only on the SPRR:**

Physical Drivers: The master variable that is driving changes in the SPRR riparian ecosystem is availability of surface water and groundwater. Groundwater pumping in concert with natural variations in stream hydrogeomorphology has created gradients of depth to groundwater along the river.

Vegetation: The riparian vegetation, in response to changes in surface and groundwater hydrology, change species composition and growth form. To best represent this, vegetation information attributes have been presented for each river reach in terms of:

1. Abundance of tall, flood-dependent, wetland trees (i.e., Fremont cottonwood and Goodding willow);
2. Abundance of short, flood-dependent, drought-tolerant shrubs (i.e., saltcedar);
3. Abundance of wetland ground cover and stream surface water.

Birds: Riparian birds, in response to both the physical drivers and changing vegetation, have changed in bird species composition and abundance. To best represent this, bird attributes would be presented for each river reach in terms of:

- 1) Canopy vs. non-canopy, where canopy nesting birds decline with the loss of tall trees on the SPRNCA occurring from the transition of wet or intermediate reaches to dry reaches.
- 2) Degree of water dependence, where water obligate birds (e.g. wading, swimming, or shorebirds) decline with loss of perennial surface water, this occurs from the transition of condition class from wet to intermediate or dry reaches.
- 3) Migrating birds, which have an overall decline with the loss of tall trees.

**ii. Goal 2-Focus only on the MRG:**

Physical Drivers: The master variable that is driving changes in the MRG riparian ecosystem is alteration of the flood disturbance regime. Secondly, human restoration actions are driving changes, where changes in the system have occurred as a result of channelization, land clearing, agricultural use, and urban use.

Vegetation: As a result of the reduction in river flooding caused by dam management, the species composition of the riparian vegetation has changed and the density of the vegetation has increased. Some parts of the MRG floodplain support tall, old, flood-dependent cottonwood forests with a very dense understory of smaller, flood-intolerant trees. Some of the understory trees are introduced species (such as Russian olive); others are native (such as New Mexico olive). As a result of changes in the pattern of river flooding (and perhaps in water table depth), other parts of the floodplain no longer support cottonwood but support dense stands of the shrub salt cedar. Restoration actions are shaping the vegetation by mechanically clearing non-native

plants in the dense mid-story vegetation. To best represent this goal, the information would be presented by each river reach in terms of:

1. Abundance of tall, flood-dependent, wetland trees (i.e., Fremont cottonwood and Goodding willow);
2. Abundance of short, flood-intolerant trees.
  - a. Abundance of short, flood-intolerant trees that are native
  - b. Abundance of short, flood-intolerant trees that are introduced
3. Abundance of short, flood-dependent, drought-tolerant shrubs (i.e., saltcedar)

Birds: As a result of changing vegetation, riparian birds change in terms of composition and abundance. To integrate the response of vegetation, information should be presented for each river reach in terms of:

1. Canopy, mid-story and understory (ground/low-shrub) nesting birds. The canopy nesting birds are predicted to increase with removal of monotypic stands of salt cedar and restoration of tall cottonwood-willow forests in the southern study area of the MRG. Mid-story and possibly understory nesting birds decline with mechanical thinning of the non-native mid-story in the short term.
2. Migrating birds may show an overall decline with loss of tall trees or from the loss of understory shrubs or trees due to mechanical thinning.

The distinct physical differences and anthropogenic pressures between the MRG and the SPRR illustrate that goals 1 and 2 would lead to a different set of vegetation and bird attributes if each site were considered individually. For vegetation the different stressors, physical drivers, and species present at the two sites exemplify this. On the SPRR natural flood regimes exist with the stressor of concern being groundwater decline. The vegetation attributes of concern are those related to changes in groundwater depth (shifts from cottonwood-willow to saltcedar) and surface flow permanence (loss of herbaceous wetland plants). On the MRG, the alteration of

flood regimes by upstream dams and bank stabilization structures is the primary stressor, with groundwater having a lesser role. This necessitates a shift in focus from plant traits related to drought tolerance/groundwater depth on the SPRR, to one dealing with responses to flooding or the lack thereof (i.e., increased abundance of flood intolerant smaller trees) on the MRG. In addition, the functional group approach, rather than a species-based approach, becomes necessary when both systems are considered, because of the differences in the species present in the SPRR and MRG (e.g., Russian olive is absent from the SPRR).

For birds, emphasis on canopy versus non-canopy nesting birds for the SPRR would need to be expanded for the MRG to emphasize the differences that occur in the mid-story and understory from mechanical thinning of the vegetation. The different attributes show how different physical and anthropogenic drivers on two river systems (alteration of groundwater regime on the SPRR; active mechanical thinning on the MRG) impact the difference in bird attributes. While the degree of water dependence is an important variable for the SPRR as obligate birds decline with loss of perennial surface water, this group would likely not be as important on the MRG as there is less expected variation in availability of surface water between current conditions and restoration scenarios. While little is known thus far how migrating birds will respond to vegetation changes on the MRG, they are included as an attribute since feedback from the focus groups have emphasized migrating birds.

**iii. Goal 3 - The SPRR is the base, but a close eye is kept on the MRG as a transfer site:**

Physical Drivers: Groundwater and flood regimes are two key driving variables that structure dryland riparian ecosystems across the SPRR and MRG river systems, while mechanical

thinning of understory vegetation (“restoration”) is an important physical driver for the MRG.

Vegetation: To capture the effects of changes in these master variables on riparian vegetation of unconstrained, low gradient, historically perennial rivers of the American Southwest, information should be presented for each river reach on:

1. Abundance of tall, flood-dependent wetland tree species (e.g., Fremont cottonwood, Goodding willow);
2. Abundance of short, flood-dependent drought-tolerant shrub species (e.g., saltcedar);
3. Abundance of short, flood-intolerant trees (e.g., Russian olive, velvet mesquite);
4. Abundance of herbaceous wetland vegetation and surface water.

Birds: The master variables that are driving changes on SPRR and/or MRG bird communities are availability and composition of riparian vegetation and surface water availability. To capture these more general influences, information should be presented on the union of attributes from the SPRR and MRG:

1. Canopy, mid-story and understory (ground/low-shrub) nesting birds. The canopy nesting birds decline with loss of cottonwood on the SPRR, while they increase with clearing of monotypic stands of salt cedar and restoration of tall riparian trees (e.g., cottonwood forests) in the southern study area of the MRG. Mid-story and possibly understory nesting birds decline with mechanical thinning of the non-native under story in the short term on the MRG.
2. Degree of water dependence. Water obligate birds decline with loss of perennial surface water on the San Pedro; this group will not likely be as important on the MRG as on the San Pedro. Water obligate birds decline with loss of perennial surface water on the SPRR; this will not likely to be a very important group on the MRG.
3. Migrating birds decline with loss of tall trees on the SPRR, and may or may not show an overall decline with loss of tall trees on the MRG.

The distinction between goals 1 or 2 with goal 3 show that the set of vegetation and bird attributes would need to be the union, or combination, of attributes for the two individual rivers systems. If each site were considered individually it would be important to have the set of attributes that best represented the specific physical drivers occurring on that river system. However, when looking across river systems the attributes would need to be expanded accordingly.

**iv. Goal 4 - Assume Goal 3 is satisfied but the taxonomy needs to be robust to all semi-riparian areas.**

Environmental Drivers: There are many key variables that shape semi-arid riparian areas in the Southwest such as hydrologic regimes (groundwater flows, base flows, flood flows) and geomorphic regimes (sediment flows and other geomorphic processes). Other key drivers include water quality (including salinity and nutrients), fire, climate, and activities of mammals including beavers (an ecosystem engineer), large herbivores, and people (including restoration actions).

The approach would need to encompass the wide range of flows regimes (ephemeral, intermittent, perennial), watershed sizes and stream orders (flood magnitude), stream geomorphologies (stream gradient, floodplain width), elevations and geographic locations found throughout the region.

Anthropogenic Changes: A taxonomy of the major types of human actions that can alter riparian areas in the Southwest needs to be created. Key actions include those that would alter water availability (diversions, pumping, interbasin transfers), flood patterns (dams, land use changes), water quality (effluent discharge, agricultural and urban runoff), stream morphology

(channelization, berming), vegetation area (conversion to agriculture, urban), and herbivory levels (livestock grazing).

Vegetation: To link changes in vegetation attributes to the above anthropogenic changes, one would create a taxonomy of riparian ecosystem types in the Southwest. One would then gather empirical and/or theoretical information pertaining to vegetation responses to changes in the environmental drivers addressed above. Efforts have been undertaken to link specific environmental changes to riparian vegetation response for specific stream types, but many scientific gaps remain.

Birds: To develop riparian bird attributes across Southwestern rivers it would be necessary to assess how birds respond to the larger set of physical drivers it would then be possible to develop a meta-analytic dataset (pulling in existing data from the literature) to look at ecological and life-history traits of birds that respond strongly to changes in riparian vegetation across all riparian areas in the Southwest. This would encompass, among other things: variations in response of birds to vegetation composition, structure and arrangement, availability of surface, water, livestock grazing, and surrounding land cover. Grouped species predictions would then be possible, however probably only in some sort of index form such as a ranking of bird abundances (not absolute abundances).

One primary distinction between goals 1 and 3 versus goal 4 is that we likely won't have an original dataset that spans Southwestern Rivers. Thus implementation of goal 4 would require the development of some sort of index to predict what is going on in a new river system without collecting a lot of additional data. Prediction to novel locations, based on existing empirical or theoretical knowledge in the natural sciences (both vegetation and birds) represents a major scientific endeavor. Because of its difficulty and novelty the scientific effort required to

provide prediction to new locations, as foundation to ecological valuation work should not be taken for granted or underestimated.

Indices are often used in ecological valuation and benefit transfer studies as proxies for specific benefits since there is often insufficient time and resources to study each attribute for which ecological valuation studies would be beneficial. Ecological indices may provide an efficient means to guide management and conservation decisions. Indices based on a relatively small set of ecological metrics have been used as substitutes for more intensive and/or expensive measurements of ecological conditions (O'Connell et al. 2000, Canterbury et al. 2000; Stromberg et al. 2004). While indices deliberately simplify complex ecological systems, they are intended to provide an efficient means to assess broad regions when more detailed studies are impractical or impossible (Karr 1991, Canterbury et al. 2000). From the natural science perspective, creation of meaningful ecological indices requires prediction of conditions in previously unstudied locations. While identification of larger ecological principles that may be operating across sites within a given region is one of the key goals of the science of ecology, it is by no means simple (Côté and Reynolds 2002).

In order for an index to be meaningful, it needs to be founded in ecological theory and be empirically based. For this project developing a predictive approach for the natural science inputs to the benefit transfer was a monumental task. Development of an appropriate index would have required collection of data across Southwestern riparian systems facing different physical drivers, and if only from the literature were available the use of meta-analysis would be required. Since the distribution of many species of birds may not cover an entire region of interest, use of ecological traits of species would have provided a means to predict expected responses of birds to changes in hydrologic and vegetation conditions across sites (Brand 2004).

Similarly, because species composition of riparian plants varies across the region, classification of plants by functional traits would have provided a means to predict riparian vegetation responses across sites. In addition to the substantial effort and time required to develop such indices, the primary stumbling block that we faced was that the structure of the ecological attributes would have been very different if an index were used for the benefit transfer site, while a non-index (e.g. bird abundance estimated from data) was used for the SPRR. Future efforts can and should be allocated to the development of predictive models in the natural sciences that begin to fulfill the need in ecological valuation for ecological indices that are meaningful across sites within a region, and are empirically and theoretically based.

## **V. Issues from the Choice Modeling Perspective**

From the CM perspective, the biggest issues faced have been:

1. Accurately portraying the science results in a way that is comprehensible to survey respondents;
2. Defining the good in a way that keeps the 'best science' available from SPRNCA but allows transfer to other sites;
3. Removing the inherent correlation that comes from using integrated scientific results.

Based on feedback from the focus groups and considerations arising from the benefit transfer we drafted a new version of the coarse SPRNCA CM survey. We sought to find a balance between the vast detail of information available from the scientific outputs and respondent comprehension level. This version was shared around the research team so that all could check the greatly "aggregated" science content for accuracy in presentation.

To put this in perspective, we had available data on 33 individual species of birds by reach with over 15 different ways that our ornithologist could potentially group this species-specific data. The final attributes that were chosen for selection in the choice question include:

1. Miles of surface water;
2. Three possible condition classes of riparian vegetation with a spatial distribution;
3. Bird abundance by condition class;
4. Cost.

This final choice of attributes represents a trade-off between scientific detail, benefit-transfer needs, and CM requirements. For example, the condition classes represent the 'best available science' at the coarse level of the SPRNCA, where the identification of a reach as wet, dry, or intermediate is based on a large number of variables that include groundwater, surface water, and vegetation types. This aggregation of information into one of three types was both a blessing and a challenge in terms of survey design. On the positive side presentation of these three types encapsulated a good deal of information in a way that was easy for individuals to understand. However this starting point created significant challenges for the economists.

A goal of the study was to determine a marginal value of water. We dealt with this by separating out surface water as an attribute and emphasizing the ground water/vegetative components of the condition classes. Although we spent significant time and energy identifying a Southwestern riparian area that was similar in many ways to the SPRR, as noted earlier, the policy drivers and the issues of concern are very different along the SPRR and MRG. In some ways the SPRR is quite unique. The 'best science' for the SPRR was designed so as to best describe the SPRR, not necessarily other Southwestern rivers.

As discussed above, the challenge facing benefit transfer in this study, just as with any study, is that the models you would choose with benefit transfer in mind may be very different than what you would choose to describe a particular study area. What drove the best science at the SPRR is not necessarily the most salient issue in the MRG. Without conducting primary

science on the MRG, it is essentially impossible to create riparian condition classes that are comparable to the SPRR. This fact has caused us to emphasize the vegetative characteristics of the condition classes. This has also resulted in additional complexity in the SPRNCA survey, as we bring in an additional vegetative component (short, flood-intolerant trees such as mesquite on the SPRR and Russian olive on the MRG) that did not change among the condition classes in the SPRNCA but varies among sites and is a focus of vegetation manipulations on the MRG.

While birds have been significantly easier to deal with from a transfer perspective, they have resulted in a fair amount of additional complexity. For example, we have six different bird categories: breeding/low-shrub; ground, breeding/high-shrub, breeding/canopy, breeding/water-dependent; breeding/non-water-dependent and migratory. Originally we had chosen categories of breeding/canopy, breeding/non-canopy, breeding/water-dependent and breeding/non-dependent to best capture the actual important changes that would occur in the SPRR from groundwater pumping. As total number of birds was predicted to stay relatively constant, total number of species did not capture the whole story; instead the important difference was in the composition of birds. Migratory was included because of the importance that focus groups bestowed on this category. Once the benefit transfer site was included, non-canopy had to be widened to encompass the real changes that are happening on the MRG. More specifically, while groundwater pumping that affects birds may be the primary concern in SPRR, it is restoration in response to fire concerns that affects birds in the MRG. The types of birds that are affected by these two policies are not the same. Thus, non-canopy was further sub-divided into low-shrub/ground and high-shrub. In trying to cover just two sites, the complexity has increased remarkably.

Finally a comment must be made from the choice-modeler's perspective. A goal of efficient CM is to create a design with independence between attributes. This is completely at odds with the idea of ecosystem services, which by their very nature are strongly linked; the desire for attribute independence has been troubling to the economists. The very heart of the scientific model employed in this study was to link disparate disciplines in creating an integrated model. Vegetation modelers linked their results to groundwater models and bird modelers based their model on the condition class model. What is the independent-attribute choice modeler to do? By its very design, the attributes of bird density are linked to condition class. One way we have tried to break these correlations is through the information presented to respondents. For example, respondents will be presented with information on miles of surface water; while this depends on condition class, it is not perfectly linked because of uncertainty in the surface water estimates and the spatial nature of the condition classes.

The agreement that has been made is that traditional design methods will be used, ignoring the correlations. The choice pairs will then be presented to the scientists for their review, so as to weed out any blatantly unobtainable combinations. Tests will then be run to check that the remaining combinations in the design will allow the economists to estimate the marginal values of interest. Because of the underlying science, we will then be able to use the estimated marginal values to estimate willingness to pay for scientifically predicted outcomes from potential groundwater changes. Once the marginal values are obtained, WTP estimation will be based on the scientific estimation of attribute levels. This represents the primary difference between traditional CM methods and our integrated approach.

## **VI. The Surveys**

In the following section, we present some extracted text from the “Coarse” SPRNCA survey, to illustrate the final form of the compromise.

### **a. The “Coarse” SPRNCA Survey**

The structure of the “Coarse” SPRNCA CM and the CVM survey will have the following:

1. Introduction, and discussion of the importance of riparian zones;
2. Background information of three important characteristics of the SPRNCA;
3. Discussion of water (focusing on surface and groundwater interactions), vegetation (focusing on types and relationships to water availability) and birds (focusing on types and relationship to vegetation cover);
4. Current conditions for the three riparian condition classes;
5. Relevant policy measures (appropriate variations for CVM);
6. Choice or dichotomous questions (appropriate variations for CVM)
7. Socio/economic/activity information.

Respondents are presented with a summary of each of the current condition classes, and provided with information about the average surface flow and density of birds by type. This is shown in Figures 5 through 7. Figure 5 shows this information for the wet condition class depicting which reaches of the SPRNCA are currently classified as wet. Figure 6 shows this information for the intermediate condition class depicting which reaches of the SPRNCA are currently classified as intermediate. Figure 7 shows this information for the dry condition class depicting which reaches of the SPRNCA are currently classified as dry.

Figure 5: Wet condition class

**Characteristics of Average Wet Stretch**



Surface Water Flow:

- 99% of the year

Mix of Vegetation

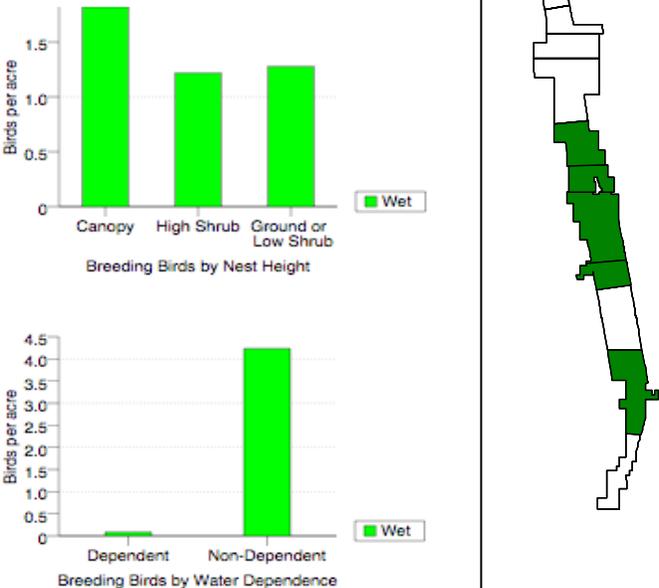
No salt cedar  
 Predominantly cottonwood-willow (89%)  
 Some mesquite (11%)  
 Contains river marsh grasses

Birds

- Breeding birds by nest height
  - Canopy: 1.8 per acre
  - High Shrub: 1.2 per acre
  - Low Shrub/Ground: 1.3 per acre
- Breeding birds by surface-water dependency
  - Non-dependent: 4.2 per acre
  - Dependent: 0.1 per acre
- Migratory birds: 3.3 per acre

**Current Conditions for Wet Stretches in SPRNCA**

- 5 wet stretches, consisting of 601 acres (30 % of the total area of SPRNCA)
- On an average day, 14.5 miles of surface water
- 3.3 migratory birds per acre



**Breeding Birds by Nest Height**

Nest Height	Birds per acre
Canopy	1.8
High Shrub	1.2
Ground or Low Shrub	1.3

**Breeding Birds by Water Dependence**

Water Dependence	Birds per acre
Dependent	0.1
Non-Dependent	4.2

Figure 6: Intermediate condition class

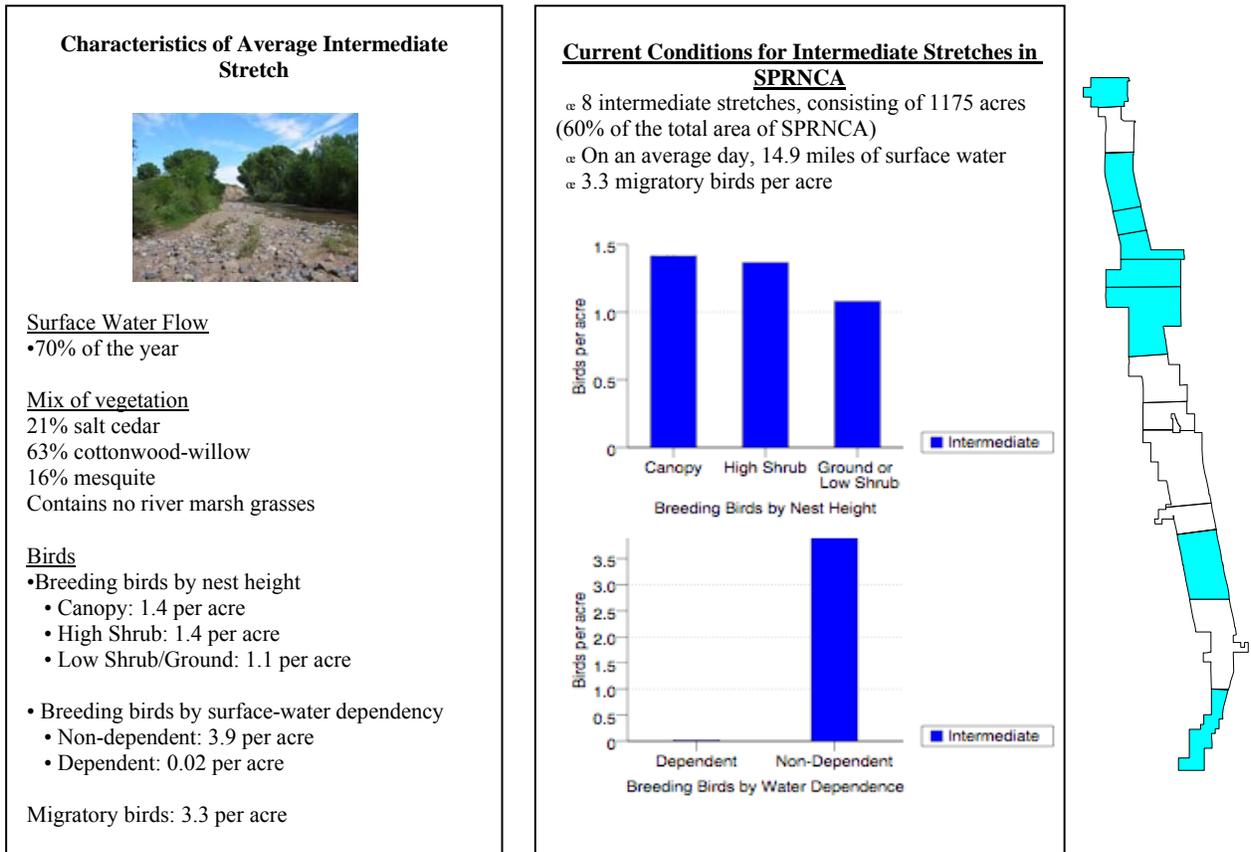


Figure 7: Dry condition class

**Characteristics of Average Dry Stretch**



Surface Water Flow

- 46% of the year

Mix of vegetation

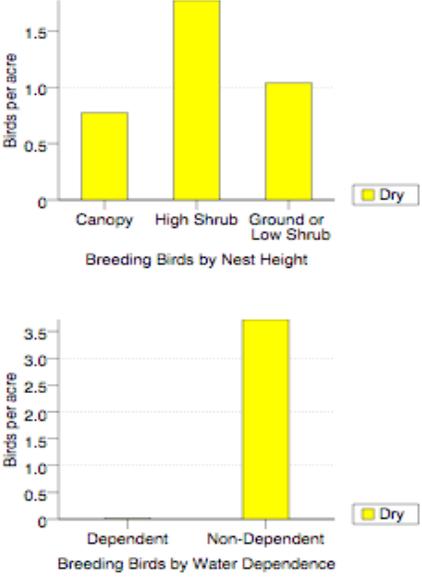
Primarily salt cedar (73%)  
 17% mesquite  
 10% cottonwood-willow  
 Contains no river marsh grasses

Birds

- Breeding birds by nest height
  - Canopy: 0.8 per acre
  - High Shrub: 1.8 per acre
  - Low Shrub/Ground: 1.0 per acre
- Breeding birds by surface-water dependency
  - Non-dependent: 3.7 per acre
  - Dependent: 0.01 per acre
- Migratory birds: 3.8 per acre

**Current Conditions for Dry Stretches in SPRNCA**

- ≈ 1 dry stretch, consisting of 196 acres (10 % of the total area of SPRNCA)
- ≈ On an average day, 1.1 miles of surface water
- ≈ 3.8 migratory birds per acre



**Breeding Birds by Nest Height**

Nest Height	Birds per acre (Dry)
Canopy	0.8
High Shrub	1.8
Ground or Low Shrub	1.0

**Breeding Birds by Water Dependence**

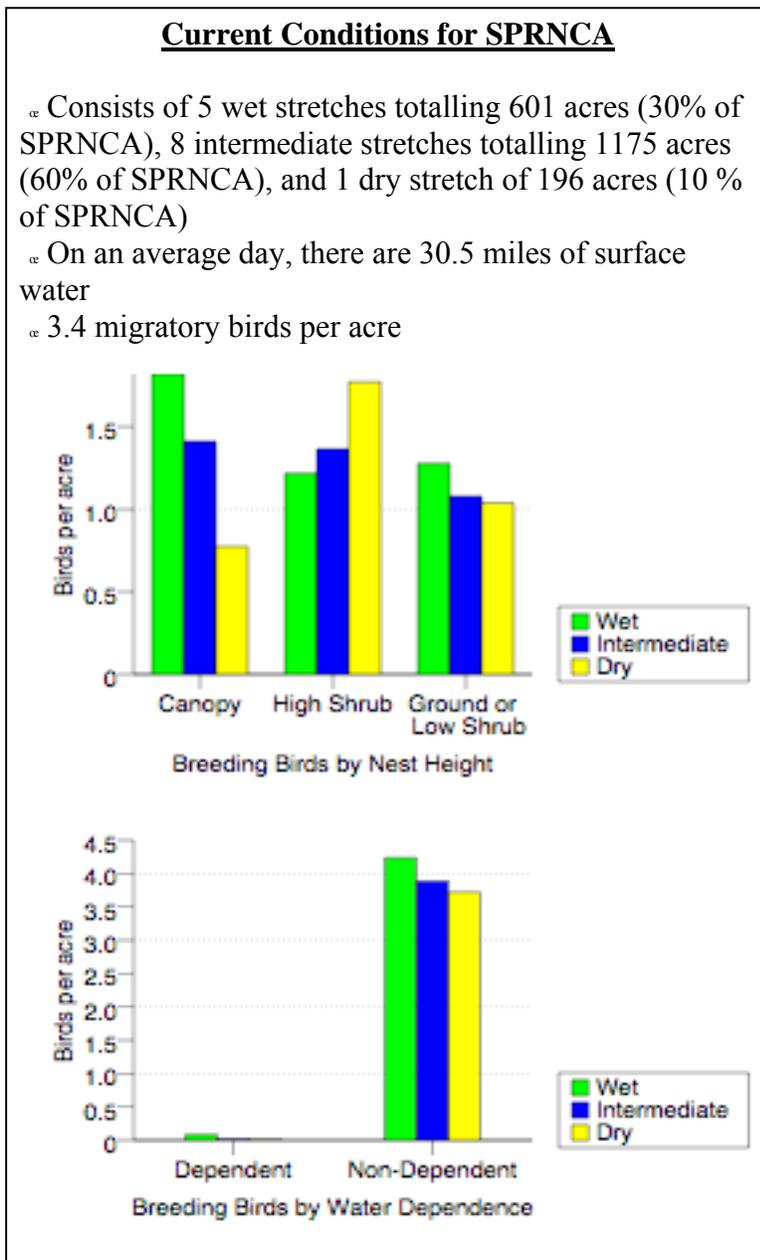
Water Dependence	Birds per acre (Dry)
Dependent	0.01
Non-Dependent	3.7



**b. Current Conditions Summary**

The information from each of the condition classes is then summarized into a single graphic (Figure 8). This graphic forms the status quo alternative and shows the format that is used to describe each of the choice alternatives.

Figure 8: Current condition class



## **VII. Reflections**

This paper has presented a case study, highlighting some of the complexity involved in creating an integrated scientific/economic framework. As discussed in this paper, difficulties in creating such a framework for a single site include: the inherent contradictions in separately valuing ecosystem services as distinct, independent attributes; the cognitive difficulties posed for survey research in having primary scientific output; the challenges of integrating disparate disciplines; and the need to develop novel methods for connecting the output between the disciplines. These difficulties, while surmountable, are made even more challenging when the goal is to conduct benefit transfer between sites, as the 'best science' is traditionally geared towards understanding a specific site as opposed to broadly describing a set of sites. Accommodating scientific differences between sites and trying to remain scientifically accurate increases the cognitive burden placed on survey respondents while limiting the level of detail at which the problem can be addressed. The necessary result has been a number of pragmatic compromises.

While we present this experience with the hope of sparking discussion, we do so retaining the belief that while complex, the effort to integrate the disciplines remains essential. Working with other disciplines has been an interesting experience, highlighting the lack of full understanding of natural systems that economists bring to valuation exercises. In order to develop meaningful welfare estimates that can contribute to policy discussion, economists must better understand the possible trade-offs resulting from policy choices. In order for the science results to have policy impact, scientists must strive to make their results understandable and transferable. Additionally they must engage with policymakers. Better environmental policy requires integrated research.

## VIII. References

- Alley, W. M., R. W. Healy, J.W. LaBaugh, and T. E. Reilly., 2002. Flow and Storage in Groundwater Systems. *Science* 296 (5575): 1985 - 1990.
- Barret, C., T.H. Stevens, and J. Willis., 1996. "Comparison of CV and conjoint analysis in groundwater valuation." Ninth Interim Report, W-133 Benefits and Costs Transfer in Natural Resource Planning, Ames, IA: Department of Economics, Iowa State University.
- Brand, L. A., 2004. Prediction and assessment of edge response and abundance for desert riparian birds in southeastern Arizona. Ph. D. Dissertation, Colorado State University.
- Boxall, P.C., W.L. Adamowicz, J. Swait, M. Williams, J. Louviere., 1996. "A comparison of stated preference methods for environmental valuation." *Ecological Economics* 18:243-253.
- Brookshire, D., and J. Chermak., 2007. "Conceptual issues of benefit transfers and integrated modeling," *Environmental Value Transfer: Issues and Methods*, Vol 9, in the Kluwer Publishers series entitled The Economics of Non-Market Goods and Resources, ed. by S. Navrud, R. Ready, and O. Olvar. New York, NY: Kluwer Academic Publishers.
- Brookshire, D., J. Chermak, and R. DeSimone., 2007. "Uncertainty, benefit transfers, and physical models: a Middle Rio Grande Valley focus" *Environmental Value Transfer: Issues and Methods*, Vol 9, in the Kluwer Publishers series entitled The Economics of Non-Market Goods and Resources, ed. by S. Navrud, R. Ready and O. Olvar. New York, NY: Kluwer Academic Publishers.
- Canterbury, G. E., T. E. Martin, D. R. Petit, L. J. Petit, and D. F. Bradford., 2000. Bird communities and habitat as ecological indicators of forest condition in regional monitoring. *Conservation Biology* 14(2): 544-558.
- Côté, I. M., and J. D. Reynolds., 2002. Predictive Ecology to the Rescue? *Science* 298: 1181-1182.
- Desvousges, W.H., V.K. Smith, and A. Fisher., 1987. "Option price estimates for water quality improvements: a contingent valuation study for the Monongahela River." *Journal of Environmental Economics Management* 14: 248-267.
- Desvousges, W H.; F.R. Johnson, and H.S. Banzhaf., 1998. *Environmental Policy Analysis with Limited Information: Principles and Applications of the Transfer Method*. Cheltenham, U.K: American International Distribution Corporation.
- Karr, J. R., 1991. Biological Integrity: A long-neglected aspect of water resource management. *Ecological Applications* 1:66-84.

- Krueper, D. J., 1999. Annotated checklist to the birds of the upper San Pedro River valley. Report prepared for San Pedro Project Office, BLM.
- Mackenzie, J., 1993. "A comparison of contingent preference models." *American Journal of Agricultural Economics* 75:593-603.
- Margat, W.A., W.K. Viscusi, and J. Huber., 1998. "Paired comparison and contingent valuation approach to morbidity risk valuation." *Journal of Environmental Economics and Management* 15:395-411.
- Morrison, M., 2000. "Aggregation biases in stated preference studies." *Australian Economic Papers* 39(2):215-30.
- Lite, S.J. and J.C. Stromberg., 2005. Surface water and groundwater thresholds for maintaining *Populus - Salix* forests, San Pedro River, Arizona. *Biological Conservation* 125: 153-167.
- O'Connell, T. J., L. E. Jackson, and R. P. Brooks., 2000. Bird guilds as indicators of ecological condition in the central Appalachians. *Ecological Applications* 10(6): 1706-1721.
- Ready, R.C., J. Whitehead, and G. Blomquist., 1995. "Contingent valuation when respondents are ambivalent." *Journal of Environmental Economics and Management* 29(2):181-96.
- Richter, H.E., 2006, Participatory learning on the San Pedro: Designing the crystal ball together. *Southwest Hydrology*, Special Issue on Decision Support Systems, Vol. 5, No. 4, p 24-25.
- Stevens, T.H., R. Belkner, D. Dennis, D. Kittredge, and C. Willis., 2000. Comparison of contingent valuation and conjoint analysis for ecosystem management. *Ecological Economics* 32(1):63-74.
- Stewart, S., Y. Takatsuka, and J. Kahn., 2002. "Choice model and contingent valuation estimates of the benefits of ecosystem protection." Knoxville, TN: University of Tennessee Working Paper.
- Stromberg, J. C., R. Tiller, and B. Richter., 1996. Effects of groundwater decline on riparian vegetation of semiarid regions: The San Pedro, Arizona. *Ecological Applications* 6(1): 113-131.
- Stromberg, J., M. Briggs, M. Scott, and P. Shafroth., 2004. Riparian ecosystem assessments. Pages 314-329 in M. Baker Jr., P. Ffolliott, L. DeBano, and D. G. Neary, editors. *Riparian Areas of the Southwestern United States: Hydrology, Ecology, and Management*. Lewis Publishers (CRC Press), Boca Raton, Florida.

- Stromberg, J. C., 1998. Dynamics of Fremont cottonwood (*Populus fremontii*) and saltcedar (*Tamarix chinensis*) populations along the San Pedro River, Arizona. *Journal of Arid Environments* 40: 133-155.
- Stromberg, J. C., S. J. Lite, T. J. Rychener, L. R. Levick, M. D. Dixon, and J. M. Watts., 2006. Status of the riparian ecosystem in the upper San Pedro River, Arizona: application of an assessment model. *Environmental Monitoring and Assessment* 115: 145-173.
- Sumer, D., H. Richter, and K. Lansey., 2004. "Evaluation of Conservation Measures in the Upper San Pedro Basin," published and presented at the 2004 Environment and Water Resources Institute Conference, Salt Lake City.
- Takatsuka, Y. 2003. "A comparison of iterative contingent valuation and choice model willingness to pay." Knoxville, TN: University of Tennessee Working Paper.
- Tidwell, V.C., H.D. Passell, S.H. Conrad, and R.P. Thomas, 2004. Systems dynamics modeling for community-based water planning: An application to the Middle Rio Grande, *J. of Aquatic Sciences*, 66:357-372.