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ANALYSIS

Economic valuation of environmental services sustained by water flows in the Yaqui River Delta

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ABSTRACT

We attempted to estimate the economic value of environmental services provided by restored instream flows in the water-scarce Yaqui River Delta in Mexico. The Yaqui River begins near the U.S.–Mexico border and continues for 400 km before reaching the Oviachic dam, but has not reached the nearby Gulf of California for decades due to diversions for irrigation. These diversions have degraded the riparian ecosystem, coastal wetlands, and estuaries. Environmental services provided by restored flows in the Yaqui River would include healthy riverside vegetation, wetlands and estuaries, fish and wildlife habitats, non-use values, and recreation. A contingent valuation survey in 40 neighborhoods in the most populated Delta city, Ciudad Obregon, was administered to estimate non-market values of instream uses. Respondents were given a current and hypothetical Delta scenario (the latter assumed restored water flows in the River) and asked a willingness-to-pay (WTP) question regarding purchasing water for environmental flows through higher water bills. Results from 148 in-person interviews indicated that households would pay an average of 73 pesos monthly. WTP was found related to key variables suggested by economic theory and contingent valuation studies elsewhere: income, educational level, number of children in the household, and initial bid amount. These results will allow decision makers to compare the benefits generated by different water uses, including environmental services, and to manage scarce water resources under a long-term sustainable approach.

1. Background

The objective of this study is to estimate non-market values for water in the Yaqui River Delta, Sonora, Mexico, based on residents' willingness-to-pay for existing or potential environmental services sustained by water flows in the Yaqui River. The Yaqui River is located in a trans-boundary 72,540 km^2 basin, largely situated in the Mexican State of Sonora and a small part in Chihuahua, as well as small portions of Arizona and New Mexico in the United States (Fig. 1). The Yaqui River Basin is within one of the driest hydrologic regions in Mexico. The predominant climate is arid and semi-arid throughout the Basin, except in the eastern portion where the high mountains are located. The average annual rainfall in the area is 527 mm. The majority of the precipitation falls in the months of July to September and is dominated by the North American Monsoon (CNA, 1997). The runoff from precipitation is captured by several reservoirs on

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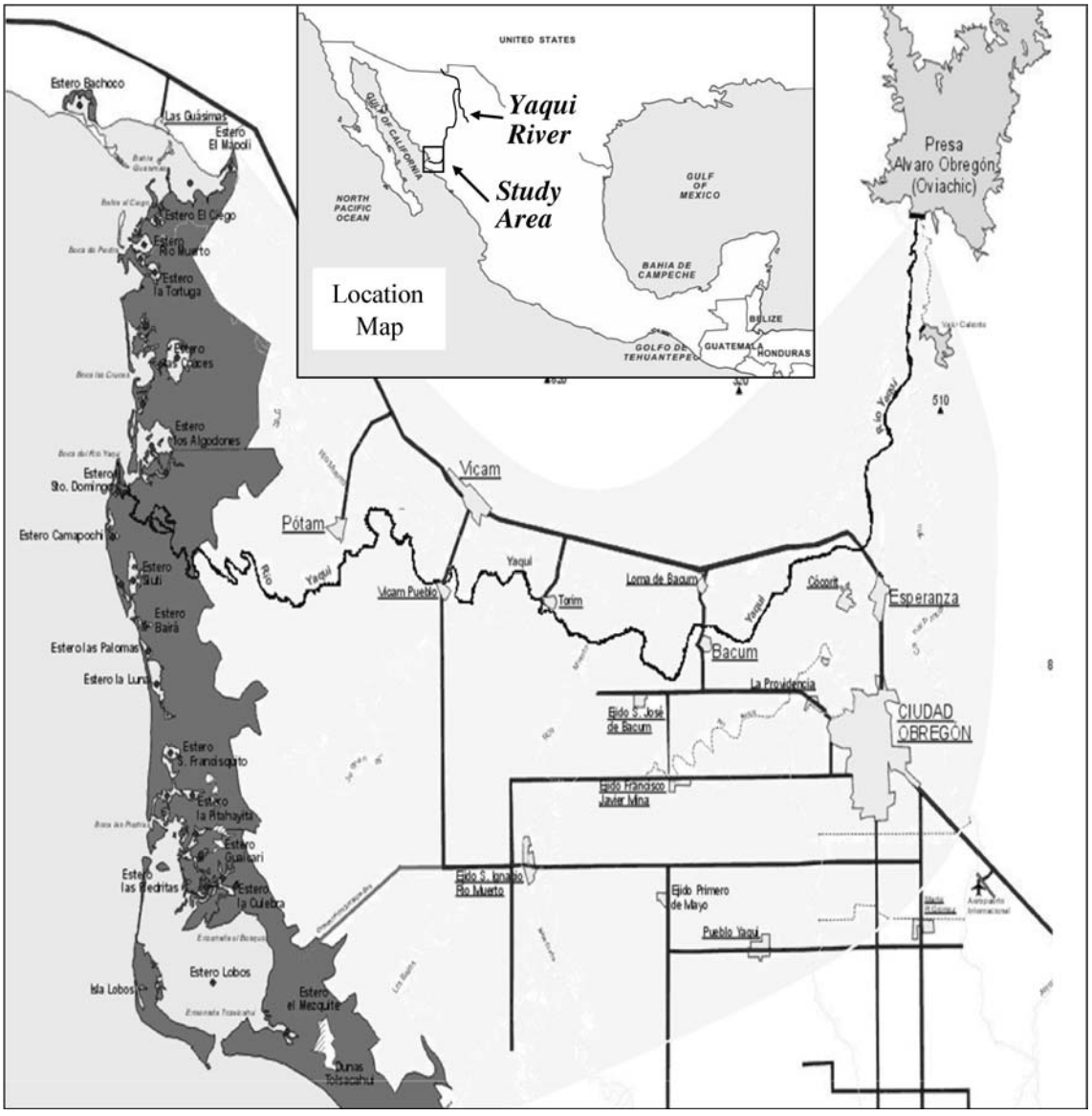

Fig. 1 – Yaqui River Delta and location of study area. Source: Adapted from Departamento de Ciencias del Agua y del Medioambiente del ITSON, 2004.

the Yaqui River and its tributaries, and is used mainly for irrigation purposes.

The Yaqui River Delta occurs where the River meets the Gulf of California, also called the Sea of Cortez (Fig. 1). The Delta is the location of two of the more important ecosystems in the lower part of the Yaqui River Basin: the riparian ecosystem, and the coastal wetlands and estuaries. The Yaqui Valley farming region, which is encompassed within the Delta, is the most important agricultural area (more than 250,000 ha) in Sonora State. Home of the Green Revolution in 1970s, this agricultural area comprises a wheat-based agricultural system developed since the establishment of the two main reservoirs on the Yaqui River between 1939 and 1964. Other crops include soybeans, cotton, maize, sorghum, and alfalfa. Agriculture is the largest user of water, representing more than 96% of the total water withdrawal in the Delta.

Water demand from cities and towns of more than 800,000 inhabitants in the entire Basin is concentrated in the growing urban centers of Ciudad Obregon (433,000 residents in 2005), Esperanza, Villa Juarez, and Bacum. The urban water demand is increasing due to the accelerated migration of rural inhabitants to nearby cities. Other significant economic activities that exert a water demand in the Delta include manufacturing, animal husbandry, aquaculture and fisheries.

The environmental concerns associated with water management in the Yaqui River Delta are clearly linked to a decrease in water flows and deterioration of water quality. These concerns can be summarized by five major problems: salinity intrusion, agrochemical pollution, deterioration of wetlands and estuaries, habitat destruction, and loss of biodiversity (Keller et al., 1996). After completion of Oviachic Dam in 1952, the majority of the flow in Yaqui River has been used for irrigation. As a result, the Yaqui River has not reached the Gulf of California for several decades. This situation has deteriorated the quality of the environmental services provided by the ecosystems that depend on the water flows in the Yaqui River Delta.

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Until the Oviachic Dam began its operations, the Delta consisted of lush, riparian forests of mezquite, alamo, willows and coastal scrubs. This vegetation, however, has effectively disappeared over the last few decades (Burquez and Martinez-Yrizar, 2000). The loss of riparian vegetation, coupled with the loss of wetlands and estuaries because of desiccation and the expansion of aquaculture farms (Departamento de Ciencias del Agua y del Medioambiente del ITSON, 2004), has reduced the habitat for resident and migratory birds and other animals, including several protected species. The lack of water in the rivers has also greatly reduced the deposition of silt that formerly replenished the wetlands and estuaries with nutrients. The deterioration of the aquatic ecosystems is now visible in some of the estuaries in the Yaqui River Delta such as La Atanasia and San Jose (Departamento de Ciencias del Agua y del Medioambiente del ITSON, 2004).

The reduction in freshwater flow in the Yaqui River Delta has also reduced the influx of nutrients to the Gulf of California, one of the world's most productive marine ecosystems, and has reduced critical nursery habitat for fisheries that thrive in the upper portion of the Gulf (Postel et al., 1998). The lack of flow in the River downstream of the Oviachic Dam has also reduced recharge of the aquifers in the Delta. The reduction of recharge, combined with the groundwater extraction for irrigation could generate the saline intrusion problems that have occurred in several neighboring aquifers such as Sonoita–Puerto Peñasco, Caborca, Costa de Hermosillo, Valle de Guaymas, and San José de Guaymas (SEMARNAT-CNA, 2005).

Water rights have been allocated in the Rio Yaqui basin to municipal, industrial and agricultural users, with the majority of the water rights being allocated to agriculture (~95%). In Mexico, water rights law has been historically based on the principle that water resources are the property of the state and thus should be a free, constitutional right for every citizen. Recent reforms, however, have been designed to promote private water rights and to allow for water rights to be traded and leased by users (Rosegrant and Schleyer, 1996). According to a report by the U.S. National Research Council and others (1995), there is a growing sense that the environment is entitled to representation in the government. There is apparently only one case in Mexico where allocations have been specified for environmental purposes: the non-governmental organization PRONATURA has contributed to the acquisition of water rights for environmental conservation in Cuatrocienagas, Coahuila, Mexico (Diario de Coahuila, 2005).

The rest of this paper is organized in the following order. First we present a short literature review that focuses on non-market valuation of instream flows and contingent valuation method (CVM) applications in developing countries. Next, we describe our multi-step methodology, following the standard approach used in most CVM studies. We then discuss our main results and conclusions.

2. Literature review

According to Loomis (1998, 2000) dollar values for instream flows can often compare favorably against the value of water in traditional economically beneficial uses (e.g., irrigation). While limited in number, attempts by ecological and environmental economists and other researchers to assess the monetary value of protecting instream flow and associated riparian areas to sustain several environmental services are increasing.

Several researchers have estimated non-market values of instream flows for recreational use (e.g., Daubert and Young, 1981; Bishop et al., 1987; Brookshire and Smith, 1987; Sanders et al., 1991; Duffield et al., 1992; Weber and Berrens, 2006); preservation of endangered and at-risk native fish species (Welsh et al., 1995; Berrens et al., 1996); bequest and existence values (Loomis, 1987; Sanders et al., 1990; Brown and Duffield, 1995); ecological integrity (Gonzalez-Caban and Loomis, 1997); and combinations of environmental services (Loomis et al., 2000; Holmes et al., 2004; Morrison and Bennett, 2004).

Non-market valuation approaches can be divided into two categories: revealed preference and stated preference methods. Revealed preference methods such as the travel cost and hedonic pricing method infer values from data on behavioral changes in actual markets, with actual purchase and consumption of marketed goods and services related in some way to the missing market to infer the value of a non-market resource. Descriptions of several revealed preference approaches, advantages, and disadvantages as well as their use for valuing water, are discussed by Agudelo (2001), Young (2005), and Pearce et al. (2006, pp. 91–103).

Stated preference methods, such as conjoint, choice experiments, and contingent valuation, attempt to solve the problem of non-use valuation of water by capturing benefits that may be neglected by the other methods. These methods are commonly used to estimate the non-use value of the environment by directly surveying consumers on their willingness-to-pay (WTP) for existing or potential environmental attributes in a hypothetical, constructed market. The most commonly used form of questioning on hypothetical futures is the contingent valuation method (CVM). According to Mitchell and Carson (1989), the advantage of CVM is that it does not require the conceptual linkage between market prices and a non-market resource, since the researcher elicits information on the value of the amenity directly by using a questionnaire or interview to create a hypothetical market or referendum in which individuals reveal the values they place on the resource.

CVM has principally been applied in highly industrialized economies. However, in the last decade, the method has also been increasingly applied in developing countries for valuation of environmental quality and for measuring the WTP for public projects aimed to provide services such as safe drinking water and sanitation (e.g. Whittington et al., 1991; Briscoe et al., 1990; Johnson and Baltodano, 2004; Choe et al., 1996; Lauria et al., 1999; de Oca and Bateman, 2006). Much less attention has been paid in developing countries to measuring the value of ecosystem services in complex natural systems such as rivers, especially the indirect use and non-use values (Venkatachalam, 2004). A few studies have been carried out to value environmental services in tropical forests (Hodgson and Dixon, 1988; Shyamsundar and Kramer, 1996; Fearnside, 1999), in wetlands (Windevoxhel, 1993), and in other applications in Mexico (Sanjurjo, 2004; Lara-Dominguez et al., 1998), but only one previous CVM study to our knowledge has focused on restoration of ecosystem services from instream river flows in a developing nation (Xu et al., 2003).

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3. Methodology

Our goal was to estimate the WTP for restoring in-stream flows in the Yaqui River Delta using the CVM, by developing an appropriate WTP survey, surveying residents in Ciudad Obregon, Mexico, and performing statistical analyses of the resulting survey data. We followed a conventional approach in the development of our methodology, adjusting it as necessary for the developing country context.

3.1. *Environmental services determination*

The first key task involved in undertaking a CVM application is the framing to determine which attributes or services should be used to depict the environmental outcomes of alternative water management strategies (Morrison and Bennett, 2004). In our study, this was particularly difficult, since only minimal flows have occurred in the Delta since the construction of the Oviachic Dam in 1952.

A four-stage process was used to select the attributes or services: (1) as proposed by Kempton et al. (1996), a basic society–environment relationship study based on information gathered from a literature review and the use of informal interviews to major stakeholder groups related to water uses in the area was arranged; (2) as suggested by Morrison and Bennett (2004), a review of the literature was undertaken to determine the attributes or services used in previous studies seeking to value instream flows or river health using the CVM or similar approaches; (3) a focus group information exchange was arranged with local stakeholders in Sonora, Mexico to identify attributes that were most relevant to respondents; and (4) a survey design that would comprehensively and clearly describe and display the natural resources being valued was selected.

Based on this methodology, the following environmental services sustained by the Yaqui River Delta were identified and used to set the scenario in the survey: preservation of riparian vegetation, wetlands, and estuaries; preservation of habitat for birds and other fauna; maintenance of local fisheries; dilution of pollutants; recreation; and other services associated with the non-use values, such as existence value, cultural value, option value, and use value for future generations.

3.2. *Description of payment vehicle*

Definition and selection of the appropriate payment vehicle depends on the resource to be valued, the socio-economic characteristics of the sample, and the institutional structure governing the area (Arrow et al., 1993). Since in our case the resource to be valued was the instream flows in the Yaqui River, we decided to use the water bill as the payment vehicle, as proposed by de Oca and Bateman (2006) in a CVM study in Mexico City and Loomis (1987) in a CVM study in California. Our hypothesis is that the water for instream flows would be purchased from irrigation districts in the Yaqui Valley, which hold water rights for almost 3000 million m^3/year. All farmers in the Yaqui Valley are organized into these irrigation districts. Since all water diverted for irrigation purposes is controlled by the irrigation districts, it is assumed that water purchased from the irrigation districts and released for instream flows would not be diverted by other users, and would remain instream.

However, during the interviews, we made it clear that other feasible options for payment would be the creation of a trust fund or the involvement of non-governmental organizations such as PRONATURA, which had already contributed to the acquisition of water rights for environmental conservation in Cuatrocienagas, Coahuila, Mexico (Diario de Coahuila, 2005). The purpose of this comment was to reduce the potential for protest zero responses and disagreement with certain aspects of the scenario, especially those entailing government responsibilities, typical of studies in developing countries because of people's distrust of the government (Hadker et al., 1997; Whittington et al., 1991; Gonzalez-Caban and Loomis, 1997; Choe et al., 1996).

3.3. *WTP elicitation format*

A draft CVM survey was pre-tested in both English and Spanish versions with 15–20 colleagues and stakeholders in Mexico and the U.S. from December 2005 through March 2006. The final CVM survey was administered through face-to-face interviews during a 1-week period in April 2006, with 15 trained sociology students from the University of Sonora, Mexico. Interviews of 197 households were attempted. The WTP elicitation format consisted of a single-bound dichotomous choice (DC) bid followed by an open-ended question eliciting maximum WTP. CVM surveys conducted in developing countries have, for the most part, used a DC format, with one or more follow-up questions (FAO Information Division, 2000). In some cases, the sequence of DC questions has been closed, with a final open-ended question eliciting the maximum WTP.

The respondents faced a single DC question of the form "Are you willing to pay X monthly for the next five years?" The bid amount X was assigned randomly to the respondents and came from a set of 15 possible values in the range of 10 to 150 pesos per month, in increments of 10 pesos. The maximum bid amount was estimated based on data on the distribution of typical household expenditures (INEGI, 2004), the purchase of agriculture water rights in Sonora (Burquez and Martinez-Yrizar, 2000), and average water bills in Ciudad Obregon (Pineda, 2006).

Our elicitation format avoided repeated questioning or iteration as in a bidding game. Repeated questioning, according to the FAO Information Division (2000), may annoy or tire respondents, causing them to say "yes" or "no" to a stated amount in hopes of terminating the interview. Mitchell and Carson (1989) found that iterated questions tended to induce various forms of compliance bias: the respondent gives higher values for an amenity, not because these values represent his or her true WTP amount, but because the respondent feels pressured by the follow-up questions to give more than he or she really is willing to pay. Finally, since we included an open-ended question on WTP at the end of the survey, not only did we not force the respondents to pick an arbitrary value but we also improved the likelihood of receiving bid amounts that would provide a more precise estimate of the individual's WTP.

Prior to the WTP question and after explaining the need for funds to restore instream flows, respondents were asked whether their households would pay anything for insuring that the Yaqui River would have instream flows again.

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The main objective of this "payment principle" question, as explained by Bateman et al. (1995) and Arrow et al. (1993), is to validate a zero WTP response.

3.4. *Survey structure*

The survey format for the heads of households in Ciudad Obregon was patterned based on previous CVM questionnaires conducted around the world (Hadker et al., 1997; Tapvong and Kruavan, 1999; Loomis, 1987; Loomis et al., 2000; de Oca and Bateman, 2006) in terms of introductory questions, background information, proposals, alternatives, visual aids, WTP questions and demographics. The survey questions are listed in Table 1. In addition, the respondents were presented with the following information to frame the hypothetical market and set the CVM scenario, in the form of photographs, color graphics, and narratives:

- Background on the Yaqui River Delta: Each interviewer presented basic geographic information on the Yaqui River Basin and Delta, a description of agricultural activity in the area, and a summary of some of the environmentally sensitive issues and ecosystem health losses that the Yaqui River Delta is facing due to the lack of water in the River.
- Environmental services sustained by the Yaqui River: Each interviewer presented information on the key environmental services that could be provided by the Yaqui River Delta if instream flows in the Yaqui River were restored. Survey respondents were told that the cost of achieving this would be spread among all households in Ciudad Obregon, and were provided with a general picture of what the alternative conditions would look like based on the upstream environment. Respondents were not told how much water could or should be purchased, since a water market in the Delta does not exist and the farmers have not been surveyed.
- Scenario description: Each interviewer explained how the overall Yaqui River Delta ecosystem functions under the current conditions and with increased ecosystem services sustained by the existence of water flows in the Yaqui River.
- Payment vehicle: Each interviewer explained that improvement of the Yaqui River Delta ecosystem would require purchasing water from farmers, and that these funds would be obtained by the local water utility increasing its charges to households in Ciudad Obregon on their monthly water bills.

3.5. *Anticipating potential biases*

It is well known that many sources of bias can occur in a poorly designed and administered CVM survey (Mitchell and Carson, 1989, pp. 231–259). Potential sources of biases in this CVM survey were addressed as follows. The significance of the population choice bias was assessed by comparing demographic information of the sample to the population of Ciudad Obregon. Sample selection bias was minimized by interviewers immediately approaching the next available house/person immediately after the end of each interview (Bateman et al., 1995). A full range of survey sites was used, giving a representative sample of the population a known and positive probability of being included in the sample, thereby minimizing the sampling frame bias. Starting point bias in the bids was assessed by determining the dependence of the WTP on the bid starting point. This tends to be greatest when a bidding game format is used, since the initial bid offered to respondents can influence the final bid tendered, but can occur in any DC CVM because of yea-saying behavior.

Since the interviews were initiated by informing potential respondents that the research was sponsored by a university, the potential sponsor bias was minimized because respondents in Mexico probably consider a university a neutral body (Navrud and Mungatana, 1994). Furthermore, because the interviews were conducted by students of a university that is 400 km from Ciudad Obregon, any interviewer bias was minimized, since respondents did not need to either please or gain status in the eyes of the interviewer. To avoid scenario misspecification biases, all interviewers were trained to conduct CVM surveys, which prepared them to answer the questions that respondents were likely to have (Whittington, 1998). Also, the use of a combination of narratives, photographs and graphics to describe the environmental services to be valued in the Yaqui River provided a clear explanation as to why people should have to pay for improving the health of the Yaqui River Delta ecosystem and what this improvement could achieve.

3.6. *Data analysis*

Three rationales were applied to justify excluding respondents from the sample. First, survey responses were rejected if the indicated WTP was unrealistically large, whereby the value for the ratio of WTP to income exceeded 5% (FAO Information Division, 2000). Second, survey responses were excluded if a respondent's indication of a WTP of zero was determined to be a "protest zero" (e.g. Carson et al., 2003; Gonzalez-Caban and Loomis, 1997; Whittington et al., 1991; Hadker et al., 1997), though valid zero responses were kept. Reasons for a protest zero include disagreement of the respondent with some aspects of the scenario described in the survey, the respondent believes that someone else should pay for the commodity or service, or the respondent indicates distrust of the organization that will manage the collected money or the program (FAO Information Division, 2000). When a respondent indicated a zero WTP, they were asked to explain their choice. If they indicated either "Preservation of the Yaqui River Delta ecosystems is my right and it is unfair to expect me to pay for it. Instead the government should pay for it." or "I do not trust in the authorities.", the respondents were counted as a protest zero bid (Mitchell and Carson, 1989). Third, responses were excluded when the interviewer lacked confidence in the sincerity of the respondent's answers, as indicated in debriefing questions related to the interviewer's perception about the respondent's understanding of the topic and their sincerity (Hadker et al., 1997).

In order to better understand the determinants of the households' WTP responses and to learn whether these determinants are consistent with economic demand theory, a series of multivariate analyses were performed. If a group of independent variables believed to be theoretical determinants of people's demand for the good being valued are significant and have the expected relationship (e.g. WTP increases with income), we have more confidence that the WTP is theoretically valid (Urama and Hodge, 2006).

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Table 1 – Questions addressed and information collected in the survey

Variable	Question/information	Possible response
HEARD	Has the respondent ever heard of the Yaqui River?	1=Yes; 0=No
VISIT	Has the respondent ever visited the Yaqui River or the coastal zone?	1=Yes; 0=No
VISITFUTURE	Does the respondent plan to visit the Yaqui River or the coast?	1=Yes; 0=No
INFORMATION	Was the information presented in Card A new to the respondent?	1=Yes, very new; 2=Only some of it is new; 3=I know all this already
VEGETATION, FAUNA, FISHERY, OPTION, EXISTENCE, FUTGENERATIONS, CULTURAL, CLEANSER, RECREATION	Possible reasons for valuing water flows or environmental services in the Yaqui River	For each reason, 1=not important, 2=somewhat important, and 3=very important,
PAY	Is the respondent willing to pay anything at all?	1=Yes; 0=No
WHYNOT	Reasons why the respondent is not willing to pay anything at all?	1=The household does not receive any benefits; 2=The household cannot afford to pay currently; 3=Government should pay for it; 4=I do not trust in the authorities; 5=Other
BIDAMOUNT	Monetary amount the respondent was asked to pay in the dichotomous choice CVM WTP question	10–150 $M per month in 15 $M intervals
REFERBID	Response to the bidding question	1=Yes; 0=No
WTP	Maximum monthly amount the household would pay for specified services in pesos	
AGE	Respondent's age taken as either continuous or ranked values	
PERCLIVED	Percentage of life respondent has lived in the area	1≤20%; 2=21% – 40%; 3=41–60%; 4=61–80%; 5≥80%
OCCUPATION	Which category best describes the respondent's occupation	1=Government employee; 2=Private employee; 3=Laborer; 4=Student; 5=Merchant; 6=Pensioned; 7=House worker; 8=Professor; 9=Unemployed; 10=Other
EDUCLEVEL	Which was the highest level of formal schooling the respondent has completed?	1=Primary; 2=Middle school; 3=High school; 4=Technical degree; 5=Bachelor degree; 6=Postgraduate; 7=Never went to school; 8=Other
NUMPEOPLE	Number of people living in the household taken as either continuous or ranked values	
CHILDREN	Number of children younger than 15 years old living in the household, taken as continuous values	
CONFLICT	Attitude towards projects in your city (or country) where there was a conflict between economic development and the environment	1=Favor preservation of the environment more frequently; 2=Favor economic development more frequently; 3=Favor development and preservation of the environment equally
EDUCATION, CRIME, ENVIRONMENT, UNEMPLOYMENT, HOSPITALS, CORRUPTION	Ranking of social problems according to their importance or most deserving of funding: education, crime prevention, the environment, unemployment, hospitals maintenance, fight against the corruption	For each problem: 1=most important to 6=less important
MEMBER	Was the respondent a member of an organization related to environmental conservation?	1=Yes; 0=No
FARMING	Was the respondent or his/her close family associated with the farming industry?	1=Yes; 0=No
ECONVAL	Should the environment be considered as a service that has an economic value?	1=Yes; 0=No
IMPORTECONVAL	Putting an economic value to nature could make people more aware about its importance?	1=Yes; 0=No
INCOME	Monthly income for all wage earners of the household in pesos	1<2500; 2=2500 to 5000; 3=5000 to 10,000; 4=10,000 to 20,000; 5>20,000 or more; 6=Did not answer
GENDER	Respondent's gender	1=Male; 2=Female
UNDERSTANDING	How well the respondent understood the questions?	1=Well; 2=Not too well; 3=Not at all
SINCERITY	How confident about the respondent's sincerity?	1=Very confident; 2=Not so; 3=Not at all

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Table 2 – Demographic information results

	Survey sample	Ciudad Obregon
Number of households	148	61,409
Gender (% female)	51%	51% [a]
Mean age (years)	40	39 [a]
Mean years having lived in area (years)	34	NA
Mean household size	3.9	4.1 [a]
Mean household income (M$/month)	6,100	5500 [b]
Occupation:		
Government employees	12%	35% [a]
Private employees	18%	
Professors	10%	23% [a]
Merchants	10%	
Students	5%	11% [a]
Pensioned	10%	9% [a]
House workers	24%	13% [a]
Laborers	7%	8% [a]
Farmers	3%	
Unemployed	1%	1% [a]
Highest level of formal schooling completed:		
None	3%	3% [a]
Primary school	12%	10% [a]
Middle school	28%	36% [a]
High school	23%	15% [a]
Technical degree	11%	6% [a]
Bachelor's degree	18%	30% [a]
Master's degree or higher	5%	

[a] Ciudad Obregon. Source: INEGI, 2000.
[b] Mexico. Source: INEGI, 2004.

Two different sets of household WTP information could be used as the dependent variable in these analyses: the yes/no answers to the first monthly fee offered in the DC format question and the follow-up, open-ended maximum WTP answer given by the respondent to the follow-up question. In earlier CVM studies, the most common best-fits for DC, yes/no data with a WTP distribution censored at zero have been achieved with maximum likelihood estimation methods such as logit, probit or Tobit models (Loomis et al., 2000; Tapvong and Kruavan, 1999; Venkatachalam, 2004; de Oca and Bateman, 2006). We applied a logit model to fit the yes/no answers to the first monthly fee offered in the DC format question data. We also decided to analyze the maximum WTP answer through ordinary least squares (OLS) regression to test the robustness of our model, which has been commonly applied in other such studies (e.g. Lauria et al., 1999; Hadker et al., 1997; Urama and Hodge, 2006).

To simplify the regression analysis, the socio-demographic and attitude variables presented in Table 1 were first subjected to tests for determining whether the mean responses for a given independent variable were statistically different. The *t*-test and one-way analysis of variance (ANOVA) test were used for cases where the independent variable consisted of two and greater than two discrete values, respectively. Only the independent variables that were found to be determinants of WTP at the 0.05 significance level or better were retained for further analysis. The data were also tested to determine whether sample followed a normal distribution, to ensure the validity of the *t*- and one-way ANOVA tests. We calculated the coefficient of variation, the Kolmogorov–Smirnov test statistic, and the Shapiro–Wilk test statistic. The calculated values were compared to tabulated levels corresponding to a given level of probability that the sample was normally distributed.

4. Results and discussion

4.1. *Response rate, demographics, and attitudes regarding the environment*

A total of 148 households responded out of 197 interviews attempted, for a response rate of 75%. Results from a total of five respondents were rejected for two reasons. First, two WTP

Table 3 – Results for familiarity with the Yaqui River and environmental attitudes

Question/information	Result
Heard about the Yaqui River at least once	Yes: 95%
Had visited the Yaqui River downstream of Oviachic dam or coastal zone	Yes: 82%
Plan to visit these places in the future	Yes: 75%
Was information presented on the Yaqui River and environmentally issues associated with lack of water new?	All information was new: 41% Some information was new: 35% No information was new: 24%
Preferences between economic development and environmental preservation	Favor environmental preservation: 23% Favor economic development: 9% Balance economic development and environmental preservation equally: 68%
Members of an organization related to environmental conservation	Yes: 5%
Relationship to the farming industry	Yes: 48%
Environment should not be considered as a service that has an economic value and that would not make people more aware of its importance	Yes: 3%
Environment should not be considered as a service that has an economic value, however doing so could make people more aware of its importance.	Yes: 15%
Environment should be considered as a service that has an economic value and that could make people more aware of its importance.	Yes: 79%
The environment should be considered as a service that has an economic value but that would not make people more aware of its importance.	Yes: 3%

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responses were extraordinarily high and had WTP/Income values higher than 5%. Second, three respondents were excluded because the interviewer stated he or she was "not confident at all" about the sincerity of the respondent's answers.

Demographic information for the respondents and for Ciudad Obregon as a whole is presented in Table 2. The information in Table 2 indicates that the sampled population is representative of the Ciudad Obregon population. Table 3 shows the results from the questions oriented towards the familiarity of the respondents with the Yaqui River Delta and the respondents' environmental attitudes. These results indicate that the majority of the respondents were at least somewhat familiar with the Delta and the problems associated with lack of flow in the Delta.

Fig. 2 shows the results where respondents were asked to indicate the importance of each potential reason for valuing water flows or environmental services in the Yaqui River Delta. Although the differences in importance between each environmental service valued are not significant, the results agree with findings from other studies showing that most of the total value was associated with the non-use values associated to future use and future generations (Brown, 1991; Holmes et al., 2004; Loomis, 1998). The results of the respondents' rankings of which social problems are most deserving of funding indicated that, although environmental issues are thought to be important to the respondents, they are significantly less deserving of funding than "education" and "unemployment and poverty."

4.2. *Dichotomous choice results*

Of the 148 respondents remaining after five were eliminated for reasons explained above (insincerity of response or high WTP/income ratio), 18 more responses were classified as protest zeros and were eliminated. Of the remaining 125 respondents, there were 6 other zero WTP responses (5%) and 119 non-zero responses (95%). Table 4 shows the distribution of initial bids and the corresponding answers from the respondents. The results include the six other (non-protest) zero WTP responses. The mean WTP from the dichotomous choice results was M$52 per month (equivalent to US$4.70 per month using an exchange rate of M$11 to US$1 as of April 2007), calculated as

$$\frac{1}{N}\sum_{i=1}^{N} X_i y_i \quad (1)$$

where N is the total number responses (N=125), X_i is the bid level, and y_i is the number of "yes" responses to that bid level.

Table 4 – Dichotomous choice results

Bid level in Mexican pesos	Number of respondents per given bid level	Number of respondents agreeing to bid level	Number of respondents not agreeing to bid level
10	8	8	0
20	8	7	1
30	10	9	1
40	9	8	1
50	9	5	4
60	10	5	5
70	11	10	1
80	10	6	4
90	7	7	0
100	6	5	1
110	7	5	2
120	8	4	4
130	8	6	2
140	7	4	3
150	7	3	4
Total	125	92	33

4.3. *WTP distribution*

The distribution of WTP obtained from the follow-up, open-ended question is shown in Fig. 3. The mean WTP was M$73 per month (equivalent to US$6.60 per month). The mean WTP was calculated from 125 respondent results, including the non-protest zeros. The mean WTP from the open-ended question is significantly higher than the mean WTP calculated

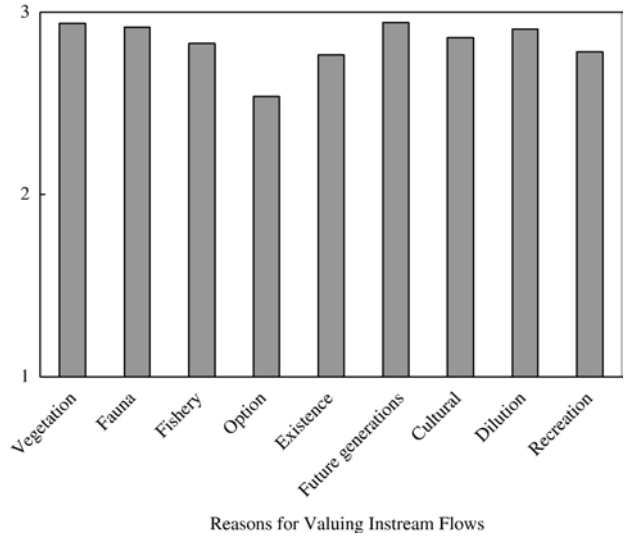

Fig. 2 – Results regarding importance of reasons for valuing water flows in the Yaqui River Delta.

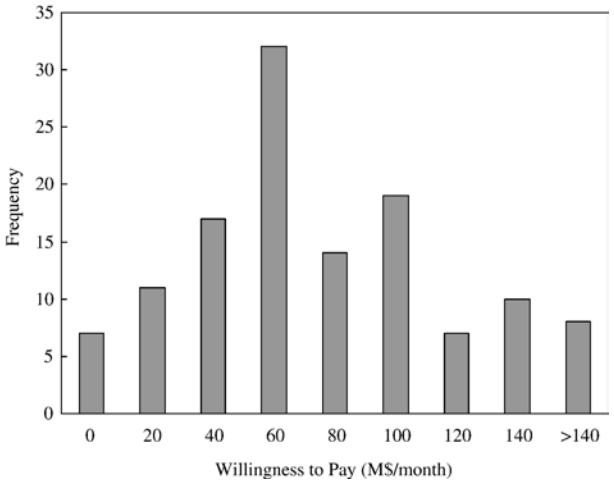

Fig. 3 – Distribution of willingness-to-pay.

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from the dichotomous choice question. This result is because, on average, most respondents who accepted the initial bids indicated a WTP estimate that was significantly higher than the initial bid when asked for their maximum WTP, whereas respondents who did not accept the initial bid, on average, chose a slightly lower WTP than the initial bid.

The WTP distribution shown in Fig. 3 appears to be normally distributed. Furthermore, the coefficient of variation (CV=0.61), Kolmogorov–Smirnov test statistic (D=0.082), and the Shapiro–Wilk test statistic (W=0.966) indicate that the sample comes from a normally distributed population of observations.

4.4. *Statistical and bid curve analysis*

Results from the t-test and the one-way ANOVA test showed that the t and F statistics, respectively, were greater than the statistical critical values (at least at the 0.05 significance level) for seven variables: INFORMATION, BIDAMOUNT, AGE, OCCUPATION, EDUCLEVEL, CHILDREN and INCOME. Thus, we could reject the hypothesis that mean WTP is equal across different groups for these variables and affirm that these variables have a significant influence on WTP.

As suggested earlier, we assessed starting point bias by calculating the maximum WTP to starting bid ratio. We found that a high percentage (43%) of these ratios equaled 1.0, while 27% were less than 1.0 and 30% were greater than 1.0. These results suggest that there may have been some starting point bias present. However, this bias can go in both directions and no generally valid method exists to adjust the findings to compensate for the effect of the starting point in a CVM survey (Carson et al., 1985).

Once the potentially significant variables were determined and several variables were recoded, multivariate linear and logit regressions of WTP versus six of the seven significant variables were fitted for the bid curve analyses of the maximum WTP and DC responses. The regressions were determined from 125 respondent results, including the non-protest zeros. The OCCUPATION variable was not included in the regressions, since the numerical values for this variable lack hierarchical order. Table 5 shows the results, including the estimated coefficients and their associated t-statistics. In addition, the sign expected for each coefficient is indicated in this table.

The linear and logit models gave roughly similar results in terms of the number of significant determinants and the corresponding levels of significance associated with the estimated coefficients. The four significant determinants for the WTP bids were found to be the initial bid amount, number of years of formal education, number of children younger than 15 years old living in the household, and household monthly income. On the one hand, as expected, the coefficient associated with the initial bid amount had a positive sign for the linear model, indicating that the higher the pesos amount the respondent was asked to pay initially, the higher the respondent's final WTP. On the other hand, also as expected, the coefficient associated with initial bid for the logit model was negative, indicating that respondents were more likely to give a negative answer as the initial bid increased. WTP also increased with income and household educational level, as has been found by most researchers (e.g. Whittington et al., 1990; Carson and Mitchell, 1993). Finally, WTP also increased with number of children in the household, which is another result found in most WTP studies (e.g. Seip and Strand, 1992). Overall these results demonstrate construct validity of our study (Mitchell and Carson, 1989, p. 213).

The adjusted R^2 of the linear and logit models were 0.44 and 0.41, respectively, which, according to Mitchell and Carson (1989) confirms that the models are reliable. The logit model fit is slightly inferior to the linear model fit, but the relatively similarity between these two types of models indicates that the WTP-determinant relationships found here are robust.

5. Conclusions

Following the guidelines and design issues suggested by the NOAA Blue Ribbon Panel Committee (Arrow et al., 1993), a CVM survey was used to obtain estimates of WTP for six environmental services (preservation of riparian vegetation, wetlands and estuaries; provision of habitat for birds and other fauna; maintenance of local fisheries; non-use values; pollutants

Table 5 – Bid curve analysis: estimated WTP model

		Linear regression model		Logit regression model	
Variable	Expected sign of coefficient	Estimated coefficient	t-statistic	Estimated coefficient	t-statistic
Constant		−22.025	−1.117	−2.523	−1.451
BIDAMOUNT	+/−	0.434	5.590[a]	−0.022[a]	3.323
EDUCLEVEL	+	1.980	1.948[b]	0.151[c]	1.788
CHILDREN	+	7.979	2.812[a]	0.558[b]	2.176
INCOME	+	0.003	4.146[a]	0.00025[a]	2.559
AGE	+	0.267	1.031	0.032	1.440
INFORMATION	+	−2.372	−0.568	0.199	−0.629
F-statistic		16.36[a]		6.36[a]	
Adjusted R^2		0.44		0.41[d]	
Number of observations		125			

[a] Significant at the 0.01 level.
[b] Significant at the 0.05 level.
[c] Significant at the 0.10 level.
[d] Pseudo R^2 (Nagelkerke, 1991).

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dilution and water quality protection; and provision of recreational uses) that could be sustained by water flows in the Yaqui River Delta. We used a single-bound DC question followed by an open-ended question eliciting maximum WTP. A total of 148 household interviews covering 40 colonies (neighborhoods) throughout Ciudad Obregon were completed. The mean WTP was N$ 73 per month, to be paid in water bills. The WTP was found to be significantly influenced by the following variables: age, initial bid amount, income, educational level, occupation, level of information about the environmental situation in the area, and number of children younger than 15 years old living in the household.

In order to determine whether these determinants were consistent with economic demand theory and to assess the theoretical validity of the CVM, a series of bid curve analyses were performed. The linear and logit models provided good fits and confirmed the reliability of the WTP data. The statistical tests indicate that WTP values were systematically related to two of the key variables suggested by economic theory and CVM studies elsewhere: respondent's income and education. In addition, the first reason for valuing restored instream flows in the Yaqui River, the future generations, was also confirmed when the number of children younger than 15 years old in the household was also found to be significantly related to WTP. The bid curve analyses also indicated that the answers to the open-ended WTP question were apparently influenced by the initial bid amount.

This study is one of the few that has used CVM to value several environmental services sustained by water flows in a developing-country delta, setting a precedent for this type of analysis in a complex socio-economic context. The valued environmental services included the existence, option and bequest values, whose estimation is necessary if we want to manage water resources under a sustainable approach over the long-term under unknown conditions, which is especially important in water-scarce basins.

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