Economic Value of Riparian Ecosystem Services

State of Knowledge and Implications for the Sacramento River Corridor

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1. Introduction

The Sacramento River is the largest river in California. It supplies approximately 35% of the state's total water supply. Although a scientific consensus of exact magnitude of land use change does not exist, there is little doubt that riparian forests and wetlands have been replaced by agricultural and residential uses in the river corridor (Kelly, 1989).

Since the late 1980s, an effort has been made by federal, state, and non-profit agencies to protect and improve the remaining riparian habitat along the Sacramento River. As a result, land along the River has been taken out of agricultural use and restored to native habitat. The main approach followed by state and non-state actors was to purchase agricultural land bordering the river and permanently convert it from agricultural production to habitat by revegetating with native trees, shrubs etc. (Golet et al., 2003). Some of these lands have been made available for outdoor recreational use to the public. For example, the Sacramento River National Wildlife Refuge was established in 1989 with a goal to provide up to 7,284 hectares of habitat for endangered and threatened species, migratory birds, and anadromous fish. The Sacramento River National Wildlife Refuge is situated in the Sacramento Valley on 29 individual units along a 110-mile stretch of the Sacramento River from Red Bluff to Princeton in Tehama, Butte, Glenn, and Colusa Counties. Rough estimates suggest that thousands of recreationists visit the river for boating, fishing, hiking or other activities.

Often goods and services provided by human-natural ecosystems cannot be produced simultaneously. For example, clearing land for food production may eliminate habitat for certain species, increase flooding in downstream areas and reduce recreational opportunities.[2] Conversely, conservation efforts to restore certain ecosystem services often require a change in agricultural practices that may affect local agricultural economy. Since a change in land use practices or policy typically involves a tradeoff among ecosystem goods and service, quantifying and valuing ecosystem services can inform such tradeoffs and provide incentives to allocate land use for higher valued uses.

The goal of this report is to summarize key approaches and conclusions of the economics literature on the benefits of riparian habitat conservation. There is a sizeable economics literature on valuation of ecosystem services in riparian habitats, although no comprehensive assessment of ecosystem services of Sacramento River corridor exists. We provide an overview of the current literature on ecosystem services valuation of riparian habitats in other geographical settings to provide a context for a better understanding of the potential effects of conservation efforts in the Sacramento River corridor on ecosystem

[2] By reducing the "roughness" in the area conveying the floodwaters, clearing allows them to move more quickly and at a lower stage through the cleared area. Recreational opportunities will be reduced if the land was previously publicly accessible for recreational opportunities, or may increase if private landowners use their property for recreational use.

services and resulting economic benefits. A summary of this information can also help prioritize future research needs.

Our criteria for selecting economic studies to include in this report were twofold: (i) relevance of the ecosystem service for the Sacramento river corridor (e.g. we paid special attention to recreational values of the river system and flood control which are directly relevant for Sacramento River); and (ii) some similarity of the geographical location (i.e. we have not included studies on coastal or lake riparian ecosystems but focused river riparian ecosystems). [3]

This report is organized as follows: Section 2 describes the concept of ecosystem services and how it relates to the framework of total economic value, with a brief outline of valuation techniques. Section 3 describes the ecosystem services provided by riparian habitat. Section 4 provides an annotated bibliography, briefly summarizing a selection of studies, papers, and articles that may be used to assist with the analysis of riparian habitat restoration efforts. Comprehensive literature reviews and/or meta-analyses, and California study area papers were emphasized, and listed before selected case studies. An online database with links the original sources will also be provided for readers interested in obtaining the complete analysis of the summarized work.

2. Ecosystem Services and Total Economic Value

Economic valuation of the services provided by nature is widely perceived by scientists and policy makers as an appealing and important approach to support management decisions. The notion of total economic value (TEV) provides an all-encompassing measure of the economic value of any environmental asset (Pearce and Turner, 1990). The concept of TEV was established prior to 1990, but the concept of ecosystem services came to prominence after the Millennium Ecosystem Assessment in 2000. The two concepts are closely related; in effect TEV provides a suitable framework for valuing ecosystem services.

2.1. Ecosystem Services

The Millennium Ecosystem Assessment (2000) defines Ecosystem services as benefits people obtain from ecosystems. Four kinds of ecosystem services can be distinguished:

- **Supportive** services those that lead to the maintenance of the conditions for life, such as nutrient cycling.
- **Provisioning** services those that provide direct inputs to human economy, such as food and water.

[3] A related body of economic literature is concerned with the choice of optimal policy instruments, such as subsidy programs, conservation easements, mitigation credits, or other market-based payments for particular ecosystem services, to incentivize land use practices that reduce runoffs or enhance habitats. That literature is a beyond the scope of this report.

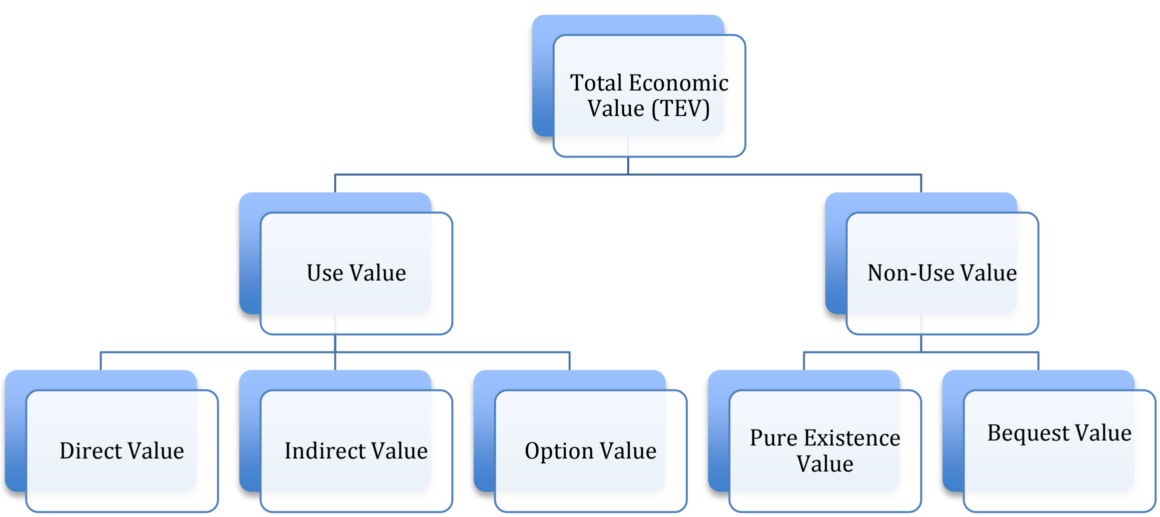
- **Regulating** services such as flood and disease control.
- **Cultural** services such as provision of opportunities for recreation and spiritual or historical purposes.

To avoid the problems associated with too broad and economically imprecise definitions of ecosystem services, Brown et al. (2007) argue that ecosystem services should be defined as "flows from an ecosystem that are of relatively immediate benefit to humans and occur naturally" (Brown et al., 2007:334). Boyd and Banzhaf (2007:619) suggest narrowing this definition even further to include only end-products: components of nature, directly enjoyed, consumed, or used to yield human well-being." The framework of total economic value is useful in this regard.

2.2. Total Economic Value

Total economic value is an expression of the total value of the benefits derived from a marginal change in an ecosystem, expressed in monetary terms. It can be divided into use and non-use values. Use values are concerned with the enjoyment or satisfaction received directly by biological resources. Use values in turn can be divided into direct, indirect, and option values (see Figure 1).

Figure 1: The Total Economic Value Framework



Direct use values can be relatively easily observed and measured, often by assigning prices to them. For example, the value of environmental products such as raw materials and food are exchanged in well-defined markets where value can be determined in a straightforward manner. Indirect values are primarily derived from ecosystems such as environmental self-regulation and flood control. Often the market does not price all direct use values of the environment e.g. recreational or subsistence fishing and hunting are public goods are not priced by the market. It is also the case that indirect use values and non-use values are not exchanged in or priced by markets. Option values are future values derived from complete and healthy environments.

Non-use value is the value that people assign to economic goods even if they have never used it nor do they intend to use in the future. Nonuse values encompass a variety of values such as bequest and intrinsic or existence values Altruistic/bequest value is the value of leaving the environment for rest of humanity and future generations. Intrinsic value is the satisfaction derived from the existence of nature.

Ecosystem services have economic values, and thus investments in conservation can be judged in economic terms. The total economic value approach provides a basis to assess the benefits and costs of protecting or conserving biological resources such as riparian ecosystem. The value of conserving biological resources can be considerable. However, in the case of ecosystem services, much of the total economic value may lie in indirect use or non-use values. Quantifying ecosystem services values can be very challenging as there are many assumptions to be made, including valuation methodology.

2.3. Valuation Techniques

Environmental resources impart a complex set of values to individuals and various benefits to society. Environment valuation is based on the assumption that individuals are willing to pay for environmental gains, and conversely, are willing to accept compensation for environmental losses. Individuals demonstrate preferences, which, in turn, place values on environmental resources. Environmental economists have developed a number of market and non-market-based techniques, based on the preferences, to value the environment. These preferences can be either revealed preferences or stated preferences.

2.3.1. Revealed Preference Methods

In the absence of clearly defined markets, the value of environmental resources can be derived from information acquired through surrogate markets. The most common markets used as surrogates when monetizing environmental resources are those for property and labor. The surrogate market methods discussed below are the hedonic price method and the travel cost method.

- **Hedonic Pricing Method:** The Hedonic Price method is based on consumer theory, which seeks to explain the value of a commodity as a bundle of various characteristics. It decomposes real estate prices into components attributable to different characteristics like pollution, accessibility, proximity to schools, shops, parks, etc. The method seeks to determine the increased willingness to pay for improved local environmental quality, as reflected in housing prices in cleaner surroundings (Freeman, 1979).

- **Travel Cost Method:** The Travel Cost method is a method has been used to measure the value of an ecosystem used for recreational purposes, by surveying recreationists on the economic costs they incur (time, out-of-pocket expenditures) when visiting the site. It determines the willingness to pay for access to the recreational benefits provided by the site, as a function of variables like consumer income, price (travel cost), and various socio-economic characteristics (Freeman, 1979).

2.3.2. Stated Preference Methods

Stated Preference Methods seek to measure individuals' value for environmental goods directly, by asking them to state their preferences for the environment. Unlike Revealed Preference Methods, these are used mainly to determine non-use values of the environment such as existence value, altruistic value and bequest value since these values do not turn up in any related markets.

- **Contingent Valuation Method:** This method asks people what they would be willing to pay for an ecosystem good or service. The approach uses a questionnaire or interview to present respondents with market-like situation where they can express a monetary value for a carefully described nonmarket good or service. A referendum format is often used to ask whether a respondent would vote yes or no for a referendum that would raise taxes a specified amount to provide a nonmarket good (Carson and Mitchell, 1989).

- **Choice Experiments:** In a choice experiment, individuals are given a hypothetical setting and asked to choose their preferred alternative among several alternatives in a choice set, and they are usually asked to perform a sequence of such choices. Each alternative is described by a number of attributes or characteristics. A monetary value is included as one of the attributes, along with other attributes of importance, when describing the profile of the alternative presented. Thus, when individuals make their choice, they implicitly make trade-offs between the levels of the attributes in the different alternatives presented in a choice set (Alpizar, Carlsson and Martinsson, 2003).

2.3.4. Cost/Defensive Expenditures

Defensive expenditure approach is based on the premise that technological substitutes for ecosystem services exist. The value of the ecosystem service is the expenditures to prevent or counteract the loss of an ecosystem service with a substitute (Freeman, 1979). These methods do not provide strict measures of economic values, which are based on peoples' willingness to pay for a product or service. Instead, they assume that the costs of avoiding damages or replacing ecosystems or their services provide useful estimates of the value of these ecosystems or services. This is based on the assumption that, if people incur costs to avoid damages caused by lost ecosystem services, or to replace the services of ecosystems, then those services must be worth at least what people paid to replace them.

- **Avoided Cost Method**: This method calculates the economic value of benefits that an ecosystem provides that would not exist without the ecosystem in place, and therefore, would represent an added cost to society if this environmental service no longer existed. For example, a wetland that supplies flood protection provides the avoided cost of having to invest in additional flood protection measures such as additional levees.

- **Replacement cost:** The loss of a natural system service is evaluated in terms of what it would cost to replace that service (e.g., tertiary treatment values of wetlands if the cost of replacement is less than the value society places on tertiary treatment).

2.3.5. Benefits Transfer

As valuation exercises are costly, researchers need some means of estimating non-market benefits without always having to undertake an individual study by one of the methods outlined above. Benefits transfer mainly works by taking estimates from one or more original studies, and transferring the results to a new context by adjusting for two factors: (a) differing socio-economic characteristics of beneficiaries, and (b) differing environmental characteristics of the two different contexts. There are three main approaches to benefit transfers:

- **Point estimate:** Transfer of mean willingness to pay from a study to case to a new case.

- **Transfer of benefit functions:** Employ exogenous variables from the new study into a valuation equation estimated from another study.

- **Meta-analysis**: A meta-analysis is a statistical analysis of past valuation studies. It combines values from various studies, estimates a value function and then employs valued of exogenous variables from the new study area to determine value of ecosystem services.

3. Ecosystem Services Derived From Riparian Habitat

Riparian areas are lands that occur along watercourses and water bodies. Typical examples include flood plains and stream banks. They are distinctly different from surrounding lands because of unique soil and vegetation characteristics that are strongly influenced by the presence of water. The character of a riparian area is dependent upon the condition of the watershed in which it is located and because of their variation across the U.S., riparian areas function in different ways. In spite of their differences, all riparian areas possess some similar ecological characteristics such as energy flow, nutrient cycling, water cycling, hydrologic function, and plant and animal population. Riparian area functions include (Steiger et al., 2005): maintenance of channel form, provision of bank stability, sediment regulation, organic matter and woody structure contribution, provision of shade, retaining organic matter, flood attenuation, nutrient movement and cycling, and habitat (e.g., food, refugia, reproduction)

The Millenium Ecosystem Assessment identified the types of ecosystem functions provided by wetlands (defined for the purposes of the assessment as including rivers) as summarized in Table 1.

Table 1. Ecosystem Services from Wetlands

Services	Description and Examples
Provisioning	
Food	Production of fish, wild game, fruits and grains
Fresh Water	Storage and retention of water for domestic, industrial and agricultural use
Fiber and fuel	Production of logs, fuelwood, peat and fodder
Biochemical	Extraction of medicines and other materials from biota
Genetic materials	Genes for resistance to plan pathogens, ornamental species, etc.
Regulating	
Climate regulation	Source of and sink for greenhouse gases; influence local and regional temperature, precipitation and other climatic processes
Water regulation (hydrologic flows)	Groundwater recharge/discharge
Water purification and waste treatment	Retention, recovery and removal of excess nutrients and other pollutants
Erosion regulation	Retention of soils and sediments
Natural hazard regulation	Flood control, storm protection
Pollination	Habitat for pollinators
Cultural	
Spiritual and inspirational	Source of inspiration
Recreational	Opportunities for recreational activities
Aesthetic	Beauty or aesthetic values
Educational	Opportunities for formal and informal education and training
Supporting	
Soil formation	Sediment retention and accumulation of organic matter
Nutrient cycling	Storage, recycling, processing and acquisition of nutrients

Source: Millenium Ecosystem Assessment (2005)

Sweeney et al. (2004) studied 16 streams in eastern North America focusing on the effects of deforestation and showed that riparian deforestation causes channel narrowing, which reduces the total amount of stream habitat and ecosystem per unit channel length and compromises in-stream processing of pollutants. Wide forest reaches had more macroinvertebrates, total ecosystem processing of organic matter, and nitrogen uptake per unit channel length than contiguous narrow deforested reaches. Stream narrowing nullified any potential advantages of deforestation regarding abundance of fish, quality of dissolved organic matter, and pesticide degradation. These findings show that forested stream channels have a wider and more natural configuration, which significantly affects the total in-stream amount and activity of the ecosystem, including the processing of pollutants. In another study

Studies by natural scientists have reinforced both current policy of the United States that endorses riparian forest buffers as best management practice and federal and state programs that subsidize riparian reforestation for stream restoration and water quality, the challenge for economics studies is to convert these benefits into monetary units. The next section contains an annotated bibliography of economic studies that have valued river riparian ecosystems.

4. Annotated Bibliography

This section contains an annotated bibliography of the literature reviews or meta analyses of economic values of riparian habitat, organized by the ecosystem services.

4.1. Literature Reviews and Meta Analyses

4.1.1. Wetlands

Woodward, Richard T., and Yong-Suhk Wui (2001). The Economic Value of Wetland Services: a Meta-Analysis. Ecological Economics 37 (2001) 257–270.

The authors note that the number of studies that quantify the value of wetlands and their services is rapidly expanding. A recent review of the thirty-three studies indicated that the per acre values of wetlands range from $.06 to $22,050. The authors assess thirty-nine studies to evaluate the relative value of different wetland services, the sources of bias in wetland valuation and returns to scale exhibited in wetland values. The authors conclude that the prediction of wetland's value based on previous studies remains highly uncertain and need for site-specific valuation efforts remains high. The following table summarizes the predicted values per acre for each possible single service wetland and the 90% confidence intervals around those estimates. Bird watching and commercial fishing are the highest valued services while amenity services are the least valued services. The authors also note that it would be highly speculative to use the mean values for a benefit transfer given the extraordinary confidence intervals.

Table 1. Predicted Values, Per Acre, of Single-Service Wetlands

Service	Mean	90% Confidence Interval Lower	Upper
Flood	$393	$ 89	$1747
Water Quality	$417	$126	$1378
Water Quantity	$127	$6	$2571
Recreation Fishing	$357	$95	$1342
Commercial Fishing	$778	$108	$5618
Bird Hunting	$70	$25	$197
Bird Watching	$1212	$528	$2782
Amenity	$3	$1	$14
Habitat	$306	$95	$981
Storm	$237	$11	$5142

Brander, Luke M, Raymond J. G. M. Florax, Vermaat, Jan E. (2006). The Empirics of Wetland Valuation: A Comprehensive Summary and a Meta-Analysis of the Literature Environmental and Resource Economics. 33(2): 223.

Wetlands are highly productive ecosystems, providing a number of goods and services that are of value to people. The open-access nature and the public-good characteristics of wetlands often result in these regions being undervalued in decisions relating to their use and conservation. There is now a substantial literature on wetland valuation, including two meta-analyses that examine subsets of the available wetland valuation literature. The authors collected over 190 wetland valuation studies, providing 215 value observations, in order to present a more comprehensive meta-analysis of the valuation literature that includes tropical wetlands (e.g., mangroves), estimates from diverse valuation methodologies, and a broader range of wetland services (e.g., biodiversity value). They also aim for a more comprehensive geographical coverage. They find that socio-economic variables, such as income and population density, that are often omitted from such analyses are important in explaining wetland value. They also assess the prospects for using this analysis for out-of-sample value transfer, and find average transfer errors of 74%, with just under one-fifth of the transfers showing errors of 10% or less.

4.1.2. Endangered Species

Richardson, Leslie and John Loomis (2009). The Total Economic Value of Threatened, Endangered and Rare Species: An Updated Meta-Analysis. Ecological Economics 1535-1548

This paper updates a 1996 meta-analysis of studies using the Contingent Valuation Method (CVM) to value threatened, endangered and rare species published in 1995. Studies conducted in or after 1995 were added to the model to test if new studies are systematically different from old studies and to determine whether willingness to pay for these species have changed over time. The authors conclude that newer studies generally yield higher willingness to pay. The average values per household by from 31 studies with 67 willingness-to-pay observations are reported below.

Table 2. Summary of Economic Value of Threatened, Endangered and Rare Species ($2006)

	Low Value	High Value	Average of all Studies
Studies Reporting Annual Willingness to Pay			
Bald Eagle	$21	$45	$39
Bighorn Sheep			$17
Dolphin			$36
Gray Whale	$24	$46	$35
Owl	$39	$130	$65
Salmon/Steelhead	$10	$139	$81
Sea Lion			$71
Sea Otter			$40
Sea Turtle			$19
Seal			$35
Silvery Minnow			$38
Squawfish			$12
Striped Shiner			$8
Turkey	$11	$15	$13
Washington State Anadromous Fish Pop.	$147	$311	$241
Whooping Crane	$44	$69	$56
Woodpecker	$13	$20	$16
Studies Reporting Lump Sum Willingness to Pay			
Arctic Grayling	$20	$26	$23
Bald Eagle	$245	$350	$297
Falcon			$32
Humpback Whale			$240
Monk Seal			$166
Wolf	$22	$162	$61

4.1.3. Groundwater or Drinking Water Quality

Boyle, Kevin J., Gregory L. Poe, and John C. Bergstrom (1994). What Do We Know About Groundwater? Preliminary Implications From a Meta-Analysis of Contingent-Valuation Studies. American Journal of Agricultural Economics,
Vol. 76, No. 5, Proceedings Issue (Dec., 1994), pp. 1055-1061.

In this study, the authors use meta-analysis to statistically investigate whether the eight contingent valuation studies of groundwater protection collectively provide a richer picture of the benefits of groundwater protection than can be developed from a qualitative comparison of the study features and results. Authors conclude that meta-analysis may provide an improved process of benefit transfer over the traditional ad hoc benefit transfers of estimated means from previous studies. However the authors also state that, because of inconsistent definition of groundwater contamination across studies, care should be taken in using the findings of the meta-analysis for benefit transfer purposes. Below is a summarizing the willingness to pay estimates from the eight studies included in the meta-analysis.

Table 3. Willingness to Pay For Improvement in Drinking Water Quality

Reference	Willingness to Pay ($1992)
Caudill (1992)	$56
Edwards (1988)	$1154
Jordan and Elnagheeb	$139
McClellan et al. (1992)	$118
McClelland et al. (1992)	$126
Poe (1993)	$320
Powell (1991)	$70
Schultz (1989)	$165
Sun (1990)	$750

4.1.4 Recreation

Rosenberger, Randall S. and John Loomis (2001). Benefit Transfer of Outdoor Recreation Use Values: A Technical Document Supporting the Forest Service Strategic Plan (2000 revision). Gen. Tech. Rep. RMRS-GTR-72. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 59 p.

This report provides information from a literature review of economic studies spanning 1967 to 1998 in the United States and Canada. These studies estimated outdoor recreation use values. The authors also provide guidelines on performing benefit transfers in the context of recreation use valuation. The authors conclude that the review of the literature and benefit transfer methods in this report should increase the defensibility of benefit estimates transfers when management and policy impacts of outdoor recreation are evaluated. Below are the summary statistics from recreation demand studies, 1967-1998, provided by the authors.

Table 4. Summary of Average Consumer Surplus Values per Activity Day per Person from Recreation Demand Studies – 1967 to 1998 ($1998)

Activity	Number of Studies	Mean of Estimates	Range of Estimates
Camping	$22	$30.36	$1.69 –187.11
Picnicking	$7	$35.26	$7.45 – 118.95
Swimming	$9	$21.08	$1.83 – 49.08
Sightseeing	$9	$35.88	$0.54 –174.81
Off-road driving	$3	$17.43	$4.37 – 33.64
Motorized boating	$9	$34.75	$4.40 –169.68
Non-motorized boating	$13	$61.57	$15.04 – 263.68
Hiking	$17	$36.63	$1.56 – 218.37
Biking	$3	$45.15	$17.61 – 62.88
Downhill skiing	$5	$27.91	$12.54 – 52.59
Cross-country skiing	$7	$26.15	$11.70 – 40.32
Snowmobiling	$2	$69.97	$36.23 – 103.70
Big game hunting	$35	$43.17	$ 4.74 – 209.08
Small game hunting	$11	$35.70	$3.47 – 190.17
Waterfowl hunting	$13	$31.61	$2.16 – 142.82
Fishing	$39	$35.89	$1.73 – 210.94
Wildlife viewing	$16	$30.67	$2.36 – 161.59
Horseback riding	$1	$15.10	$15.10 – 15.10
Rock climbing	$2	$52.96	$29.82 – 85.74
General recreation	$12	$24.26	$1.18 – 214.59
Other recreation	$11	$40.58	$4.76 – 172.34

4.1.5. Flood Risk

Daniel, Vanessa E., Raymond J.G.M. Florax , Piet Rietveld (2009). Flooding Risk and Housing Values: An Economic Assessment of Environmental Hazard, Ecological Economics (69) 355–365

The purpose of this paper is to explore the magnitude and determinants of the implicit price of the risk of flooding. They use a meta-analysis of 19 studies, exclusively from the US providing a total of 117 point estimates, to investigate the impact of exposure to flood risk in terms of the implicit price differential associated with the location of a house in a flood zone. Specifically, they use the meta-analysis to shed light on the difference between pre- and post-event valuation, and the potentially confounding effect of the coincidence of positive water-related amenities with flood risk. An overview of the 19 available studies shows that estimates of the implicit price of flood risk vary considerably. A multivariate meta-analysis, controlling for observable and unobservable differences across studies through fixed and random effects, shows that the marginal effect of an increase in the probability of flood risk of 0.01 in a year amounts to a difference in transaction price of an otherwise similar house of − 0.6%. The actual occurrence of a flooding event or increased stringency in disclosure rules causes ex-ante prices to differ from ex-post prices, but these effects are small. The marginal willingness to pay for reduced risk exposure has increased over time, and it is slightly lower for areas with a higher per capita income. They show that obfuscating amenity effects and risk exposure associated with proximity to water causes systematic bias in the implicit price of flood risk.

4.2. Case Studies

4.2.1. Riparian Habitat

Holmes, T. P., Bergstrom, J. C., Huszar, E., Kask, S. B., & Orr, F. (2004). Contingent Valuation, Net Marginal Benefits, and the Scale of Riparian Ecosystem Restoration. Ecological Economics, 49(1), 19-30

This study was used to estimate the benefits and costs of riparian restoration projects along the Little Tennessee River in western North Carolina. The Little Tennessee River is located in the southern Appalachian Mountains, the majority of the land within the watershed of the Little Tennessee River is privately owned and this has led to a major impact on ecosystem structure and function. They identified ecosystem services in the Little Tennessee River under five categories: habitat for fish, habitat for wildlife, erosion control and water purification, recreational activities, and ecosystem integrity. Then they measured these five categories using a categorical scale, which involved the level of provision, they used low, moderate, and high to measure the level of provision of the ecosystem services. Then five programs were developed. The first was proposed as introducing no change. The other programs provided BMP protection for all small streams plus river restoration increasing by an increment of 2-miles for each program. Then they showed people the affect the programs had on the ecosystem services with the categorical scale. They used a computerized survey, which asked yes or no questions to certain bids on the programs being offered. If they said yes then the bid price would go up in price for the next program, if they said no then the price would stay the same. They found the present value of public benefits generated by full restoration was estimated to be $472,560 per mile for a program that would restore 6 miles of the Little Tennessee River.

Loomis, John, Paula Kent, Liz Strange, Kurt Fausch, and Alan Covich (2000). Measuring the Total Economic Value of Restoring Ecosystem Services in an Impaired River Basin: Results From a Contingent Valuation Survey. Ecological Economics (33) 103-117

Five ecosystem services that could be restored along a 45-mile section the Platte River were described to respondents using a building block approach developed by an interdisciplinary team. These ecosystem services were dilution of wastewater, natural purification of water, erosion control, habitat for fish and wildlife and recreation. Households were asked dichotomous choice willingness to pay questions regarding purchasing the increase in ecosystem services through a higher water bill. Results from nearly 100 in-person interviews indicate that households would pay an average of $21 per month or $252 annually for the additional services. Generalizing this to the households living along the river yields a value of $19 million to $70 million, depending on how those that refused to be willing to be interviewed are treated. Even the lower bound estimates exceed the high estimate of water leasing cost of $1.13 million and conservation reserve program farmland easements cost of $12.3 million necessary to produce the increase in ecosystem services.

Kline, Jeffrey D., Ralph J. Alig, and Rebecca L. Johnson (2000). Forest Owner Incentives to Protect Riparian Habitat. Ecological Economics (33) 29-43

The authors examine the willingness of nonindustrial private forest owners in the Pacific Northwest to forego harvesting within riparian areas to improve riparian habitat. An empirical model is developed describing owners' willingness to accept an economic incentive to adopt a 200-foot harvest buffer along streams as a function of their forest ownership objectives and socioeconomic characteristics. Results suggest that owners' willingness to forego harvest varies by their forest ownership objectives. Mean incentive payments necessary to induce owners to forego harvest in riparian areas are higher for owners possessing primarily timber objectives ($128-137/acre/year) than for owners possessing both timber, and non-timber objectives ($54-69/acre/year), or primarily recreation objectives ($38-57/acre/year).

4.2.2. <u>Wetlands</u>

Pate, J., & Loomis, J. (1997). The Effect of Distance on Willingness to Pay Values: a Case Study of Wetlands and Salmon in California. Ecological Economics, 20(3), 199-207

Most contingent valuation studies in the literature utilized a pre-determined geographic market area for their sample frame. In other words, they did not include variables that would measure the extent of the geographic areas over which to aggregate willingness to pay. These studies implicitly assumed that the effects of geographic distance were moot; an assumption that could have led to an understatement of the aggregate benefit values computed in these studies. The overall goal of this study was to determine if distance affects willingness to pay for public goods with large non-use values. The data used came from a contingent valuation study regarding the San Joaquin Valley, CA. Respondents were asked about their willingness to pay for three proposed programs designed to reduce various environmental problems in the Valley. A logit model was used to examine the effects of geographic distance on respondents' willingness to pay for each of the three programs. Results indicate that distance affected willingness to pay for two of the three programs (wetlands habitat and wildlife, and the wildlife contamination control programs). We calculate the underestimate in benefits if the geographic extent of the public good market is arbitrarily limited to one political jurisdiction.

Table 5. Aggregate Willingness to Pay for Wetland Improvement and Contamination Control by Subsample

	San Joaquin Valley	Rest of California	Oregon	Washington	Nevada
Wetland Improvement					
Average WTP	$ 215.55	$ 210.77	$ 67.80	$ 99.75	$ 196.01
Aggregate (millions)	$ 175.00	$2,357.00	$ 81.00	$203.00	$ 102.00
Contamination Control					
Average WTP	$ 233.86	$ 222.69	$51.92	$ 86.35	$203.08
Aggregate (millions)	$ 190.00	$2,490.00	$62.00	$175.00	$105.00

Jenkins, W. A., Murray, B. C., Kramer, R. A., & Faulkner, S. P. (2010). Valuing Ecosystem Services from Wetlands Restoration in the Mississippi Alluvial Valley. Ecological Economics, 69(5), 1051-1061

This study area takes place in the Mississippi Alluvial Valley, which is the largest floodplain in the U.S.. About three quarters of the original bottomland hardwood forests have been converted to row crop agriculture. This study looks at valuing ecosystem services for restored wetlands and for croplands. They collected data in 2006 and 2007 for the following ecosystem services; carbon sequestration, nutrient retention, sediment retention, and amphibian and Neotropical migrant bird species richness. They were able to track the carbon accumulation growth by looking at the soil, live biomass, and other non-soil. They tracked nitrogen by computing the nitrate prevented from entering the local waterways by applying average annual values for nitrate lost in surface-water running, in lateral subsurface flow and in leachate from agricultural sites using output from the EPIC model. Then they measured waterfowl recreation through a meta-analytical study on outdoor recreation values conducted for the U.S. Forest Service.

Table 6. Annual GHG Mitigation, Nitrogen Mitigation, and Waterfowl Recreation Social Values (US$2008) for Wetland Reserve Project Land Aggregated at the Mississippi Alluvial Valley Level

Ecosystem service	WTP per ha (range)	All WRP land = 207,751 ha
GHG mitigation	$193 - $366	$44,844,289
Nitrogen mitigation	$918 - $1896	$249,088,722
Waterfowl recreation	$16	$3,322,896
Total	$1,127 - $2,278	$297,255,907

Gurich, John J., Fred J. Hitzhusen (2004). Assessing the Substitutability of Mitigation Wetlands for Natural Sites: Estimating Restoration Lag Costs of Wetland Mitigation. Ecological Economics (48) 409-424

The extent and rate to which mitigation wetlands can replace the functions of natural ones remains uncertain. Further, the economic time lag costs of wetland function restoration and therefore cost-effective and efficient means of wetland mitigation have yet to be adequately addressed. In this study, 16 mitigation wetlands were assessed, comprised of eight low elevation inland freshwater emergent marshes in Ohio and eight high elevation (>2285 m) freshwater emergent marshes in a wetland complex in Colorado, USA. This research identified the ecological substitutability of mitigation inland freshwater marshes for natural ones, estimated economic restoration lag costs to society and addressed least-cost approaches to successful mitigation.

Years required to achieve full functional equivalency for both floristics and soils for the Ohio sites under logarithmic growth ranged from 8 to 50 years with a median of 33 years. Years required to achieve floristic functional equivalency for the Colorado sites ranged from 10 to 16 years with a median of 13 years. Restoration lag costs per acre (0.4 ha) in Ohio ranged from $3460 to $49,811 per acre with an average of $16,640 per acre (2000 US$). Lag costs as a percentage of total restoration costs ranged from 5.6% to 52.8% with an average of 25%. Restoration lag costs per acre to achieve full floristic equivalency in Colorado ranged from $22,368 to $31,511 per acre with an average $27,392 per acre. Time lag costs as a percentage of total restoration costs ranged from 44% to 53% with an average of 49%. Findings of this research suggest that society is currently incurring significant wetland restoration costs due to time lags of mitigation sites. Requiring the posting of an interest accruing performance bond can serve to internalize the time lag costs to the permittee and provide an incentive for more cost-effective wetland restoration efforts.

Milon, Walter J., and David Scorgin (2006). Latent Preferences and Valuation of Wetland Ecosystem Restoration. Ecological Economics, 56(2), 162–175

The authors employ a latent class choice model to evaluate the effects of alternative ecological characterizations of wetland functions and services on individual preferences, and to determine whether socioeconomic factors and psychometric measures of environmental attitudes can explain differences in individual's preferences and values for wetland restoration. This analysis combines a multi-attribute choice model with information on individual's characteristics to evaluate preferences for restoration of the Greater Everglades ecosystem, one of the largest and most comprehensive wetland ecosystem restoration projects. To identify potential endpoints for Everglades restoration, two alternative ecological characterizations of the ecosystem were developed using the familiar distinction between function and structure. Survey data from a representative sample of the general population were used in a split-sample design based on the ecological characterization treatment. Within each subsample, the latent class analysis identified three groups who varied in their preferences for ecosystem restoration and socioeconomic profiles. The ecological characterizations had a significant influence on respondents' preferences and willingness to pay. The subsample responding to the structural characterization had a significantly larger share of respondents in the group who favored proposed restoration plans than the functional attribute subsample. In both subsamples, the group who favored restoration had a higher willingness to pay for restoration than other groups. The latent class analysis also revealed socioeconomic and attitudinal factors that explain some of the heterogeneity in preferences and willingness to pay within each subsample; this heterogeneity would not be identified with a standard choice model. In the context of Everglades restoration, the results provide a baseline assessment of public support and willingness to pay that suggests an emphasis on structural rather than functional restoration endpoints. The approach described in this article can be used in other policy studies of wetland ecosystems because multiple ecosystem services can be represented within a stated choice survey and differences in preferences and values for these services can be measured.

Table 7. Willingness to Pay for Everglades Restoration from the Function and Structural Attributes Subsample

Ecosystem Change	Mean	Group1	Group2	Group 3
WTP for Everglades restoration from the functional attributes subsample				
Partial Restoration				
Everglades National Park	$7.95	$51.45	---	-$6.46
Water Conservation Areas	$17.48	$54.80	---	-$3.00
Lake Okeechobee	$3.90	$12.60	----	-$7.20
Full Restoration	$29.33	$195.27	---	-$29.37
WTP for Everglades restoration from the functional attributes subsample				
Partial Restoration				
Wetland Species	$29.03	-$8.52	---	$43.67
Dryland Species	-$17.37	-$6.28	---	$17.56
Estuarine Species	$17.98	-$5/32	---	$32.00
Full Restoration	$59.26	-$40.23	---	$186.44

Carlsson, Fredrik, Peter Frykblom, and, Carolina Liljenstolpe (2003). Valuing Wetland Attributes: an Application of Choice Experiments. Ecological Economics 47:1: 95-103

The interest for wetlands is increasing, not only because of the possibility of a cost-efficient uptake of nutrients, but also because wetlands can be designed to provide other services. What values that are supplied depend largely on the design. There are numerous different design options, and different actors may promote different alternatives. Whether design of a wetland is for nutrient retention alone, or one that also serves other interests, policy makers need information about the value of different options. Conducting a choice experiment, the authors are able to identify attributes that increase and decrease citizens perceived value of wetlands. Using a random parameter model they find that biodiversity and walking facilities are the two greatest contributors to welfare, while a fenced waterline and introduction of crayfish decrease welfare.

4.2.3. <u>Endangered, Threatened, Rare Species</u>

Montgomery, C. A., & Helvoigt, T. L. (2006). Changes in Attitudes About Importance of and Willingness to Pay for Salmon Recovery in Oregon. Journal of Environmental Management, 78(4), 330-340.

The state of Oregon is trying to reverse the declines in the salmon and steelhead stocks in Oregon. Oregon uses as biennial phone survey, which is called the Oregon Population Survey to track changes in the socioeconomic characteristics of Oregonians to solicit their opinions on a variety of policy issues. They asked two questions toward salmon recovery. The first was a based on a Likert scale where they only had 4 answers: very important, somewhat important, not too important, and not at all important. The second question asked them how much they are willing to pay to help the recovery of salmon runs. The brackets started at $0, then $1-$3, $4-$6, $7-$10, and then more than $10. They looked at the years of 1996, 1998, 2000, and 2002 and found lower income households are more likely, and higher income households are less likely, to say that salmon recovery is important. But lower income households appear to be less likely to support salmon recovery efforts as reflected by their willingness to pay answers. The survey also shows that there is a decline in support for salmon recovery efforts from 1996 to 2002. In any survey year less than 5% of the respondents selected 'not at all important', 22% to 25% selected that they would pay $0 in every year. Along with 84% to 92% responded that recovery efforts is 'somewhat' or 'very important', while only 25 to 30% said they will pay $7 to $10 or more than $10 to help salmon recovery efforts.

Layton, D., Brown, G., & Plummer, M. (1999). Valuing Multiple Programs to Improve Fish Populations. Dept. of Environmental Science and Policy, University of California, Davis, CA.

Regulatory efforts to conserve natural resources rarely consist of a single program covering a single type of resource. Evaluating the benefits and costs of multiple programs affecting multiple resources presents regulators with a problem because the net benefits of any one program depends on the effects of the others. Washington State is currently considering a number of different programs that would each mitigate negative impacts upon its fish populations. A program-by-program attempt to estimate these net benefits independently would be expensive and cumbersome. The authors use the Stated Preference method to estimate benefits for different types of fish, which allow programs to be evaluated incrementally, conditional upon the amount of fish population improvements to date. This study evaluates the value of changes in the Washington State fish populations to the residents of Washington State. They look at the waters of Washington that encompass Puget Sound and coastal saltwater bodies, as well as the Columbia River system and other freshwater bodies.

Table 8. Willingness to Pay per Month per Household for 50% Increase in Fish Population and Willingness to Pay per Fish per Year for 2 Million Households.

	"High" Status Quo		"Low" Status Quo	
Fish Type	**WTP per month, per household for 50% Increase in Fish**	**WTP per Fish per year for 2 million households**	**WTP per month, per household for 50% Increase in Fish**	**WTP per Fish per year for 2 million households**
Eastern Washington & Columbia River Freshwater Fish	$ 14.27	$5.71	$14.55	$9.31
Eastern Washington & Columbia River Migratory Fish	$ 9.92	$238.08	$18.97	$1,821.12
Western Washington & Puget Sound Freshwater Fish	$15.52	$10.64	$ 28.84	$ 26.12
Western Washington & Puget Sound Migratory Fish	$ 20.83	$199.97	$ 28.63	$ 549.70
Western Washington & Puget Sound Saltwater Fish	$ 21.07	$4.70	$ 31.28	$27.80

4.2.4. Recreation: Fishing

Loomis, John, and Joseph Cooper (1990) Economic Benefits of Instream Flow to Fisheries: A Case Study of California's Feather River. Rivers Volume 1, Number, P. 23-30

The authors estimate the effect on recreationists' benefits of a change in instrem flow. Authors utilize a travel cost model demand equation that includes the level of fish catch as the quality variable, that is, in turn, a function of river flow.

Table 9. Consumer Surplus Estimates for Increases in Flow for Section 3 of North Fork Feather River in 1981.

	Consumer Surplus		
Marginal change Average Flow per cfs	**Total**	**Net Change**	
(initial):	$108,465	---	----
20 cfs increase:	$109,923	$1,458	$72.90
100 cfs increase:	$114,137	$5,672	$56.72
200 cfs increase:	$117,605	$9,140	$45.70

Pendleton, L. H., & Mendelsohn, R. (1998). Estimating the Economic Impact of Climate Change on the Freshwater Sports fisheries of the Northeastern U.S. Land Economic, 74(4), 483-496.

This study links models of global climate circulation, ecology, and economic valuation (hedonic travel cost and random utility models) to value the impact of global warming on freshwater sportfishing in the northeastern United States. An origin-specific linear random utility model (RUM) is introduced. The results of the RUM are shown to be comparable to those of a hedonic travel cost model. A doubling of atmospheric carbon dioxide is predicted to generate between a $4.6 million loss and a $20.5 million net benefit for the Northeast, depending on the climate scenario. The results compare the study against two different ecological and economic models based on actual data, one is the Gooddard Institute of Space Science (GISS) the other is Oregon State University (OSU).

Table 10. Total Welfare Impact for Recreational Fishing Under a Doubling of CO2 (1990 US$ Millions).

Total Welfare Impact for Recreational Fishing Under A Doubling of CO2 (1990 US$ Millions)						
	2C Change Only		OSU Predictions		GISS Prediction	
	RUM	HTC	RUM	HTC	RUM	HTC
Totals For Maine, New Hampshire, New York, and Vermont	$ 4.63	$13.04	$14.77	$12.32	$4.62	$20.47

Loomis, John, Cameron, T. A., Shaw, W. D., Ragland, S. E., Mac Callaway, J., & Keefe, S. (1996). Using Actual and Contingent Behavior Data with Differing Levels of Time Aggregation to Model Recreation Demand. Journal of Agricultural and Resource Economics, (1). 130.

A model of recreation demand is developed to determine the role of water levels in determining participation at and frequency of trips taken to various federal reservoirs and rivers in the Columbia River Basin. Contingent behavior data are required to break the near-perfect multicollinearity among water levels at some waters. The authors combine demand data for each survey respondent at different levels of time aggregation (summer months, rest of year, and annual), and our empirical models accommodate the natural heteroskedasticity that results. The empirical results show it to be quite important to control carefully for survey nonresponse bias.

Average expected monthly willingness to pay varied from about $13 (each summer month) for Lake Koocanusa to $99 (August) for Lake Roosevelt.

Duffield, J., Brown, T., & Neher, C. (1992). Recreation Benefits of Instream Flow: Application to Montana's Big Hole and Bitterroot Rivers. Water Resources Research, 28(9), 2169-2181.

Allocation of water between instream uses such as recreation and consumptive uses such as irrigation is an important public policy issue in the western United States. One basis for identifying appropriate levels of instream flows is maximization of net economic benefits. A general framework for estimating the recreational value of instream flows was developed and applied to Montana's Big Hole and Bitterroot rivers. The paper also provides a synthesis of methods for interpreting covariate effects in dichotomous choice contingent valuation models. Precision of the estimates is examined through a simulation approach. The marginal recreational value of instream flow in these rivers is in the range of $50 per acre foot (1 acre foot equals 1233.5 m3) for recreation at low-flow levels plus $25 per acre-foot for downstream hydroelectric generation. These values indicate that at some flow levels, gains may be achieved on the study, rivers by reallocating water from consumptive to instream uses.

4.2.5. Recreation: Waterfowl Hunting

Bergstrom, J.C., J.R. Stoll, J.P. Titre, and V.L. Wrigth (1990). Economic Value of Wetlands-Based Recreation. Ecological Economics 2:129-147.

The loss of wetlands is an issue of growing concern. Previous studies have focused primarily on quantifying the commercial, storm protection, and energy-output values of wetlands. Relatively little research has been devoted to quantifying the outdoor recreational value of wetlands. In this paper, the recreational value of wetlands is discussed conceptually within a total economic value framework. Total economic value contains many value components, which are broadly divided into non-use, current use, and future use values. Each of these value categories can be further subdivided into expenditures and consumer's surplus.

An empirical study was conducted to measure expenditures and consumer's surplus associated with on-site, current recreational uses of a coastal wetlands area. Aggregate expenditures were estimated at approximately $118 million and aggregate consumer's surplus was estimated at approximately $27 million. These results suggest that the economic impacts and net economic benefits associated with wetlands-based recreation may be substantial. Hence, recreational functions provided by wetlands may be important considerations for wetlands policy and management.

Cooper, J. and J. Loomis (1993). Testing Whether Waterfowl Hunting Benefits Increase With Greater Water Deliveries to Wetlands. Environmental and Resource Economics 3:545-561.

The change in waterfowl hunting benefits due to an increase in water deliveries to the levels required for biologically optimal wildlife refuge management at California's San Joaquin Valley National Wildlife Refuges are estimated with the Travel Cost Method, using both ordinary least squares and Poisson count data estimators. To test whether these increases were statistically significant, the Krinsky and Robb technique was used to find confidence intervals around the consumer surplus point estimates. The increases in consumer surplus were found to be statistically significant in 5 of the 6 refuges based on OLS regression estimates and in all 6 refuges using Poisson count data regression estimates. The consumer surplus, or net willingness to pay, per trip averaged $26.21 for the Poisson model and $15.62 for the OLS model. Total consumer surplus per refuge was highest at Mendota and lowest at Merced. In addition, a comparison of the marginal value of an acre-foot of water in consumptive recreational use versus agriculture use is made, with the finding that the marginal value of water in waterfowl hunting was greater than the marginal value of water in agriculture for one of the six refuges.

4.2.6. Recreation: Deer Hunting

Creel, M.D. and J.B Loomis (1990). Theoretical and Empirical Advantages of Truncated Count Data Estimators for Analysis of Deer Hunting in California. American Journal of Agricultural Economics 72: 434-441.

Truncated Poisson and truncated negative binomial count data models, as well as standard count data models, OLS, nonlinear normal, and truncated nonlinear normal MLE were used to estimate demand for deer hunting in California. The truncated count data estimators and their properties are reviewed. A large sample (N = 2223) allowed random segmenting of the data into specification, estimation, and out-of-sample prediction portions. Statistics of interest are therefore unbiased by the specification search, and the prediction results allow comparison of the statistical models' robustness. The new estimators are found to be more appropriate for estimating and predicting demand and social benefits than the alternative estimators based on a variety of criteria. Depending on model specification wtp ranged from $36.72 to $172.82 per hunter.

4.2.7. Recreation: Hiking

Baerenklau, K.A. (2010). "A Latent Class Approach to Modeling Endogenous Spatial Sorting in Zonal Recreation Demand Models." Land Economics 86(4): 800-816.

A method for incorporating unobserved heterogeneity into aggregate count data frameworks is presented and used to control for endogenous spatial sorting in zonal recreation models. The method is based on latent class analysis, which has become a popular tool for analyzing heterogeneous preferences with individual data but has not yet been applied to aggregate count data. The method is tested using data on backcountry hikers for a southern California study site and performs well for relatively small numbers of classes. The latent class model produces substantially smaller welfare estimates ($423,749/year) compared to a constrained version that assumes homogeneity throughout the population ($573,169/year).

4.2.8. Flood Control

Troy, J. Romm (2004). Assessing the Price Effects of Flood Hazard Disclosure Under the California Natural Hazard Disclosure Law (AB 1195), Journal of Environmental Planning and Management, 47 (1), pp. 137-162

This study uses hedonic analysis to estimate the effects of flood hazard disclosure under the 1998 California Natural Hazard Disclosure Law (AB 1195) on property values throughout California. It finds that the average floodplain home sold for 4.2% less than a comparable non-floodplain home following AB 1195 while before that law there was no significant price differential. The introduction of interaction terms indicates that the magnitude of the price reduction due to AB 1195 varies positively with Hispanic population share. An average floodplain home in a half-Hispanic neighborhood saw a $12,324 negative capitalization due to AB 1195, while that amount was only $2191 for a neighborhood with 10% Hispanic residents. Results suggest that, in particular, homebuyers in Hispanic communities are better disclosed to under AB 1195 than they were under the National Flood Insurance Program (NFIP), which was the primary policy regulating flood disclosure in California prior to passage of AB 1195.

4.2.9. Water Quality

Farber, Stephen, and Brian Griner (2000) Valuing Watershed Quality Improvements Using Conjoint Analysis. Ecological Economics 34, p63-76.

This paper reports on a study of valuation of multiple stream quality improvements in an acid-mine degraded watershed in Western Pennsylvania. A technique extensively used in marketing research, conjoint (CJ) analysis, is used in conjunction with a random utility model (RUM) to establish shadow valuations for various combinations of stream quality improvements in two streams. The technique shows promise in the valuation of ecosystems, which provide a complex variety of services. Several variations on respondent choice, binary choice (BC) and intensity of preference (IP) were used, where the latter allowed for an expression of degree of preference between status quo and alternative conditions. The sample constituted a panel data set from which user and non-user valuations were distinguished. In addition, sample respondents were identified by the distances of their residences to the stream sites, permitting the analysis of effects of distance on quality improvement valuations. These valuations suggested that persons living within roughly 50 miles of the evaluated stream segments place some positive value on stream improvements.

The stream facing potential improvement from Moderately Polluted to Unpolluted status, defined on the basis of habitat support value, resulted in valuations ranging from $26.63 to $51.35 per household per year for 5 years. The stream facing potential improvement from Severely Polluted to Moderately Polluted status showed valuations ranging from $35.90 to $67.64 per household per year for 5 years. The same stream exhibited valuations ranging from $75.63 to $112.44 per household per year for 5 years for potential improvement from Severely Polluted to Unpolluted status. The study attempted to separately estimate non-user and user values. While not a perfect distinction, non-use and use were distinguished on the basis of whether members of a household visited either of the two streams during the year prior to the survey. Model estimates for the small non-user group were poor and the resulting valuations were not statistically significant. Stream improvement values ranged from $1.39 to $54.26 per household per year for 5 years, depending on the improvement and estimating model. On the other hand, estimates for the user group were highly significant statistically. User valuations ranged from $23.09 to $125.25 per household per year for 5 years, depending on the improvement and estimating model. Distance from residence to each stream had the expected negative effect on user valuations. The 'extent of the market,' defined as the distance beyond which marginal valuations for stream improvement became zero, ranged from roughly 45 to 55 miles, varying directly with the magnitude of quality improvement, as expected.

4.3. Ecosystem Services – Regional Scale

Ingraham, M. W., & Foster, S. G. (2008). The Value of Ecosystem Services Provided by the U.S. National Wildlife Refuge System in the Contiguous U.S. Ecological Economics, Vol. 67, Issue 4, 608-618

Studies that demonstrate the economic value of the ecosystem services provided by public conservation lands can contribute to a more accurate appraisal of the benefit of these lands. The objective of this study was to estimate the economic value, in real (2004) dollars, of the ecosystem services provided by the U.S. National Wildlife Refuge System (Refuge System) in the contiguous U.S. In order to estimate this value, the authors determined the ecosystems present on the Refuge System in the contiguous 48 states, the proportion in which they are represented, and the dollar value of services provided by each. They used land cover classes as an approximation of ecosystems present in the Refuge System. In a geographic information system (GIS), they combined land cover geospatial data with a map of the Refuge System boundaries to calculate the number of acres for each refuge and land cover class within the Refuge System. They transferred values for the following ecosystem services: climate and atmospheric gas regulation; disturbance prevention; freshwater regulation and supply; waste assimilation and nutrient regulation; and habitat provision. They conducted a central tendency value transfer by transferring averaged values taken from primarily original site studies to the Refuge System based on the ecoregion in which each study site and refuge was located and the ecoregion's relative net primary productivity (NPP). NPP is a parameter used to quantify the net carbon absorption rate by living plants, and has been shown to be correlated with spatially fungible ecosystem services. The methodologies used in the site studies included direct market valuation, indirect market valuation and contingent valuation. They estimated the total value of ecosystem services provided by the Refuge System in the contiguous U.S. to be approximately $26.9 billion/year. This estimate is a first cut attempt to demonstrate that the value of the Refuge System likely exceeds the value derived purely from recreational activities. Due to limitations of current understanding, methods and data, there is a potentially large margin of error associated with the estimate.

Figure 2:

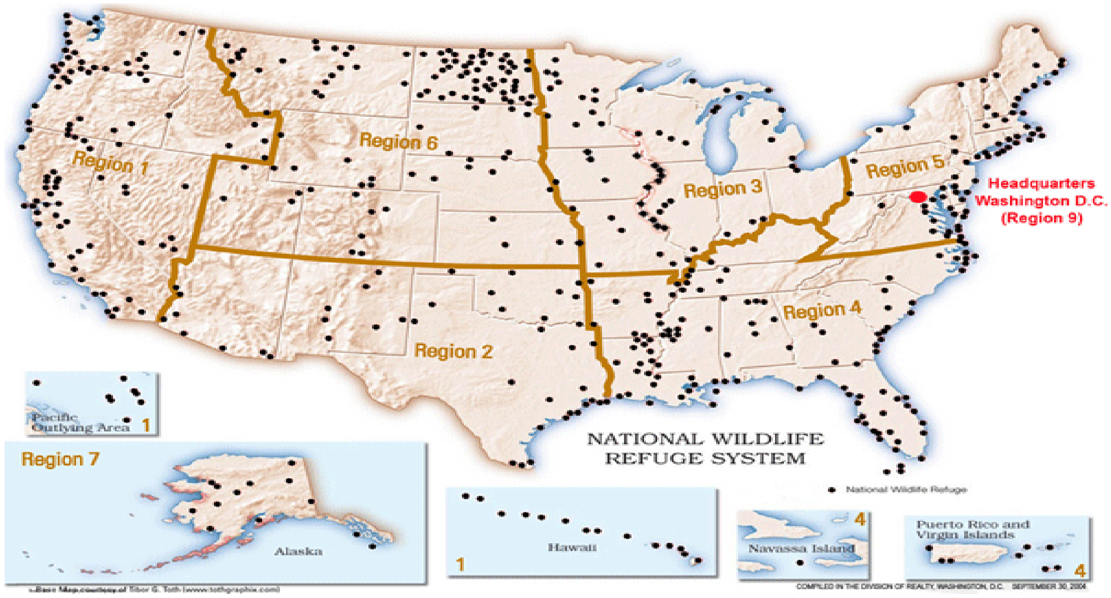


Table 11. Transfer Values by Land Cover Class and Ecosystem Services, According to NPP – Gradient ($/year).

	Ecoregion Group										
Ecosystem Service	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Carbon sequestration	$1,361	$1,361	$1,361	$1,361	$1,361	$1,361	$1,361	$1,361	$1,361	$1,361	$1,361
Disturbance prevention	$644	$1,003	$1,280	$1,510	$1,689	$2,002	$2,236	$2,236	$2,668	$3,013	$3,337
Freshwater Regulation	$697	$1,009	$1,392	$1,643	$1,840	$2,182	$2,437	$2,563	$2,909	$3,286	$3,640
Nutrient removal waste assimilation	$1,055	$1,648	$2,107	$2,487	$2,786	$3,303	$3,689	$3,880	$4,403	$4,975	$5,511
Habitat provision; disturbance prevention	$23	$36	$46	$54	$60	$71	$80	$84	$95	$108	$119

4.7 Carbon Sequestration

Hansen, L. T. (2009). The viability of creating wetlands for the sale of carbon offsets. Journal of Agricultural and Resource Economics, 350-365

This analysis estimates the profitability of restoring wetlands for the sale of carbon offsets. Results indicate that about 7% to 12% of the recently restored grassed wetlands of the prairie pothole and high plains regions and 20% to 35% of the forested wetlands of the Mississippi alluvial valley and Gulf-Atlantic coastal flats regions could have carbon offset values that exceed the cost of restoring the wetland and the opportunity cost of moving the land out of agricultural production. Given the uncertainties, the analysis applies conservative estimates of wetlands' costs, offset prices, and wetlands' effects on greenhouse gases.

Table 12. Wetland Costs and Potential Values of Carbon Sequestered Based on Nordhaus Price Scenario ($/acre)

Wetland Regions	Wetlands Carbon Value
Prairie Pothole Wetlands	$ 368.00
High Plains	$ 368.00
Mississippi Alluvial Valley	$ 627.00
Coastal Flats	$ 627.00
Rolling Plains	$ 523.00
Central Valley	$ 498.00

6. Discussion and Conclusions

We have given an overview of the approaches used to value non-market goods and an annotated bibliography of relevant case studies of non-market valuation of ecosystem services provided by riparian habitat. The values summarized in the tables illustrate the wide variation in the values of ecosystem services related to riparian habitat.

Although it is tempting, and inexpensive, to derive values of ecosystem services for the Sacramento river corridor, using numbers from studies conducted in arguably 'similar' riparian habitats, evaluations of such benefit transfer methods have been critical (Bergstrom and DeCivita 1999, Brouwer and Spaninks, 1999, Brookshire and Neill 1992). These evaluations have identified problems with aggregation, differences in goods between the policy and study cases, out-of-sample extrapolation, violations of utility theory, and a lack of values that correspond to the marginal changes of policy interest.

Loomis and Rosenberger (2006) have further added that the original study and targeted policy sites need to be similar in regards to ecosystem commodity, market context, and welfare measures for benefits transfers to be reliable and valid. The approach must consider differences in the environmental good or service either quantity or quality; the change in the quantity and or quality of the environmental good or service; differences in the population size, distribution, and demographics; and their use of the good, market characteristics including income and income distribution, institutional setting, environmental attitudes, social and cultural values, time between primary study and transfer; as well as geographic location. These differences can reduce the validity and reliability of benefit transfers (Spash and Vatn, 2006).

If adjustments cannot be made in regards to differing socio-economic characteristics of beneficiaries, and or differing environmental characteristics of the two different contexts, then the usefulness, accuracy, and relevance of the benefit transfer is in question. However, most valuation studies utilize a limited set of socio-economic demographic variables - income, age, gender and education. Factors such as ethnicity, social class, neighborhood characteristics, environmental attitudes, cultural differences rarely are accounted for in valuation studies (Spash and Vatn, 2006). Even when attitudinal, experience, and preference based variables are included in the original study, it is difficult to find the data for the targeted site from secondary resources (Loomis and Rosenbeger, 2006). The availability and quality of fine land cover data are also highly variable from region to region (Troy and Wilson, 2006). The omission of relevant variables, the lack of secondary source and fine land cover data, make it difficult to account and adjust for biophysical, and socio-economic differences between the primary study and policy site and ensure a valid and accurate benefit transfer.

Riparian habitat in lands along the Sacramento River is critically important for various threatened species, fisheries, migratory birds, plants, and the natural system of the river itself. Given the complexity and importance of this habitat we also make a few observations regarding such a study that is undertaken for an assessment of conservation efforts:

- **Choice of the baseline**: While comparing benefits and costs of conservation efforts, choice of the baseline could affect the valuation of benefits and costs, and the final conclusions of the study. The restoration efforts may appear to some citizens to have caused major disruptions in local agricultural economy, a longer view of the changes, however, suggests that they have been a modest effort to undo the anthropogenic change that occurred in the valley since the Gold Rush that had resulted in the loss of 95 percent of natural wetlands (Kelley, 1989). The choice of baseline by the researcher--comparing current stock of habitat to the mid-19th century level or to mid-20th century habitat--is critical for a meaningful evaluation of the benefits of conservation.

- **Cumulative effects versus marginal changes:** If a large amount of a natural habitat is available, there may be greater societal benefits from developing and thereby sacrificing part of it. Such actions will lead to a 'marginal' loss of the ecosystem service values provided by the habitat. The marginal loss of the habitat may be bearable. These changes also work in reverse i.e. if a small area is lost to agriculture, it may have a marginal effect to the local agricultural economy. However, if a number of such decisions are made independently of each other, the resource and its values may soon be lost. It might be that the combined value of the losses may be greater than the assumed one off individual losses. Such 'scale' effects are common in habitat and biodiversity-related land use changes but it often difficult to predict the point in the continuum where the marginal changes accumulate to have major systematic effects. Economic valuation techniques outlined above are best suited for measuring benefits from marginal changes but not discrete jumps in the resource stock.

- **Data on ecosystem functions**: Economic analyses of ecosystem services require a clear understanding of the linkages between final values, benefits and ecosystem services over temporal and spatial scale. Often researchers have an incomplete understanding of ecosystem functions and difficulties in predicting the effect of conservation efforts on major ecosystem functions and services; lack of measurable and regularly collected performance indicators when effects are relatively well understood; and problems in relating changes in the flow of ecosystem services to human welfare. Time lags, and spatial (scale) effects further complicate the measurement of social, economic, and environmental impacts from conservation efforts (Shiferaw et al. 2005). A consistent inventory of stocks of natural resource at finer grains would be needed for sound economic analysis. This will allow the decision makers to integrate the ecosystem services into mainstream decision-making processes (Johnston et al 2014).

For these reasons it may be difficult, if not misleading, to assign a causal relationship between conservation efforts and benefits of ecosystem services measured afterwards. While conservation efforts can increase habitat areas and improve their quality, and economic approaches described above can be useful in valuing the ecosystem services, care must be taken in assigning a causal relationship between conservation efforts and resulting flow of ecosystem services such as enhanced recreational benefits.

In our view, a potentially fruitful approach for understanding the economic benefits from ecosystem services Sacramento River Corridor could be a linking of land use and land cover change combined with fine-scaled economic and demographic data. Much of the recent research and policy emphasis on ecosystem services has focused on services linked to land use and cover including those flowing from agriculture, wetlands, and riparian habitat (Bauer and Johnston 2013). Among the primary motivations of the research is to quantify and value the tradeoffs in ecosystem services associated with land use change related to restoration programs, land set asides, conservation easements, habitat mitigation, and agricultural or land use changes (Johnston et al. 2014).

Given the limitations of benefits-transfer methods outlined above, and lack of original studies for the Sacramento River corridor, which is surprising given the economic importance of this river to the economy of California, our overall conclusion is that a primary study is the preferred method be undertaken to determine the economic value of riparian habitat for the Sacramento River. If benefits transfer methods is necessary, caution should be taken in applying the benefits of ecosystem services from other study areas to the Sacramento River System.

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