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Estimating Environmental Benefits of Natural Hazard Mitigation with Benefit Transfer: Results from a Benefit-Cost Analysis of FEMA Hazard Mitigation Grants[1]

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Abstract. This paper summarizes methods, data, and results associated with the first major attempt to evaluate the environmental benefits of FEMA natural hazards mitigation grants. The study relied heavily on the refinement of benefit transfer methods. Categories of benefits include water quality for recreational and commercial fishing, drinking water, outdoor recreation, hazardous waste, wetlands and aesthetic, health and safety benefits. Environmental and historic benefits proved to be a very minor proportion of the total benefits in dollar terms. Only a very small percentage of earthquake and wind-related hazards yielded environmental benefits, while a sizeable percentage of flood hazard grants did so. We also discuss the prospects that environmental benefits might have been much greater had data been available to analyze more environmental impacts.

Key Words: Natural Hazard Mitigation, Environmental Benefits

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[1] This paper was presented at the 2006 Southern Economic Association Meetings in Charleston, SC. This research is part of a larger report to the U.S. Congress (MMC, 2005). The Multihazard Mitigation Council (MMC) of the National Institute of Building Sciences (NIBS) organized the research team of which the authors were chief environmental specialist and benefit-cost analysis track leader, repectively. The authors acknowledge the helpful input of other researchers involved in the project, but assume full responsibility for any errors or omissions contained in this paper.

1. Introduction

The increasing number and severity of both man-made and natural disasters is the subject of growing concern. The impacts of these events are typically measured in terms of property damage, direct and indirect business interruption, injuries, and deaths (Cutter, 2001; Cutter and Emrich, 2005). Often there is some mention of various categories of other indirect effects, such as sociological and psychological impacts, with some attempts at measurement (Paton, 2003; Dash et al., 2007). More recently, awareness of potential environmental impacts has been articulated (Heinz Center, 2000), but to this date there has been very little measurement.

The focus on environmental considerations represents an important paradigm shift. This area of impacts had previously been ignored in a manner analogous to the philosopher's conundrum -- if a tree falls in the forest and there is no one around, is there a noteworthy sound? Likewise, if an earthquake happens in a remote area, is it of any serious interest? In fact, however, resources in remote locations may be needed in the foreseeable future (e.g., trees for lumber or biodiversity for pharmaceuticals) and environmental intrusions may have transboundary effects on populated areas (e.g., drifting volcanic ash). This is in addition to the many possible types of environmental damages that are typically centered in or adjacent to populated areas, including destruction of natural resources, salt-water contamination of fresh water, aesthetic damage, etc. Instances of hazard mitigation for primarily environmental purposes are rare but do exist, a primary example being the placement of many miles of the Alaska Oil Pipeline on flexible foundations that reduce the likelihood of breakage, and hence damage to the tundra ecosystem, in the event of an earthquake.

Of course, awareness of these impacts is only a first step, and the assessment will only be as successful as the data and methods brought to bear. Damage estimation is even more difficult in this realm, because it relates to "goods and services" that are less tangible than their ordinary counterparts and where market prices do not exist.

The primary objective of this paper is to report on the improvised methods, data, and results associated with the first major attempt to evaluate the environmental benefits of a broad range of natural hazard mitigation activities. The paper summarizes a component of a report to the U.S. Congress on the total benefits of FEMA hazard mitigation grants. These benefits are in effect the damage prevented by the mitigation activities.

We provide a background foundation for and review of benefit transfer methods for estimating environmental benefits of hazard mitigation. Categories of benefits include water quality for recreational and commercial fishing, drinking water, outdoor recreation, hazardous waste, wetlands and aesthetic, health and safety benefits. We first describe the potential environmental benefits of natural hazard mitigation and the stated preference and revealed preference approaches of environmental valuation. We then describe how the benefit estimates were developed for the FEMA study and summarize the benefit estimates used in the benefit cost analysis.

Another objective is to place these results in context. The study finds that environmental benefits of these mitigation projects are a very small percentage of total benefits. However, the results underestimate impacts for two reasons. First, they omit some types of environmental damages that are very difficult to measure. We identify these impacts and the methods and data that might best be used to measure them in the future, as well as the likely effect their

measurement might have on the overall size of the calculations of impacts. Second, there is a bias in the sample because FEMA mitigation grants are oriented toward life and property savings, and environmental benefits would appear to be an afterthought in nearly all cases. Here we identify some areas in which mitigation expressly for environmental objectives is warranted.

The analysis in this paper has broader application to issues relating to other types of impacts that have non-market characteristics, e.g., infrastructure, iconic, and historic sites. Interestingly, mitigation projects expressly intended to protect these values have been implemented for many years, but the ability to measure their benefits lags far behind. We also summarize some results relating to historic sites, and how research in that area can be improved through the lessons learned from our environmental analysis.

2. Background

The Multihazard Mitigation Council (MMC) of the National Institute of Building Sciences (NIBS) organized an interdisciplinary research team to quantify the future savings from hazard mitigation activities (MMC, 2005; Rose et al., 2007). The study responded to a mandate from Congress and was based on a detailed work plan implemented by a team of experts convened by the MMC Board. Although funding for the study was provided by the Federal Emergency Management Agency (FEMA), the study was conducted independently of FEMA.

Future savings, in terms of losses avoided, were estimated for hazard mitigation activities related to earthquake, wind, and flood funded through three major natural hazard mitigation grant programs (the Hazard Mitigation Grant Program, Project Impact, and the Flood Mitigation Assistance Program). Two types of mitigation activity were addressed: "project" and "process" mitigations. Project activities include physical measures to avoid or reduce damage

from disasters. Process mitigations include activities that lead to policies, practices, and projects that reduce risk and loss.

The MMC study involved two interrelated components. The first estimated the future savings from FEMA mitigation grant expenditures using a statistically representative sample of FEMA-funded mitigation grants so that results could be generalized for the entire population of FEMA mitigation grants. The unit of analysis was the individual FEMA-funded grant. The second component assessed the future savings from mitigation activities through empirical research on FEMA-funded mitigation activities carried out in community contexts. The community studies were both quantitative and qualitative and examined mitigation activities in a purposive sample of communities. Both components employed common methodologies where possible based on benefit-cost analysis. The primary tool used to measure benefits for earthquake and wind hazard mitigation was HAZUS®MH; supplemental methods were used to assess other reduced losses from flood and tornado, business interruption loss for utilities, environmental and historic preservation benefits, and process mitigation activities (MMC, 2005).

Not all mitigation measures evaluated in this study could be analyzed using traditional environmental valuation methods. Alternative approaches for assessing some categories of environmental benefits were needed. For environmental and historic benefits, a feasible approach for measuring the benefits of hazard mitigation is the *benefit transfer* approach. The approach was developed for situations in which the time or money costs of primary data collection are prohibitive. In this approach, benefit estimates from other case studies are spatially or temporally transferred to the policy case study.

The overall study (see also Rose et al., 2007) found that the benefit cost-ratio (BCR) for

nearly six thousand FEMA grants from mid-2003 to mid-2004 was 4 to 1. Not every grant had a positive BCR, but the study indicates that on average mitigation does pay. Below, we discuss in detail the extent to which environmental benefits contributed to this result.

3. Environmental Benefits

Natural hazard mitigation, such as relocation of structures in a floodplain, can lead to environmental benefits such as improved wildlife habitat, improved wetland functions, and increased water quality. Related to these ecological benefits are the increased recreation opportunities and increased property values from open space amenities. Retrofitting and floodproofing of wastewater treatment facilities and other sensitive structures will lead to decreased risk of drinking water contamination and lead to improved human health after hazard events. Earthquake hazard mitigation that reduces the risk of fire and drinking water contamination will increase air quality and drinking water quality, and will thereby lead to improved human health.

A major source of environmental losses from hazard events is the increased debris that must be absorbed by the waste management system and the environment. Some debris are collected and disposed of in landfills and incinerators; others are deposited on land and in the water negatively affecting ecosystems. Existing structural mitigation measures address this issue, e.g., structural mitigation measures such as engineering buildings to resist earthquakes and developing designs for hazard resistant construction and retrofitting techniques reduce the damage caused by hurricane winds and flooding. The reduced damages lead to reduced debris removal and disposal.

Some of these damages can be minimized by government policy. The extent to which the unmitigated damages should be monetized and considered an economic loss depends on the type of damage, cause and effect, and the context of natural hazard mitigation.

For example, consider a pristine wilderness area that experiences a flood event. A large amount of environmental damage would be caused by a flood, including loss of flora and fauna. However, from one perspective this damage is the natural course of nature, and it is inappropriate to measure the economic losses of the environmental damage. However, when humans benefit from the natural environment these environmental damages may be economic losses. For example, hikers may enjoy the pristine wilderness area, and thus lost or degraded hiking trips may, in fact, be economic damages. Loss of non-use (i.e., passive use) values may also be a consideration.

Natural hazard mitigation projects are not typically able to cope with much environmental damage. It is impossible to mitigate damages to a coastal forest area from a hurricane strike. It is impossible to mitigate damages to visibility and, to some extent, health from a volcanic eruption. On the other hand, mitigation processes that focus on information provision can lead to improved human health through advisories to avoid contaminated areas following hazard events.

Public policy, such as natural hazard mitigation, is designed to improve the human condition. In a market economy, public policy should be used to mitigate the impacts of market failure. Some markets are available to allow economic decision makers to self-protect against risk. For example, some damages can be insured against through organized markets (i.e., flood insurance), while other damages can be remedied through self-protection after the hazard event

(i.e., boiling drinking water). Hazard mitigation can minimize the losses for some types of these damages, but it may not have been attempted or may have little effect on others. For example, losses to commercial fishing and forestry due to naturally occurring events have not been targets of hazard mitigation policies. Lessons are available, however, from the related area of technological accidents, such as oil spills, where double-lined tanker hulls help to reduce the probability of breach and booms serve to contain the oil if it is spilled.

In summary, mitigation policies can be used to avoid damages to the natural environment. The effectiveness of these policies should be compared to a baseline of environmental damages that would occur without these policies.

4. Environmental Valuation

There are several non-market valuation methodologies available to estimate the mitigation benefits. These methodologies include stated preference and revealed preference approaches. The travel cost method, averting behavior method and the hedonic price method are examples of revealed preference approaches. The contingent valuation, contingent behavior, and conjoint/choice analysis methods are examples of stated preference approaches.

Revealed Preference Approaches

The travel cost method is a revealed preference method that is most often used to estimate the benefits of outdoor recreation; for example, the improved hunting and fishing opportunities in wetlands and floodplains following structural relocation. The travel cost method recognizes that the major cost of outdoor recreation is the travel and time costs incurred to get to the recreation site. Since individuals reside at varying distances from the recreation site, the

variation in distance and the number of trips taken are used to trace out a demand curve. The demand curve is used to derive the benefits of the recreation site. With the appropriate demand shifters (i.e., independent variables such as measures of water quality), the benefits of changes in policy variables can be derived.

The averting behavior method recognizes that individuals seek to protect themselves when faced with environmental risk, such as contaminated drinking water, after earthquakes and floods. Defensive behavior requires expenditures that would not normally be made. For example, the purchase of bottled water or water filters may only be made when faced with the risk of contaminated drinking water. These increased expenditures represent a lower bound on the environmental benefits of hazard mitigation that reduces the risk.

The hedonic price method exploits the relationship between characteristics of land and labor markets, including environmental quality, and housing prices and wages (Palmquist, 1991; Freeman 1993). The hedonic price method has been used to value hurricane mitigation (Simmons, Kruse, and Smith, 2002), earthquakes (Murdoch, Singh, and Thayer, 1993) and flood zones (Harrison, Smersh, and Schwartz, 2001). For example, relocation of structures from floodplains leads to open space amenities for some property owners. These parcels command higher prices in land markets. Job markets with greater locational amenities are associated with lower wages as the supply of labor is higher relative to other locations. The housing price and wage differentials are measures of the implicit price of locational amenities such as open space. Housing and labor market differentiation can be used to trace out the demand for open space and the measure of environmental benefits.

Stated Preference Approaches

The contingent valuation method is a stated preference approach that elicits willingness (and ability) to pay statements from survey respondents (Mitchell and Carson, 1989; Carson and Hanemann, 2005). The survey method involves the construction of a hypothetical market. Respondents are informed about the current problem and the policy designed to mitigate the problem. For example, respondents could be presented with a hazard mitigation program that involves the retrofitting of wastewater treatment plants and reduced drinking water contamination following a hurricane, flood, or earthquake. The state of the environment before and after the policy is described. Other contextual details about the policy are provided such as the policy implementation rule (e.g., majority rule) and the payment vehicle (e.g., increased taxes or utility bills). Finally, a hypothetical question is presented that presents respondents with a choice about improved environmental quality (e.g., safe drinking water) and increased costs versus the status quo. In the hazards literature, the contingent valuation method has been used to estimate flood control values (Hammitt, Liu, and Liu, 2001; Shabman and Stephenson, 1996).

The contingent behavior approach is similar to the contingent valuation method in that it involves hypothetical questions (Freeman, 1993). In contrast, the questions involve hypothetical behavior instead of hypothetical willingness to pay. For example, respondents can be asked about hypothetical hurricane evacuations (Whitehead, 2001), recreation trips in floodplains, hypothetical bottled water purchases after hazard events, or hypothetical home location choice with improved floodplain mapping.

Benefit Transfer

It is costly to use the revealed and stated preference valuation methods. First, the travel cost and hedonic pricing method require location specific data sets. A single study would be feasible in the time allotted, but a number of studies, as required to assess the environmental benefits of several mitigation projects, is not feasible due to time constraints. Second, using a single revealed preference method will exclude large classes of environmental values from the benefits assessment. While the travel cost method focuses on recreation benefits, the hedonic price method focuses on benefits to property owners. Since mitigation projects can have recreation, property value and other environmental benefits, a focus on one valuation method could lead to large errors. Consideration of multiple revealed preference valuation methods is costly.

The contingent valuation method requires a mail, telephone, or in-person survey that elicits the willingness to pay for changes in governmental policy that leads to environmental change. In the context of hazard mitigation, the survey would describe mitigation policies that limit environmental damage from natural hazards and determine the value of those policies. The entire CVM survey and reporting process would require a significant amount of time.

The benefit transfer approach was developed for situations in which the time and/or money costs of primary data collection are prohibitive. Environmental benefit estimates from other case studies are spatially and/or temporally transferred to the policy case study. There are three types of benefit transfer: benefit estimate transfer (Boyle and Bergstrom, 1992), benefit function transfer (Kirchoff, Colby, and LaFrance, 1997), and meta-analysis (Smith and Pattanayak, 2002). Benefit estimate transfer uses summary measures of the environmental

benefit estimates directly. Researchers simply obtain a benefit estimate from a similar study conducted elsewhere and use it for the current policy analysis case study.

Benefit function transfer uses the statistical model to transfer benefits. Characteristics of the current policy situation or case study (e.g., population demographics, site characteristics) are substituted into the statistical model from the transfer case study to develop benefit estimates that are more suitable for the current policy situation than the directly transferred benefit estimates.

Meta-analysis requires the collection of a large number of studies related to the policy situation. A data set is constructed with measures of the environmental benefits as the dependent variable and characteristics of the individual studies (e.g., water quality) as the independent variables. Regression models are developed which are used to relate the study characteristics to environmental benefits. These regression models are used as benefit function transfer models where the characteristics from the case study are inserted and environmental benefits related to the case study are developed.

The benefit function transfer method is typically the preferred of the three methods given time constraints. The benefit transfer method does not consider differences between case studies. This can potentially lead to errors in benefit estimation. A meta-analysis requires significant resources devoted to literature review and interpretation. In contrast, the benefit function transfer method can be used to quickly transfer benefit estimates from one case study to another and develop those estimates around the particular parameters of the case study of interest.

5. Methods

After conduct of a pilot study benefits transfer, we decided that project by project benefit

transfer analysis would be too time-consuming for a large number of projects. In order to conduct a large number of benefit transfers efficiently, we developed templates for benefit estimation instead. The following sub-sections summarize the benefit transfer methodology for particular types of environmental and historical benefits provided by hazard mitigation. Sensitivity analysis is used to develop upper and lower bound estimates (see Appendix).

Drinking Water

We assume that mitigation of flood hazards provide drinking water quality benefits. A review of 16 averting behavior and contingent valuation studies of the economic value of safe drinking water finds that the monthly mean value of safe drinking water per household is $69 (Whitehead and Van Houtven, 1997). Trimming the 3 lowest and highest values to avoid the influence of outliers in a small sample, yields a monthly mean midpoint value of safe drinking water of $39. We use the lower value for estimation of drinking water benefits.

Since there is some uncertainty about whether drinking water problems would be experienced by all households in the municipality, we assume that there is a 50% chance that the drinking water supply will remain safe. The total benefits are the product of the length of time that drinking water is contaminated, the monthly household benefit, the percentage of households affected and the population.

Water Quality: Fishing

We assume that mitigation of flood hazards provides water quality benefits. When site specific studies on water quality benefits are not available we assume that water quality benefits are primarily enjoyed by freshwater recreational anglers in the form of increased catch. The

USFWS report from the 1991 National Survey estimates the value of an additional bass/trout caught per year (Waddington, Boyle, and Cooper, 1994). We use the 1991 report because the USFWS report from the 2001 National Survey was not yet available and the 1996 National Survey fails to estimate reliable measures of the value of bass fishing for Florida due to data limitations.

The total water quality benefit is equal to the product of the number of anglers affected by the policy and the value of additional catch. To calculate the number of anglers, we adopt two conservative assumptions. We assume that the water quality improvement would allow only one in 10 recreational anglers to catch an additional fish. We also calculate the number of anglers in the population using the percentage of those who fish but do not also hunt in the relevant state. This estimate is obtained from the 2001 USFWS National Survey. The number of anglers affected by the hazard mitigation policy is equal to the product of the percentage of anglers in the relevant state, the 10% of these anglers assumed to enjoy the water quality improvement, and the relevant population. We assume that the negative recreational impacts of a flood event last for one year. The total benefit is the product of the time period of damage, the individual benefit, and the number of anglers affected.

Flood hazards that affect marine waters (e.g., sewage spills in the Gulf of Mexico) are assumed to affect the number of saltwater fishing trips. We estimate the access value of trips using benefit estimate transfer (Haab, Whitehead, and McConnell, 2001). The number of marine anglers in inland waters off coastal counties is obtained from the National Marine Fisheries Service and county trip allocation data found in Haab, Whitehead, and McConnell (2001). Benefits are equal to the product of value per trip and number of trips affected. Sensitivity

analysis is conducted over the number of trips affected and the amount of time fishing is affected.

Flood hazards that affect marine waters are also assumed to negatively affect commercial fishery landings and ex-vessel value. Landings and ex-vessel value data are obtained from the National Marine Fisheries Service. Sensitivity analysis is conducted over the percentage of landings affected and the amount of time fishing is affected.

Water Quality

Seismic mitigation of a major river dam is a special case for which benefit templates did not cover all of the types of benefits. We assume that seismic mitigation of this dam in Southern California provides downstream urban water quality benefits. These are not necessarily recreational fishing benefits, since the waterway is a concrete canal. Benefit estimate transfer is used. The benefit estimate is the household annual willingness to pay to remove impairment to all of California's water bodies using the contingent valuation method (Larson and Lew, 2001).

The river on which the dam is located represents a small fraction of all of the water bodies in California. One approach to dividing the total willingness to pay into the willingness to pay for avoiding coastal water degradation in and the city at the mouth of the river is to apply the percentage of water area in Los Angeles County relative to California to the total willingness to pay. This is potentially an overestimate of the benefits since the river is a fraction of the water resources in the County. A more conservative lower and upper willingness to pay estimate, which we adopt, assumes that 10% and 25% of the water resources in Los Angeles County would be impacted. The total benefits are the product of the number of years affected, the

percentage of the state affected, the household benefit and the population.

Outdoor Recreation

The reservoir behind the dam provides outdoor recreation benefits. To value these we use the midpoint of benefit estimate transfer and meta-analysis transfer. The benefit estimate transfer is the average recreation value per person per activity day for wildlife viewing and hiking on the Pacific Coast (Rosenberger and. Loomis, 2000). The meta-analysis transfer employs Table 2 of Rosenberger and Loomis (2000). Values for state-of-the-art valuation methodology variables are chosen to calibrate the meta-analysis function.

We obtain an estimate of the number of trips to the reservoir as the product of recreation participants and the number of trips per participant. Recreation participation estimates are from the 1995 National Survey of Recreation and the Environment (NSRE). We assume one trip for each participant and the reduced visitation is for two years. The total benefit is the time period affected, the individual benefit, the percentage of the population that participates in recreation and the number of recreation trips.

Hospitals and Hazardous Waste

We assume that mitigation of seismic and wind risk reduces the risk of death from hospital hazardous wastes. We assume the risk of exposure to hazardous waste from a hospital experiencing a natural hazard is small. The benefit estimate transfer method is used. duVair and Loomis (1992) present estimates of the value of avoiding premature death from hazardous waste (e.g., heavy metals) for 25%, 50%, and 75% reduction in the risk of death. Based on historical data, we assume that a natural hazard event would lead to a small increase in the average risk of

premature death (.01%). From a baseline of a 25% reduction in the risk of premature death we assume that the marginal willingness to pay is equal to the average willingness. Then the willingness to pay for a .01% reduction in the risk of premature death is extrapolated from the benefit estimates assuming linearity. We assume that the increased risk of death is for two years. The total benefit is the product of the time period affected, the household benefit and the population.

Wetlands

We assume that projects that involve the purchase and removal of flooded residences create open space areas and, potentially, functioning wetlands. The environmental benefits of these projects are estimated by applying wetland values to each acre created. We adopt low, medium, and high assumptions for the number of acres of open space/wetlands created is assumed to be X% of an acre for each property purchased. We use a meta-analysis of wetland values (Woodward and Wui, 2001). We calibrate Woodward and Wui's Model C for the hazard mitigation application by using the mean values for most all independent variables and adjust the benefits estimate for the number of wetland acres provided by the project. In effect, we are conducting benefit estimate transfer averaged over a number of studies adjusted for wetland acres. We adopt low, medium and high assumptions for the number of years of aggregation.

The present value of annual wetland values is measured with discount rates of r=2% and r=7%. The time horizon for benefits is in perpetuity (i.e., PV = AV/r). The wetland values are not aggregated across the population. The average population of the wetland studies in the meta-analysis is embedded in Model C. The total benefits accrue after the project is concluded with or without a hazard event. Sensitivity analysis is conducted over the acreage of each property,

percentage of property acreage that function as wetlands, and the number of years that property provides wetlands functions. The total benefits are the product of the number of acres and the per acre benefit.

Aesthetic, Health and Safety Benefits from Underground Power Lines

Burying power lines provides aesthetic, health and safety benefits. Aesthetic benefits are generated as the power lines do not obstruct views. Health benefits may accrue due to reduced electromagnetic pollution. Safety benefits accrue because natural hazards increase the risk that downed power lines will cause negative human health impacts. Aesthetic and health benefits are similar to wetland benefits, in that they accrue after the project is concluded in perpetuity with or without a hazard event.

We use the benefit estimate transfer method to estimate the benefits of burying power lines. A recent unpublished study conducted for the Palm Beach (FL) County Government asked respondents about their willingness to pay to bury power lines (Palm Beach County 2002). The question posed was: "There are a variety of opinions about overhead power lines. Would you be willing to pay an annual tax assessment for the cost of burying some of the overhead power lines in your area? Would you pay $50 a year or less, between $50 and $100 per year, over $100 per year, or would you be unwilling to pay for this activity?" Despite the lack of appropriate incentives to respond truthfully to this question, the results are probably the best information about the willingness to pay for burying power lines, since no other study has specifically addressed this issue. Annual aesthetic, health and safety benefits are measured by the product of per household total power line benefit and the household population. Benefits accrue with or

without a natural hazard event. Sensitivity analysis is conducted over the portion of households affected by power lines.

Cultural and Historical Resources

Cultural and historical values are estimated with the meta-analysis function found in Model 3, Table V of Noonan (2003). The meta-analysis consists of 65 contingent valuation method studies of historical and cultural resources. To calibrate the model, values for state-of-the-art methodology variables and site variables to best fit the case study are chosen. The total benefits are the product of the household benefit (a one-time payment) and the number of households. Strictly speaking, cultural and historical values are not part of the natural environment. However, because they are similar to many standard environmental values in terms of their intangible character and amenability to estimation methods, they are included here.

6. Results

Data were acquired for 5,479 approved or completed grants for flood, earthquake, or wind risk mitigation activities. The data were stratified by hazard type (flood, earthquake, or wind) and mitigation type (project or process activity). A selection of 357 mitigation grants was made for examination. Each combination of mitigation type (project or process) and hazard represents one stratum. The sample grants were selected to represent the distribution of mitigation costs; to ensure the inclusion of low, medium, and high-cost mitigation efforts in each stratum; and to minimize the uncertainty in the estimated total benefit. Eventually, 257 grant applications had enough information available to be examined for environmental and historical benefits.

The earthquake stratum of grants for project mitigation activities includes grants for both structural activities (e.g., base isolation of public buildings) and nonstructural activities (e.g., retrofit of pendant lighting in schools). The majority of sample grants for the wind grant stratum provided hurricane storm shutters and safe rooms. The majority of the grants in the flood grant stratum were for buyouts of residential structures that had experienced repeated flooding.

We developed decision rules that led to the identification of projects that provide environmental and/or historical benefits. The total number of cases with potential environmental impacts and that had enough information for analysis was determined to be 71. The criterion for determination of whether the project grants may generate environmental impacts was by assessment of the project type description in the Hazard Mitigation Grant Program proposal. Environmental and historic losses are not applicable if the Project Type Description includes the following: Applied Research and Development in the Building Sciences; Developing, Implementing and Enforcing Codes, Standards, Ordinances and Regulations; Feasibility, Engineering and Design Studies; Miscellaneous; Other Equipment Purchase and Installation; Professional Education (Building Inspectors, Architects, Engineers, Contractors, etc.); Public Awareness and Education (Brochures, Workshops, Videos, etc.); Safe Room (Tornado and Severe Wind Shelter) - Private Structures; Warning Systems (as a Component of a Planned, Adopted, and Exercised Risk Reduction Plan); Elevation of Private Structures – Riverine; Mitigation Plans (various); Missing (Project Title is Project Impact). Each of the Project Titles associated with these Project Type Descriptions were reviewed to ensure whether the project should be excluded.

Environmental losses are potentially applicable for the following Project Type Descriptions: Acquisition of Private Real Property (Structures and Land) – Riverine (and Coastal); Dry Floodproofing Public Structures – Riverine; Flood Control - Berm, Levee, or Dike; Localized Flood Control System to Protect Critical Facility; Other Minor Flood Control; Stormwater Management – Culverts (and Detention/Retention Basins); Utility Protective Measures (Electric, Gas, etc.); Water and Sanitary Sewer System Protective Measures; Wetland Restoration/Creation. Environmental losses are potentially applicable for some Protect Titles within the following Project Type Descriptions: Generators; Non Structural Retrofitting/Rehabilitating Public Structures – Seismic; Other Non Construction (Regular Project Only); Retrofitting Public Structures – Wind; and Structural Retrofitting/Rehabilitating Private Structures – Seismic.

The total number of cases with potential historical impacts is 5. Project Titles were screened for specific properties mentioned. An internet search was conducted to determine if the property may have historic value.

Five earthquake projects provide environmental and/or historical benefits (Table 1). One project had recreational fishing, drinking water, wildlife watching, hiking and historic benefits. The middle estimate of benefits is over $5 million. One project generated only drinking water benefits. One project generated only hazardous waste benefits. Two projects generated only historical benefits. The highest project benefit, $15 million, is for earthquake retrofitting of the City Hall Building of a major U.S. city.

Sixteen flood projects provide environmental and/or historical benefits (Table 2). Six projects provide only recreational fishing benefits, two projects provide recreational fishing and

drinking water benefits, one project provides drinking water, marine recreational and commercial fishing benefits and one project provides only drinking water benefits. The largest benefits are over $1.1 million for protection of a coastal wastewater treatment facility.

Two wind hazard projects provide aesthetic benefits and two provide historical benefits (Table 3). The largest benefit estimate is $1.3 million for door and window protection for an historic town hall.

Fifty one flood projects involve removal of structures in floodplains and wetlands creation (Table 4). The number of properties ranges from one to 268. The wetland values per acre range from $137 to $674. The mean wetland value per acre is $1046. The total wetland value is equal to the product of the wetland value per acre and the number of acres. The total wetland values range from $674 to $40,000. The mean of the total wetland values is $9946.

In Table 5 we list all of the project grants evaluation for environmental and historical benefits and whether it is included in the final sample. The mean benefit is $399,410. The lowest benefits (less than $10,000) are for 2 flood projects in small towns. The highest is over $15 million. Removing these outliers from the sample leads to mean present value of environmental and/or historical benefit of $196,406 per project.

The mean benefit of the five earthquake grants evaluated for environmental and historical benefits is $4,203,890 (Table 6). The mean benefit of the 62 flood grants is $92,755. The mean benefit of the 4 wind grants is $377,393. The mean benefit of the three earthquake projects in the final sample is nearly $176 thousand. The average benefit of the 16 flood projects in the final

sample is nearly $96 thousand. The benefit of the lone wind grant in the final sample is $109 thousand.

7. Broadening the Scope of Analysis

The methods used here and the cases available due to the limited scope of hazard mitigation grants funded lead to an underestimation of the potential environmental benefits of hazard mitigation. The MMC study avoided estimates of, for example, the value of air quality and biodiversity, because there had been little or no documentation of the effects of unmitigated hazards on these environmental endpoints. Recent hazard events like the Florida wildfires and Hurricane Katrina have highlighted the potential for mitigating these impacts. Revealed preference approaches can be used to estimate the environmental costs of these events, and other studies can be used to estimate the potential to mitigate these costs. For example, following Hurricane Katrina much economic research has been conducted assessing the negative environmental impacts (e.g., Posados, 2007).

Some generalizations can be made about the relative scope and size of environmental impacts of natural hazards. Earthquake and wind hazards are unlikely to cause extensive environmental damage directly, except in the most extreme cases where an earthquake causes the diversion of a river or where wind strength is so great as to fell large stands of trees. Otherwise, the impacts are likely to occur indirectly through impacted structures such as dam, levee, or pipeline breaks in the case of the former, or the release of toxic materials and fires started by downed power lines associated with both types of hazards. Floods are more likely to lead to direct environmental damage by various forms of water contamination (including salt-water intrusion) and by reduced biodiversity. This summary should help provide a guide to cases

where environmental damage is likely to he high.. This would include high-intensity earthquake and wind events or more moderate cases in areas where hazardous materials are manufactured/stored or where large tracts of standing timber exist. It would also include cases of major floods, or cases where more moderate flooding could take place in pristine areas, areas with especially sensitive eco-systems, heavily populated areas, or areas where hazardous materials are manufactured or stored.

Many of these environmental impacts cannot readily be mitigated with the options at hand. Wind damage to standing timber can only be reduced by land-use changes. Likely earthquake impacts on sensitive eco-systems are almost impossible to predict and hence, with the exception of strengthening dams, are unlikely to be viewed as cost-effective strategies. The most effective strategies, though not necessarily the most cost-effective, in reducing all types of environmental impacts, are those that reduce the probability of the event in the first place. Of course, this is not yet possible in the case of earthquakes or wind events, but it is with respect to flood hazards. Reducing the vulnerability of the built and natural environments to those events that do take place is not possible against all hazards but will involve competition for limited resources between potentially impacted categories.

It should also be noted that mitigation itself can cause environmental damage, which should then be added to the cost side of the ledger. The classic example is a dam intended for flood control, where a new reservoir is created that alters an eco-system or destroys a unique scenic view. Interestingly there are a number of regulations that prohibit various types of environmental damage from hazard mitigation activities, though there are few regulations that require mitigation to protect the environment in the first place. The prime examples are associated with the building of structures in hazard prone areas, such as the Alaska pipeline or

factories built near bodies of water, or structures that pose grave dangers when breached no matter what the location, such as nuclear power or chemical plants.

Note also that mitigation benefits are not absolute nor dependent solely on physical characteristics of hazards or the geographic areas they affect. They are also highly dependent on public policy responses. In the FEMA study, benefit categories varied significantly by type of hazard. Avoidance of death and injury was the dominant category for earthquake mitigation grants, because of the strong emphasis on life safety in relation to this hazard. Property damage avoidance was the major category for floods, because life safety can be addressed relatively well by warning and because properties vulnerable to repeated flooding are so easy to identify. Direct and indirect business interruption was a major category in wind-related events because small investments in burying power lines underground can prevent major electricity outages in urban areas. In effect, environmental benefits of hazard mitigation are likely to increase over time with the increased trend of public concern for the environment and with increased experience in mitigation of potential damage in this area.

Much of the past research assessing the environmental impacts of natural hazards employs an ex-post revealed preference approach. In other words, researchers assess damages after a disaster event. Future research could broaden the scope of the benefits of mitigation by considering an ex-ante stated preference approach. For example, the contingent valuation method could be used to address the cost of environmental impacts of natural disasters. This method requires a mail, telephone, or in-person survey that elicits the willingness to pay for changes in governmental policy that leads to environmental change. In the context of hazard mitigation, the survey would describe mitigation policies that limit environmental damage from natural hazards and determine the value of those policies.

After leading respondents through a number of attitudinal and perception questions related to the mitigation policy, willingness to pay questions are presented. The most incentive-compatible form of contingent valuation is the referendum question in which each respondent is randomly assigned one of several different policy costs in the form of tax increases or other realistic payment vehicles. Respondents are then asked if they would be willing to vote for the mitigation policies that limit environmental damage with a tax increase. Willingness to pay for the mitigation policy can be determined from statistical analysis of these discrete choice responses. Regional valuation models in which willingness to pay is related to demographic, regional and other variables will be developed. This model could be used to transfer willingness to pay estimates to other regions.

8. Conclusions

Rose et al. (2007) find that the total benefits of FEMA-funded mitigation grants between mid-1993 and mid-2003 are four times greater than the cost. These grants are intended to prevent physical damage and economic disruption, avoid hundreds of fatalities and thousands of nonfatal injuries, prevent environmental damage and the loss of historic buildings, and reduce human trauma. Within the limitations of our study, environmental and historic benefits were estimated to be very minor in dollar terms. Three out of twenty-five earthquake grants sampled provided environmental or historical benefits, including improving water quality, protecting historic buildings, and positive health benefits. The benefit of these three grants accounted for less than 1 percent of the total benefits in the earthquake project grant stratum. Sixteen of the forty-two flood mitigation grants considered yielded environmental benefits. Fourteen of the environmental benefits pertained to establishing wetlands following the removal of structures,

rather than direct environmental benefits of reduced flooding per se. The environmental benefit associated with these 16 grants accounts for less than 1 percent of the total benefits. Extrapolating the overall results to the population yields aggregate 10-year benefits of about $14 billion. The 10-year environmental and historical benefits of hazard mitigation are about $140 million.

The estimation of environmental damages from natural hazards is still in its infancy. Recent assessments of research on natural hazards have laid out a broad set of possible environmental impacts, and suggested sources of data, and appropriate methods (see, e,g., Heinz Center, 2000), but this only scratches the surface on the actual work that must be done. There are a number of environmental impacts that were not included in our study. The conventional items, such as air pollution, would seem to be innocuous. However, recent events like the World Trade Center attacks indicate that in some instances local air quality effects may be devastating when toxic materials are present or formed by such actions as combustion. Likewise, other likely rare but still possible outcomes such as radiation leaks, infectious disease releases, and incursions on biodiversity may be monumental. A case by case analysis is needed, rather than the application of any generalization from our study that environmental benefits of natural hazard mitigation are relatively minor.

Table 1. Environmental Benefits of Earthquake Mitigation

(units expressed in 2004 dollars unless otherwise noted)

ID Number	Benefit Type	Benefit	Population	Lower	Middle	Upper
3904	Drinking Water	39	59,400	11,583	231,660	1,158,300
7063	Historic	69	8,500	146,625	293,250	439,875
7085	Recreational Fishing	37	461,522	426,908	4,269,079	16,908,899
7085	Drinking Water	39	22,917	4,469	89,376	446,882
7085	Watching Wildlife	18	15,813	17,790	142,317	422,765
7085	Hiking	12	22,237	16,678	133,422	396,342
7085	Historic	100	17,145	428,625	857,250	1,285,875
7144	Hazardous Waste	0.2	34899	174	1745	6911
7151	Historic	91	329,700	7,500,675	15,001,350	22,502,025

Table 2. Environmental Benefits of Flood Mitigation

(units expressed in 2004 dollars unless otherwise noted)

ID Number	Benefit Type	Benefit	Population	Lower	Middle	Upper
19	Recreational Fishing	10	1,446	374	3,738	14,805
19	Drinking Water	39	5,196	405	5,066	25,331
327	Recreational Fishing	2	887	51	508	2,011
2101	Drinking Water	39	5,124	400	4,996	24,980
2101	Commercial Fishing	0.05	26,239	1,312	2,624	13,120
2101	Marine Recreational Fishing	2	47,235	4,747	9,494	47,471
2457	Recreational Fishing	4	360,538	36,504	365,045	1,445,863
2457	Drinking Water	39	776,774	60,588	757,355	3,786,773
2464	Recreational Fishing	4	360,538	36,504	365,045	1,445,863
2469	Recreational Fishing	4	118,978	12046	120465	477135
4841	Recreational Fishing	4	4,232	370	3,703	14,667
5046	Recreational Fishing	4	5,505	500	4,996	19,787
5883	Drinking Water	39	34,772	2,712	33,902	169,512
5911	Recreational Fishing	1	14,873	305	3,049	12,076
5911	Drinking Water	39	36,313	2,832	35,405	177,026
7299	Recreational Fishing	37	4,645	4,297	42,966	170,180

Table 3. Environmental Benefits of Wind Mitigation

(units expressed in 2004 dollars unless otherwise noted)

ID Number	Benefit Type	Benefit	Population	Lower	Middle	Upper
2170	Historic	69	3,346	57,719	115,437	173,156
4481	Power Lines	24	3,906	2,346	23,456	70,367
4493	Power Lines	24	108	65	649	1,946
7594	Historic	69	39,711	685,015	1,370,030	2,055,044

Table 4. Environmental Benefits of Flood Mitigation (Wetlands Creation)

(units expressed in 2004 dollars unless otherwise noted)

		Per Acre			Annual		
ID Number	Properties	Lower	Middle	Upper	Lower	Middle	Upper
2082	4	45	454	1,361	181	1,814	5,443
2977	1	67	674	2,023	67	674	2,023
3167	17	30	300	900	510	5,098	15,294
3562	208	15	147	440	3,048	30,476	91,429
3567	178	15	153	460	2,727	27,269	81,806
3584	77	19	195	584	1,499	14,991	44,972
3637	24	27	272	815	652	6,521	19,564
3644	50	22	220	661	1,101	11,014	33,041
3863	13	32	324	971	421	4,209	12,628
4063	7	39	387	1,160	271	2,706	8,117
4548	6	40	404	1,212	242	2,424	7,271
4551	4	45	454	1,361	181	1,814	5,443
5494	262	14	137	411	3,594	35,936	107,809
6100	120	17	171	514	2,058	20,578	61,734
723	3	49	493	1,478	148	1,478	4,433
974	26	27	266	797	690	6,905	20,715
975	179	15	153	459	2,738	27,378	82,134
1151	1	67	674	2,023	67	674	2,023
1420	1	67	674	2,023	67	674	2,023
1665	61	21	208	624	1,269	12,694	38,081
2218	8	37	372	1,116	298	2,976	8,929

Table 4 continued

2769	179	15	153	459	2,738	27,378	82,134
2911	258	14	138	413	3,554	35,544	106,631
2914	59	21	210	630	1,240	12,395	37,186
3419	7	39	387	1,160	271	2,706	8,117
3620	234	14	142	425	3,315	33,150	99,451
3638	16	31	305	915	488	4,882	14,646
3662	4	45	454	1,361	181	1,814	5,443
3689	83	19	191	572	1,582	15,816	47,447
3692	2	55	553	1,659	111	1,106	3,318
3707	36	24	242	726	871	8,711	26,133
3963	236	14	141	424	3,335	33,352	100,057
4001	49	22	222	665	1,086	10,856	32,568
4035	29	26	257	772	746	7,465	22,394
4599	15	31	311	932	466	4,662	13,987
4626	11	34	340	1,019	374	3,736	11,208
4694	51	22	219	657	1,117	11,170	33,511
4808	26	27	266	797	690	6,905	20,715
5184	46	23	226	677	1,038	10,377	31,131
5633	1	67	674	2,023	67	674	2,023
5656	1	67	674	2,023	67	674	2,023
5658	2	55	553	1,659	111	1,106	3,318
5716	174	15	154	463	2,683	26,830	80,490
5815	2	55	553	1,659	111	1,106	3,318
5864	20	29	286	859	573	5,725	17,176
6196	1	67	674	2,023	67	674	2,023
6386	1	67	674	2,023	67	674	2,023

Table 4 continued

6430	2	55	553	1,659	111	1,106	3,318
6473	73	20	198	593	1,443	14,430	43,291
7620	6	40	404	1,212	242	2,424	7,271
7954	3	49	493	1,478	148	1,478	4,433

Table 5. Environmental and Historical Benefits (Present Value)

(units expressed in 2004 dollars unless otherwise noted)

ID Number	Peril	Lower	Middle	Upper
19	Flood	5,570	8,804	40,136
2082	Flood (Wetlands)	352	16,298	121,910
2170	Wind	57,719	115,437	173,156
2977	Flood (Wetlands)	131	6,057	45,307
3167	Flood (Wetlands)	990	45,794	342,537
3562	Flood (Wetlands)	5,917	273,757	2,047,690
3567	Flood (Wetlands)	5,294	244,944	1,832,175
3584	Flood (Wetlands)	2,911	134,655	1,007,213
3637	Flood (Wetlands)	1,266	58,579	438,165
3644	Flood (Wetlands)	2,138	98,931	740,000
3863	Flood (Wetlands)	817	37,811	282,828
3904	Earthquake	11,583	231,660	1,158,300
4063	Flood (Wetlands)	525	24,303	181,789
4548	Flood (Wetlands)	471	21,770	162,842
4551	Flood (Wetlands)	352	16,298	121,910
5494	Flood (Wetlands)	6,977	322,801	2,414,538
5911	Flood	36,618	38,454	189,102
6100	Flood (Wetlands)	3,995	184,843	1,382,619
7063	Earthquake	146,625	293,250	439,875
7144	Earthquake	174	1,745	6,911

Table 6. Summary of Environmental and Historic Benefit Estimates (Present Value)

(units expressed in 2004 dollars unless otherwise noted)

	Projects	Low	Mid	High
		Full Sample		
Earthquake	5	$1,710,705	$4,203,890	$8,713,575
Flood	62	$4,025	$92,755	$635,675
Wind	4	$186,286	$377,393	$575,128
		Final Sample		
Earthquake	3	52,794	175,552	535,029
Flood	16	4,645	95,881	709,422
Wind	1	14,521	108,810	656,450

Appendix. Benefit Estimation Methods

The parametric changes used in the sensitivity tests of environmental and historical benefit estimates are presented below. Please note that only a subset of the parameters are involved in the estimation of benefits from nearly all mitigation grants.

TB = total benefit
B = individual/household benefit

Drinking Water

- TB = t x B x β x H

Parameter	Lower	Mid	Upper
t (Months-Earthquake)	.25	1	2
t (Months-Flood)	.10	.25	.50
β (% of households affected)	.02	.10	.25

Earthquake:

- Lower = .005 x B x households
- Middle = .10 x B x households
- Upper = .50 x B x households

Flood:

- Lower = .002 x B x households
- Middle = .025 x B x households
- Upper = .125 x B x households

Water Quality: Recreational Fishing

- TB = t x B x δ x Anglers
- Anglers = % who participate in fishing (NSFHWAR) × Population

Parameter	Lower	Mid	Upper
t (Years)	.25	1	2
δ (% that catches one more fish)	.10	.25	.50

- Lower = .025 x B x Anglers
- Middle = .25 x B x Anglers
- Upper = .50 x B x Anglers + (.50 x B x Anglers)/(1 + r)

Outdoor Recreation Trips

- TB = t x B x θ x Participants
- Participants = % who participate in recreation (NSRE) × Population

Parameter	Lower	Mid	Upper
t (Years)	.25	1	2
θ (% of participants who take 1 trip)	.25	.5	.75

- Lower = .0625 x B x Participants
- Middle = .5 x B x Participants
- Upper = .75 x .B x Participants + (.75 x B x Participants)/(1 + r)

Hospitals and Hazardous Waste

- TB = t x B x β x households

Parameter	Lower	Mid	Upper
t (Years)	.25	1	2
β (% of households affected)	.25	.50	.75

- Lower = .0625 x B x Households
- Middle = .5 x B x Households
- Upper = .75 x B x Households + (.75 x B x Households)/(1 + r)

Cultural and Historical Resources

- TB = B (one-time payment) x β x households

Sensitivity Analysis

Parameter	Lower	Mid	Upper
β (% of households)	.25	.50	.75

- Lower = .25 x B x Households
- Middle = .5 x B x Households
- Upper = .75 x B x Households

Wetlands

- $TB = \Sigma_t(B \times \lambda)/(1.02)^t$
- $B = \exp(7.90 - (0.286*\ln(\rho \times \lambda)))$

Sensitivity Analysis

Parameter	Lower	Mid	Upper

ρ (% of acres that function as wetlands)	.10	.5	1
λ (acres for each property)	.25	.5	.75
t (number of years that property provides wetlands functions`)	2	10	30

- Lower = Σ_2 (.025 x B)/$(1.02)^2$
- Middle = Σ_{10} (.25 x B)/$(1.02)^{10}$
- Upper = Σ_{30} (.75 x B)/$(1.02)^{30}$

Aesthetic, Health and Safety Benefits from Underground Power Lines

- TB = B x β x households

Parameter	Lower	Mid	Upper
β (% of households)	.25	.50	.75

- Lower = .25 x B x Households
- Middle = .5 x B x Households
- Upper = .75 x B x Households

Marine Recreational Fishing

- TB = t x B x β x Trips

Parameter	Lower	Mid	Upper
t (Months)	.25	1	2
β (% of trips affected)	.02	.10	.25

- Lower = .05 x B x Trips
- Middle = .10 x B x Trips
- Upper = .50 x B x Trips

Commercial Fishing

- TB = t x β x Landings

Parameter	Lower	Mid	Upper
t (Months)	.25	1	2
β (% of landings affected)	.02	.10	.25

- Lower = .05 x Landings
- Middle = .10 x Landings
- Upper = .50 x Landings

References

Palm Beach County. 2002. "Final Report - Palm Beach County Survey of Residents," http://www.co.palm-beach.fl.us/PubInf/News_Room/03-03/03-18-03_Survey.htm.

Bergstrom, J. C., P.DeCivita. 1999. "Status of Benefit Transfer in the United States and Canada: A Review," Canadian Journal of Agricultural Economics 47:79-87.

Brookshire, D. S., and H. Neil. 1992. Benefit Transfers: Conceptual and Empirical Issues. Water Resources Research 28:651-655.

Carson, Richard T., and W. Michael Hanemann, "Contingent Valuation," Chapter 17 in Handbook of Environmental Economics: Volume 2 Valuing Environmental Changes, edited by Karl-Göran Mäler and Jeffrey R. Vincent, Elsevier North-Holland, 2005.

Cutter, S. 2001. American Hazardscapes, the Regionalization of Hazards and Disasters. Washington, DC: Joseph Henry Press.

Cutter, S. and C. Emrich. 2005. "Are Natural Hazards and Disaster Losses in the U.S. Increasing?", EOS, Transactions, American Geophysical Union 86: 381, 388-89.

Dash, N., B. H. Morrow, J. Mainster, and L. Cunningham. 2007. "Lasting Effects of Hurricane Andrew on a Working-Class Community," Natural Hazards Review 8(1): 13-21.

duVair, P. and J. Loomis. 1992. "Household's Valuation of Alternative Levels of Hazardous Waste Risk Reductions: An Application of the Referendum Format Contingent Valuation Method," Journal of Environmental Management 39:143-155.

Haab, Timothy C., John C. Whitehead, and Ted McConnell. 2001. The Economic Value of Marine Recreational Fishing in the Southeast United States: 1997 Southeast Economic Data Analysis. NOAA Technical Memorandum NMFS-SEFSC-466, 79 p.

Heinz Center. 2000. The Hidden Costs of Coastal Hazards: Implications for Risk Assessment and Mitigation, Island Press.

Larson, Douglas M. and Daniel K. Lew, "Clean Water in California: What is it Worth?" Agricultural and Resource Economics Update, University of California, Davis, pp. 3-6, Summer 2001

Loomis, J.B. 1992. "The Evolution of a More Rigorous Approach to Benefit Transfer: Benefit Function Transfer," Water Resources Research 28:701-705.

Luken, R.A., F. R. Johnson, and V. Kibler. 1992. "Benefits and Cost of Pulp and Paper Effluent Controls Under the Clean Water Act," Water Resources Research 28:665-674.

Noonan, D.S. 2004. “Contingent Valuation and Cultural Resources: A Meta-Analytic Review of the Literature,” Journal of Cultural Economics 27:3-4.

Paton, D. 2003. "Disaster Preparedness: A Social-Cognitive Perspective." Disaster Prevention and Management 12: 210-16.

Posados, Benedict, Economic Assessment of the Impacts of Hurricane Katrina on Coastal Mississippi Marine Resources, Mississippi State University, http://www.msstate.edu/dept/crec/disaster.html, Accessed: August 22, 2007.

Rose, A., K. Porter, N. Dash, J. Bouabid, C. Huyck, J. Whitehead, D. Shaw, R. Eguchi, C. Taylor, T. McLane, L. T. Tobin, P. Ganderton, D. Godschalk, A. Kiremidjian, K. Tierney, C. . West. 2007. “Benefit-Cost Analysis of FEMA Hazard Mitigation Grants,” Natural Hazards Review, 8(4): 1-15.

Rosenberger, R.S., and J.B. Loomis. 2000. Using Meta-Analysis for Benefit Transfer: In-Sample Convergent Validity Tests of an Outdoor Recreation Database. Water Resources Research, 36:1097-1107.

Smith, V.K., G. Van Houtven, and S.K. Pattanayak. 2002. “Benefit Transfer via Preference Calibration: ‘Prudential Algebra’ for Policy,” Land Economics 78:132-252.

Waddington, D.G., K. Boyle, and J. Cooper. 1994. “1991 Net Economic Values for Bass and Trout Fishing, Deer Hunting and Wildlife Watching,” US Fish and Wildlife Service, Washington DC.

Whitehead, J.C., and G. Van Houtven. 1997. “Methods for Valuing the Benefits of the Safe Water Drinking Act: Review and Assessment,” East Carolina University Department of Economics Working Paper 9705.

Woodward, R.T. and Y.-S. Wui. 2001. The Economic Value of Wetland Services: a Meta-Analysis. Ecological Economics 37:257-270.